Selection of Radio Propagation Model for Long Term Evolution (LTE) Network

Premchandra Kumar, Bhushan Patil, Suraj Ram

Under Graduate, Computer Engineering, MIT Academy of Engineering, Pune

Premchandra12345@gmail.com , +918483974081

Abstract— Path loss causes attenuation of an electromagnetic wave when it transmits through space. In our project we are considering path loss as a major component in the analysis and design of the of a telecommunication system. We are simulating radio propagation models for the upcoming 4^{th} Generation (4G) of cellular network known as Long Term Evolution (LTE). There are different models like SUI model, Okumura Model, Hata COST 231 model, COST Walfisch-Ikegami and Ericsson 9999 model. The radio propagation models or path loss model calculates path loss in transmission. In this paper path loss is used as constraint for comparison, between different proposed radio propagation models that would be used for LTE, Path loss varies as per different terrain. So the path loss for different terrains e.g. urban, suburban, and rural areas is calculated and comparison is made.

Keywords— Long Term Evolution, Path loss, Radio Propagation Models, Shadowing, uplink, downlink, Correction factor

INTRODUCTION

Long Term Evolution (LTE) is the next step to the cellular 3rdGeneration (3G). It is also known as 4th Generation (4G) service. 3rd Generation Partnership Project (3GPP) has developed some standards. LTE is based on 3GPP standards.

The main objectives for LTE [1] are as follows.

- Downlink and uplink peak data rates are increased.
- Bandwidth is scalable
- Spectral efficiency has improved
- All IP network
- Multitude of user types are supported by standard's based interface

LTE will be having Bandwidth of channel scalable between 1 MHz to 20 MHz. Frequency Division Duplex (FDD) and Time Division Duplex (TDD) [1] both are supported by it. Downlink speed of 100 Mbps and an uplink of almost 50 Mbps will be given by LTE. By increasing number of antennas both at the transmitter and receiver the data rates can be further increased.

There are different propagation models for LTE. By comparing different models the selection of a suitable radio propagation model for LTE is very important. The suitable radio propagation model is chosen by comparing the behaviour of the signal during transmission from transmitter to receiver. The behaviour of the signal during transmission depends on the path loss and the distance of transmitter and receiver. Suitable propagation model gives the relation between the path loss and the distance of transmitter and receiver. The model gives an idea of allowed path loss and the maximum cell range. There are different factors that can affect path loss like environmental conditions, frequency on which we are operating, condition of atmosphere and the distance between the transmitter and receiver.

RADIO PROPAGATION MODELS

SUI Model

Stanford University Interim (SUI) model is developed for IEEE 802.16 by Stanford University [2], [3]. It is used for frequencies above 1900MHz. In this propagation model, three different types of terrains or areas are considered (Table 1). These are called as terrain A, B and C. Terrain A represents an area with highest path loss, a very dense populated region while Terrain B represents an area with moderate path loss, a suburban environment. Terrain C has least path loss which represents a rural or flat area. These different terrains and their factors used in SUI model are described in following table.

TABLE 1: DIFFERENT TERRAINS & THEIR PARAMETERS

Parameters	Terrain A	Terrain B	Terrain C
A	4.6	4	3.6
B(1/m)	0.0075	0.0065	0.005
C(m)	12.6	20	20

The path loss in SUI model can be given as

$$PL = A + 10\gamma log\left(\frac{d}{d_0}\right) + X_f + X_h + S - - - (1)$$

Where PL is path loss in dBs, d is the distance between the transmitter and receiver, d_0 is the reference distance (Here its value is 100), X_f is the frequency correction factor, X_h is correction factor for Base station height, A is free space path loss, S is shadowing factor and γ is the path loss component.

The path loss component is given as

$$\gamma = a - bh_b + \frac{c}{h_b} - - - (2)$$

Where h_b is the height of the base station and a, b and c represents the terrain factors for which the values are selected from the above table.

The free space path loss is given as

$$A = 20\log\left(\frac{4\pi d_0}{\lambda}\right) \qquad - - - - - (3)$$

Where d_0 is the distance between transmitter and receiver and λ is the wavelength.

The correction factor for frequency is

$$X_f = 6\log\left(\frac{f}{2000}\right) \qquad - - - (4)$$

Where f is frequency in MHz.

The correction factor for base station height is

$$X_h = -10.8log\left(\frac{h_r}{2000}\right) \qquad - - - -(5)$$

Where h_r is height of receiver antenna.

The above expression is used for terrains A and Band for terrain C the expression is as given below:

$$X_h = -20log\left(\frac{h_r}{2000}\right) \qquad ----(6)$$

The shadowing factor S is given as following:

$$S = 0.65(log\ f)^2 - 1.3\log(f) + \alpha \quad ---(7)$$

Here, α=5.2 dB for rural and suburban environments (Terrain A and Terrain B) and 6.6 dB for urban environment (Terrain C).

Okumura Model

Okumura's model[4], [9] is one of the most widely used models for signal prediction. It can be used for frequencies in the range 150–1920 MHz (it can be expanded up to 3000 MHz) [12] and distances between transmitter and receiver of 1–100 km. It can be used for base-station antenna heights ranging from 30–1000 m. while the receiver height can be 3 m to 10 m. This model is basic model for development of almost all other models. To determine path loss using Okumura's model, the free space path loss is first calculated. Median attenuation relative to free space (Amu) is added to it. Later correction factors according to the type of terrain are added to it. The path loss in model can be calculated as

$$pl(db) = L_f + A_{(m,n)}(f,d) - G(h_c) - G(h_r) - G_{AREA} \quad ----(8)$$

Here L_f is the free space path loss. Free-space path loss is proportional to the square of the distance between the transmitter and receiver, and also proportional to the square of the frequency of the radio signal. Free space path loss is calculated by

$$L_f = -20\log(\frac{\lambda}{4\pi d_0}) \quad ----(9)$$

Here $G(h_c)$ and $G(h_r)$ gives the Base Station antenna gain factor and receiver gain factors respectively. They are calculated as follows:

$$G(h_b) = 20\log(\frac{h_b}{200}) \quad ----(10)$$
$$G(h_r) = 10\log(\frac{h_r}{3}) \quad ----(11)$$

Where h_b and h_r are the heights of base station and receiver respectively. The area gain G_{AREA} depends on the area being used. Okumura developed a set of curves giving the median attenuation relative to free space, $A_{(m,n)}(f,d)$ is median attenuation relative to free space.

Cost – 231 Hata Propagation Model

The Cost hata model [6] is a radio propagation model, which is based on the Okumura model to cover a more elaborated range of frequencies. It is also known as the COST 231 Hata Propagation Models. This model is applicable to urban areas. It works for Frequency up to 1500–2000 MHz. Mobile station antenna height is 1–10 m [12]. Base station antenna height is 30–200 m [12]. Median path loss in urban areas is given by

$$PL(db) = 46.3 + 33.9\log(f) - 13.02\log(h_b) - a(h_r) + [44.9 - 6.55\log(h_b)]\log d + c \quad ----(12)$$

Here, f represents the frequency in MHz, distance between the transmitter & Receiver is denoted by d, *C*orrection factors for base station height and receiver height are h_b & h_r respectively. The parameter c has a value of 3 for urban. It is zero for suburban & rural environments. a(h_r) is Mobile station antenna height correction factor, for urban areas it is given by

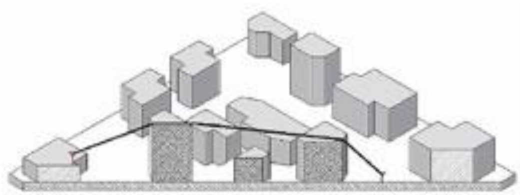
$$a(h_r) = 3.2(\log(11.75h_r))^2 - 4.97 \quad ----(13)$$

And for rural area it is given by

$a(h_r) = (1.1\log(f) - 0.7h_r - (1.58f - 0.8))$ ----(14s)

Cost – 231 Walfisch – Ikegami Model

This model is a combination of the models of J. Walfisch and F. Ikegami,developed mainly for operating in Urban area.



Scenerio of Walfisch-Ikegami Model in Urban Area.

The main idea behind Walfisch-Ikegami model is to consider the vertical plane between the transmitter and the reciever.

The classical COST Walfisch-Ikegami model determines the mean street width, mean building height, mean building separation for the whole building database.

To understand the working of this model we need to consider following parameters.

- 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)
  These parameters are shown as follows

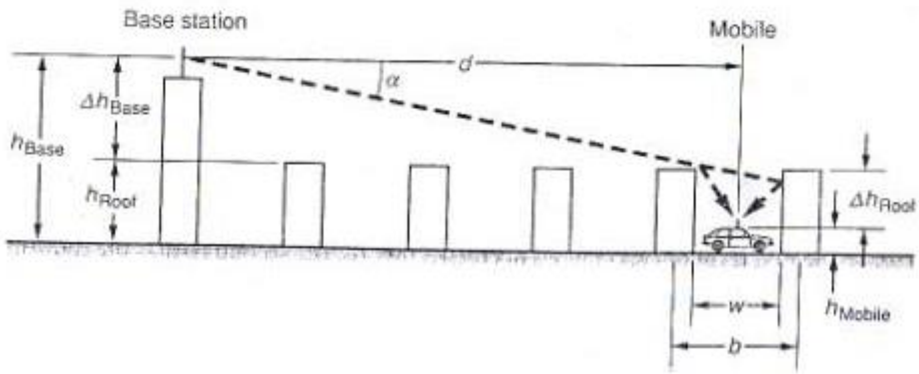
But the main problem in implementing this model is that the urban areas are not homogenous i.e the building heights and separations between them differs on a large scale.

Parameters and Formulations of Walfisch - Ikegami Model

Cost - 231 Walfich-Ikegami is a combination of the parameters and the excess pathloss from Walfisch-Bertoni model and building path loss from Ikegami model. How ever this model is restricted to urban areas only.

ISSN 2091-2730

The figure given below denotes various parameters considered in this model.



If a free LOS exists in a street canyon then, path loss defined as

$$L_{los} = 42.6 + 26\log R + 20\log f \;\; for\ R\ 20\ m$$

If a non-LOS exists, path loss defined as follow:

$$L_b = \begin{cases} L_{FS} + L_{rts} + L_{msd} & \\ L_{FS} & \text{IF} \;\; L_{rts} + L_{msd} < 0 \end{cases}$$

L_{FS} represents free space loss, L_{rts} is rooftop to street diffraction and scatter loss, L_{rts} is the multiscreen loss.

The rooftop to street diffraction and scatter loss L_{rts} represents the coupling of wave propagating along the multi –screen path into the street mobile located.

$$L_{rts} = \begin{cases} -16.9 - 10\log f + 20\log \Delta h\,(mobile) + L_{ori} & h_{roof} > h_{mobile} \\ 0 & if\ L_{rts} < 0 \end{cases}$$

where L_{ori} defined as,

$$L_{ori} = \begin{cases} -10 + 0.354\dfrac{\emptyset}{deg} & for\ 0 =< j < 35 \\ 2.5 + 0.075\left(\dfrac{\emptyset}{deg} - 35\right) & fro\ 35 \le j < 55 \\ 4 - 0.114\left(\dfrac{\emptyset}{deg} - 55\right) & for\ 55 \le j \le 90 \end{cases}$$

The multiscreen diffraction loss L_{msd} is an integral for which Walfisch-Bertoni model approximate a solution to this for the cases base station antenna height is greater than the average rooftop. COST 231 extended this solution to the cases base station antenna height is lower than the average rooftop by including empirical functions.

Restrictions of the model is given as follow:

Frequency (MHz)	**800-2000 MHz**
Base Station Height (h_{base})	4-50 m
Mobile Height (h_{mobile})	1-3 m
Distance R,in Km	0.02 - 5 Km

Ericsson 9999 Model

This model is an extension of hata model [2], [11] which is used for frequencies upto 1900 MHz implemented by Ericsson.

Path loss in Ericsson 9999 model is evaluated by formula as follows:

$$PL = a_0 + a_1 \log(d) + a_2 \log h_b + a_3 \log(h_b) \log(d) - 3.2(\log(11.75))^2 + g(f)$$

where

$$g(f) - 44.49 \log(f) - 4.78 (\log(f))^2$$

$a_{0,} a_1, a_2$ etc are constants which can also be changed as per scenerio(environment).

where as the default values for this model are

$$a_0 = 36.2$$

$$a_1 = 30.2$$

$$a_2 = 12.0$$

$$a_3 = 0.1$$

and the parameter f represents frequency.

PROBLEM STATEMENT

Our aim of project is to find out the radio propagation model which will give us the least path loss in a particular terrain. LTE uses various range of frequency bands in different regions of the world. For these frequency bands, there are many different radio propagation models that can be used in different terrains. We are going to make a comparison between different radio propagation models and find out the model that is best suitable in particular terrain. The comparison will be made mainly on the basis of path loss, antenna height and transmission frequency.

PROBLEM SOLUTION

In our simulation, we are going to use the empirical formulas of path loss calculation as described in the earlier section. These formulas take input parameters as frequency, distance between transmitter and receiver, height of transmitter and receiver and calculate the expected path loss of whole path during transmission of radio waves.

We will implement these formulas by developing a simple path loss calculator for Window operating system. For input parameters we have created database from different terrains. Thus based on the database we will calculate path loss for different terrains and update the tables with results. Then we will plot the path loss against different input parameters with the help of updated database.

CONCLUSION

Based on our simulation results we will make tables for path loss in different terrains (rural, suburban, urban) for different radio propagation models. Based on the tables we will also plot graphs and then compare different radio propagation models. Finally we will present the result of our simulation by representing the best suitable radio propagation model for a particular terrain.

In this way we will be able to select the best radio propagation model for design of any wireless communication system following Long Term Evolution (LTE) Network technology. Thus by following our result we can design a very efficient wireless communication system under 4G Technology which will be having very high peak data rates in comparison to under-going 3G Technology. We all know the importance of high data rates in today's wireless mobile communication system. The 4G technology will also have scalable bandwidth and large spectral efficiency with respect to 3G Technology.
One of the most advantageous thing is that 4G technology supports all IP network and thus it provides a standard's based interface that can support multitude of user types.

REFERENCES:

[1] LTE an Introduction, White paper, Ericsson AB, 2009.
[2] Josip Milanovic, Rimac-Drlje S, Bejuk K, "Comparison of propagation model accuracy for WiMAX on 3.5GHz," 14th IEEE International conference on electronic circuits and systems, Morocco, pp. 111-114. 2007.
[3] V.S. Abhayawardhana, I.J. Wassel, D. Crosby, M.P. Sellers, M.G. Brown, "Comparison of empirical propagation path loss models for fixed wireless access systems," 61th IEEE Technology Conference, Stockholm, pp. 73-77, 2005.
[4] Okumura, Y. a kol, "Field Strength and its Variability in VHF and UHF Land-Mobile Radio Service", Rev. Elec. Comm. Lab, No.9-10, pp. 825 - 873, 1968.
[5] Hata, M, "Empirical Formula for Propagation Loss in Land Mobile Radio Services", IEEE Trans. Vehicular Technology, VT-29, pp. 317 - 325, 1980.
[6] COST Action 231, "Digital mobile radio towards future generation systems, final report", tech. rep., European Communities, EUR 18957, 1999.
[7] Amarasinghe K.C., Peiris K.G.A.B., Thelisinghe L.A.D.M.D., Warnakulasuriya G.M., and Samarasinghe A.T.L.K "", Fourth International Conference on Industrial and Information Systems, ICIIS 2009, 28 - 31 December 2009, Sri Lanka.
[8] Simic I. lgor, Stanic I., and Zrnic B., "Minimax LS Algorithm for Automatic Propagation Model Tuning," Proceeding of the 9th Telecommunications Forum (TELFOR 2001), Belgrade, Nov.2001.
[9] B. Ramakrishnan, R. S. Rajesh and R. S. Shaji "An Efficient Vehicular Communication Outside the City Environments", International Journal of Next Generation Networks (IJNGN), volume 2, December 2010.
[10] M. Shahjahan, A. Q. Abdulla Hes-Shafi, "Analysis of Propagation Models for WiMAX atsss 3.5 GHz," MS thesis, Blekinge Institute of Technology, Karlskrona, Sweden, 2009.
[11] N. Shabbir, H. Kasihf, "Radio Resource Management in WiMAX," MS thesis, Blekinge Institute of Technology, Karlskrona, Sweden, 2009.
[12] Wikipedia