Simulation and Performance Evaluation of Lee model under Urban, Suburban and Rural Environments for GSM system in mobile communication

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Abstract--**The provision of wireless telephony network in a serving area requires planning and design in the most effective manner. The design involves determining the number of base stations and their locations to provide the necessary coverage in the serving area, meet the desired grade of service and satisfy the required traffic growth. In the design process the service providers generates a set of system requirements concerning the type of the desired system (e.g. Global system for Mobile Communication GSM, Code Division Multiple Access CDMA etc.), the expected traffic, and the desired service quality. In general received carrier to interference ratio (C/I), bit error rate (BER) are used as the quality of the services indicator. Estimation of path loss is very important in initial deployment of wireless network and cell planning. Numerous path loss (PL) models (e.g. Lee Model, Hata Model) are available to predict the propagation loss. If Path loss increases, then signal power decrease and also bit error rate increase. AWGN channel is used for all simulations. These models are simulated with different distance between transmitter and receiver, transmitter antenna and receiver antenna heights in urban, suburban and rural environments in Non Line of site (NLOS) condition. Our main concentration in this paper is to find out bit error rate for different environments to provide guidelines for cell planning of GSM Network.**

Keywords: **Lee Model, Hata Model, FSPL**

I. INTRODUCTION

The Global System for Mobile communications (GSM) is a digital cellular communications system initially developed in an European context which has rapidly gained acceptance and market share worldwide. It was designed to be compatible with ISDN systems and the services provided by GSM are a subset of the standard ISDN services (speech is the most basic). The functional architecture of a GSM system can be divided into the Mobile Station (MS), the Base Station (BS), and the Network Subsystem (NS). The MS is carried by the subscriber, the BS subsystem controls the radio link with the MS and the NS performs the switching of calls between the mobile and other fixed or mobile network users as well as mobility management. The MS and the BS subsystem communicate across the Um interface also known as radio link.

The GSM system is a frequency- and time-division system; each physical channel is characterized by a carrier frequency and a time slot number. GSM system frequencies include two bands at 900 MHz and 1800 MHz commonly referred to as the GSM-900 and DCS-1800 systems. The 25 MHz bands are then divided into 124 pairs of frequency duplex channels with 200 kHz carrier spacing using Frequency Division Multiple Access (FDMA). Since it is not possible for a same cell to use two adjacent channels, the channel spacing can be said to be 200 kHz interleaved. One or more carrier frequencies are assigned to individual Base Station (BS) and a technique known as Time Division Multiple Access (TDMA) is used to split this 200 kHz radio channel into 8 time slots (which creates 8 logical channels). A logical channel is therefore defined by its frequency and the TDMA frame time slot number. By employing eight time slots, each channel transmits the digitized speech in a series of short bursts: a GSM terminal is only ever transmitting for one eighth of the time.

The basic telecommunication services provided by the GSM are divided into three main groups:

Bearer services give the subscriber the capacity required to transmit appropriate signals between certain access points (i.e., user-network interfaces). **Teleservices** services provide the subscriber with necessary capabilities including terminal equipment functions to communicate with other subscribers. **Supplementary services** modify or supplement basic telecommunications services and are offered together or in association with basic telecommunications services.

Figure1: GSM transmission and reception system

The voice input is sampled at 8 kHz and coded at 13 bits/sample. The resulting 104 kbps is reduced to 13 kbps using Regular Pulse Excitation-Long-Term Prediction Linear Prediction Coding (RPE-LTPLPC). Interleaver and GMSK modulation & demodulation are used in GSM system (Figure 1).

Here 20 ms speech or 160 samples are taken. Total 260 bits divided in 36 bits for LPC coefficients, 36 bits for long-term prediction and 188 bits for excitations. The coding rate is (260 bit)/(0.02 seconds) = 13 kb/s. Bits are classified as:1) Class 1a: 50 bits are essential. 2) Class 1b: 132 bits are important. 3) Class 2: 78 bits are less important. 3 parity bits are added to the Class 1a bits to give 53 bits. These 53 bits are added to the132 bits Class 1b bits and appended by “0000” to give 189 bits. After rate ½ convolutional encoding gives 378 bits. Adding the 78 Class 2 bits gives 456 bits in 20 ms, or 456/0.02=22.8 kb/s. Two 456 bit blocks are interleaved and transmitted over 8 frames, i.e. spread out to 114 bits per frame.

A frame has duration 4.615 ms. Consists of 8 slots. Each slot can accommodate one burst of duration 577 micro-second. Two kinds of multiframe: 1) Traffic MF = 26 frames (120ms), 2) Control MF = 51 frames. 2048 superframes form a hyperframe of duration 3 h 28 m 53.76 s.

During the initial phase of network planning, propagation models are extensively used for conducting feasibility studies. There are numerous propagation models available to predict the path loss e.g. Lee Model, Hata Model.

II. CONSIDERED PATHLOSS

In this paper we compare and analyze three path loss models (e.g. Lee model, Hata model, Free space path loss model) which have been proposed in urban and suburban and rural environments for different distances, transmitter and receiver antenna heights.

By combining analytical and empirical methods the propagation models is derived. Propagation models are used for calculation of electromagnetic field strength for the purpose of wireless network planning during preliminary deployment. It describes the signal attenuation from transmitter to receiver antenna as a function of distance, carrier frequency, antenna heights and other significant parameters like terrain profile (e.g. urban, suburban and rural)

In all models, *f* is the carrier frequency in MHz, *d* is the distance between the transmitter GSM Cell BS and the receiver MS user in km, transmitter and receiver antenna height in m. Most of the models provide two different conditions i.e. LOS and NLOS. In our entire paper we concentrate on NLOS condition except in rural area, we consider LOS condition for COST 231 W-I model, because COST 231 W-I model did not provide any specific parameters for rural area.

A. *Free Space Path Loss Model (FSPL):*

Path loss in FSPL defines how much strength of the signal is lost during propagation from transmitter to receiver. FSPL is diverse on frequency and distance. The calculation is done by using the following equation [9]. The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver. H. T. Friis presented the following equation to calculate the received signal power in free space at distance d from the transmitter.

$$PLfs = 32.45 + 20 \log_{10} (d) + 20 \log_{10} (f) \quad \text{in [dB]} \qquad (1)$$

Where, d is in km and, f is in MHz

B. *Lee Model*

Named after W.C.Y. Lee, Lee model is relatively simple and intuitive to use and it is characterized by its aptitude to achieve good prediction accuracy. In addition, its prediction can be significantly improved by the incorporation of measurement data. In the beginning, the Lee model was developed for use at 900 MHz and has two modes: area-to-area and point-to-point. The Lee model is a modified power law model with correction factors for antenna heights and frequency and has the ability to be easily customized to the local environment. A typical application involves taking measurements of the path loss in the target region and then adjusting the Lee model parameters to fit the model to the measured data. This empirically derived path loss model is parameterized by Pr_o, the power at the 1-mile point of interception, and γ, an experimentally determined path loss slope

$$Pr = 10\log_{10} [Pr_o(r/r_o)^{-\gamma} (f/f_o)^{-n} \alpha_0] \qquad \text{[dBm]}$$

Where:

Pr = field strength of the received signal at a distance r from the transmitter

Pr_o: received power at 1 mile (1.6 km)

r: distance between MS and BS antennas

r_0: 1 mile (1.6 km)

γ: path loss slope (experimentally determined)

f: actual carrier frequency

f_o: nominal carrier frequency, (= 900 MHz)

n: empirically derived exponent depends on geographical locations and operating frequency ranges. $2 \le n \le 3$

α_0: correction factor accounts for antenna heights, transmit power and antenna gains which differ from nominal values

n=3 for an urban area with f > 450 MHz and n=2 is recommended for a suburban or open area with f < 450 MHz.

III. SIMULATION OF MODELS

A detailed analysis of the proposed model was obtained for four cases where in each case three parameters are fixed and one particular parameter has different value.

In our computation, we are operating frequencies at 900MHz, distance between transmitter antenna and receiver antenna is 30km, transmitter antenna height is 30 m and transmitter antenna height is 4 m in urban, suburban area and rural area. We considered different distances between transmitter antenna and receiver antenna e.g. 1.5km, 2km and 2.5Km, 3Km and 3.5Km, different base station antenna height e.g. 30m, 40m, 50m, 60m, 70m and 80m and different mobile station antenna height e.g. 3m, 4m, 5m, 6m, 7m, 8m for path loss with AWGN channel. Most of the models provide two different conditions i.e. LOS and NLOS. Base station transmitter power 43 dBm, Mobile transmitter power 30 dBm. The following presents the parameters we applied in our simulation using Lee model for urban, suburban and open area in GSM system.

Path loss for the Lee path loss model was plotted for different distances between transmitter and receiver antenna height, transmitter and receiver antenna heights. Models are simulated using SNR values in AWGN channel and at the same time path loss are kept fixed. While changing above different parameters it is observed that BER also changed.

(A) PATH LOSS VS BER FOR DISTANCS (Km)

In our calculation, we set frequency is 900MHz, transmitter antenna height is 30m, receiver antenna height is 4m and plotted for different distances are 5km, 10km, 15km, 20Km, 25Km and 30Km, in Lee propagation model with AWGN channel.

Table 1: BER analysis for different Path-loss at Distance between transmitter and receiver antenna

Distance (Km)	Urban area		Sub urban area		Open area	
	Path Loss (dB)	BER	Path Loss (dB)	BER	Path Loss (dB)	BER
1	38	.463	40	.4662	41	.4668
1.5	39	.4699	40	.4656	41	.4688
2	40	.4655	41	.4695	41	.4748
2.5	40	.4648	41	.4712	42	.4796
3	40	.462	41	.4742	42	.4842
3.5	40	.4653	41	.4736	42	.4844

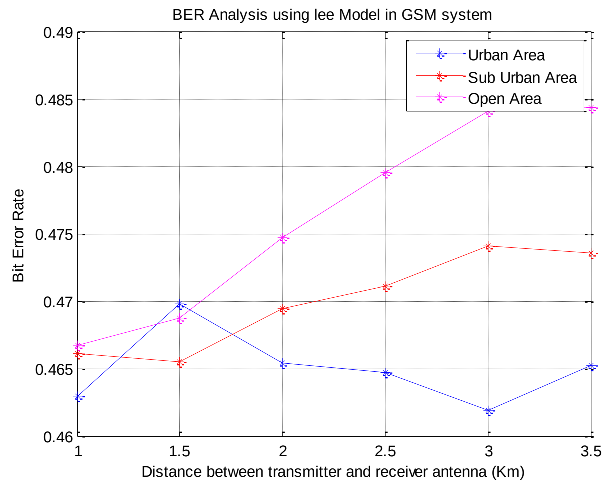

Figure.1: Distance VS BER for different Environments

(B) PATH LOSS VS BER FOR BASE STATION ANTENNA HEIGHTS (m)

In our calculation, we set distance is 30km, frequency is 900 MHz , receiver antenna height is 4m and plotted for different transmitter antenna heights are 30m, 40m, 50m, 60m, 70m and 80m in Lee propagation model with AWGN channel.

Table 2: BER analysis for different Path-loss at Base station antenna height

Base Station antenna height (m)	Urban area		Sub urban area		Open area	
	Path Loss (dB)	BER	Path Loss (dB)	BER	Path Loss (dB)	BER
30	38	.4681	40	.4636	40	.4673
40	38	.4583	40	.4653	40	.4652
50	38	.463	40	.4662	40	.4668
60	38	.4612	39	.4681	40	.4627
70	38	.4611	39	.468	40	.4677
80	38	.4609	39	.4705	40	.4669

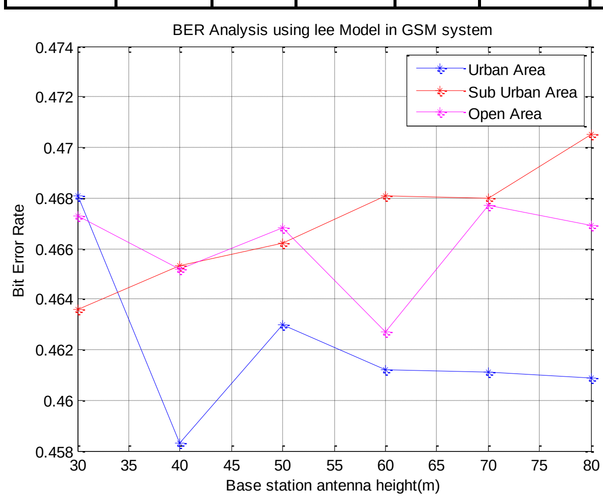

Figure.2: Base station height VS BER for different Environments

(C) PATH LOSS VS BER FOR MOBILE STATION ANTENNA HEIGHTS (m)

In our calculation, we set frequencies is 900MHz , distance is 30km, transmitter antenna height is 30m and plotted for different , receiver antenna heights are 3m, 4m, 5m, 6m, 7m, 8m in Lee propagation model with AWGN channel.

Table 3: BER analysis for different Path-loss at Mobile station antenna height

Mobile Station antenna height (m)	Urban area		Sub urban area		Open area	
	Path Loss (dB)	BER	Path Loss (dB)	BER	Path Loss (dB)	BER
3	38	.4653	40	.4736	40	.4844
4	38	.4583	40	.4654	40	.4652
5	38	.463	40	.4662	40	.4668
6	38	.4612	39	.4681	40	.4627
7	38	.4611	39	.468	40	.4677
8	38	.4609	39	.4705	40	.4669

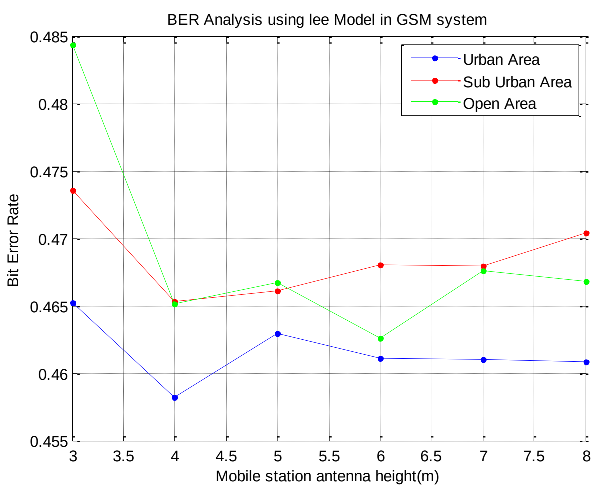

Figure.3: Mobile station height VS BER for different Environments

IV. CONCLUSIONS

It is observed that BER is sensitive to changing values of path loss in propagation model. When earlier mentioned parameters values changed the path loss is changed which directly reflected to changing values of BER.

In all Environments, if distance are increases then Path loss increases, bit error rate increase, then signal power decrease according to some value but some case path loss decrease and also bit error rate decrease and if transmitter and receiver antenna heights are increases then Path loss decreases, then signal power increase and also bit error rate decrease but we got reverse result in other values.

Our analysis indicate that due to multipath and NLOS environment in urban area, all models experiences higher path losses compare to suburban and rural areas. We need modified path loss model so we will get desired result.

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