LTE Network Planning using the Hata-Okumura and the COST-231 Hata Pathloss Models

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***Abstract*— this paper takes a look at two of the most common radio propagation models used in determining the radio coverage, with regards to Long Time Evolution, LTE. These models are the Okumura-Hata and the COST-231 Hata models. A comparative analysis through mathlab simulation for both models at different frequencies and base station heights are looked into.**

***Index Terms* — Radio Propagation model, Path loss, Okumura, Okumura-Hata, COST-231-Hata**

I. Introduction

THIS paper takes a look at some of the radio propagation models used in designing radio channels, and gives a Mathlab simulation of two-Okumra-Hata model and the COST-231 Hata model, which can be readily applied in LTE.The simulation is done using three different environments. The result is discussed.

Long Time Evolution, LTE is a standard for wireless communication of high-speed data for mobile terminal; it is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvement. LTE is developed for a number of frequency bands ranging from 800MHz to 3.5Hz.The available bandwidth available are also flexible starting from 1.25 MHz to 20 MHz, and supports both the Time Division Duplex (TDD) as well as Frequency Division Duplex (FDD).It uses Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink and Single-Carrier Frequency Division Multiple Access (SC-FDMA) for uplink, supporting a download speed of about 100Mbps and upload speed of 50Mbps.

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OFDMA splits the spectrum into smaller subcarriers closely spaced and orthogonal to each other for transmission of a single data stream using prevailing modulation schemes. As compared to single-carrier system where a deep fade in power level or an interferer can be sufficient to terminate the link between the transmitter and the receiver, in OFDM systems, only a few of the subcarriers are disturbed which allows transmission through subcarriers that are not affected. OFDMA utilizes the spectrum division of OFDMA by allocating subsets of the

Carriers to individual users. This allows a flexible use of bandwidth with conventional equipment.

LTE thrives to achieve the following:

1. Increased uplink and downlink packet data rate
2. Scalable bandwidth
3. Improved spectral efficiency
4. All IP network
5. A standard based interface that can support a multitude of user type

For the LTE deployment, an understanding of the radio channel is paramount, and modelling of this channel using the most appropriate propagation model is very important. The radio propagation models are very significant while planning for any wireless communication system. The radio propagation model describes the behaviour of the signal while it is transmitted from the transmitter towards the receiver, and the path loss .It gives a relation between the distances of the transmitter. The Path loss models are important for predicting coverage area, interference analysis, frequency assignments and cell parameters which are basic elements for network planning process in mobile radio. Path loss refers to electromagnetic wave attenuation between transmitter and receiver in the communication system. It could be due to effects such as diffraction, refraction, reflection, free space loss, coupling loss and absorption .Path loss depends on the condition of the environment(urban, urban, rural, dense, open,etc),operating frequency , atmospheric conditions.

The ability to predict the minimum power necessary to transmit from a given base station at a given frequency, and to provide an acceptable quality of coverage over a predetermined service area, and to estimate the effect of such transmission on existing adjacent services is crucial for the improvement of the frequency reuse and the implementation of band sharing schemes between different services. There is a need for a better understanding of the influence of the different urban and terrain factors on the mobile radio signal and its variability. The radio wave propagation model or path loss model plays a very important role in planning of any wireless communication system

For LTE, the radio channel technology proposed should have the following property

- Multi-carrier technology
- Multiple –antenna technology
- Utilization of packet-switching for radio interference.

There are three main types of path loss model

1) Empirical Model
2) Stochastic Model/ Statistical model also know as Semi-deterministic model
3) Deterministic Model

The empirical models are derived from measurement and observations while the deterministic model starts from the electromagnetic wave equation to determine the received signal power at a particular location. Deterministic model provides a reliable and thorough estimation of the path losses and the channel characteristics, but often require a complete three-dimensional map of the propagation environment.

The different types of path loss propagation models

II. FREE SPACE MODEL

Free Space Path loss (FSPL) is the loss in signal strength of a electromagnetic wave that would result from a line-of sight path through free space(usually air), with no obstacles nearby to cause reflection or diffraction. It does not take into consideration the gain of the antennas used at the transmitter and receiver.

The Free Space path loss is given by

$FSPL = 4\pi\lambda/d^2$ .... (1)

Taking log of (1)

$(FSPL)_{dB\,9} = 32.42 + 20log10(d) + 20\log(f)$ ..... (2)

$f = the\ frequency\ of\ operation\ in\ MegaHertz$

$d = distance\ from\ the\ transmitter\ in\ kilometer(km)$

This equation is only accurate in the far-field where spherical spreading can be assumed; it is not applicable when the receiver is close to the transmitter

III. OKUMURA MODEL

Okumura Model is the most widely used radio frequency propagation model for predicting the behaviour of cellular transmission in urban area. This is based on measurement carried out by Y. Okumura in 1960.It is used for a frequency range of 150MHz to 1500MHz

The Okumura model takes note of three terrains /environment:

Open area: defined as Open space, no tall trees or building in path.

Suburb area: defined as Villages, highway scattered with trees and houses, some obstacles near the mobile

Urban area: defined as large settlement with high building having two or more storeys, or big villages having buildings close to each other and huge trees (Built up city or large town with large buildings and houses)

Okumura used the urban area as a standard model and introduced correction factors for application of the model to other categories. The empirical path loss formula devised by Okumura, expressed in terms of dB at carrier frequency f_c and distance d is given by

$L = L_F + A_\mu - H_{TX} - H_{RX}$ .... (3)

Where

$L_F = Free\ space\ pathloss$

Aμ=Median of pathloss addition to free space pathloss in urban area with quaisi-smooth terrain

$H_{TX} = basw\ station\ antenna\ height$

$H_{RX} = Mobile\ antenna\ height$

Okumura derived H_{TX} and H_{RX}

$H_{TX} = 20\log\left(\frac{h_{tx}}{200}\right), 30m < h_{tx} < 100m$ . ... (4)

$$H_{RX} = \begin{cases} 10\log\left(\frac{h_{rx}}{3}\right) & , 30m < h_{tx} < 100m \\ 20log(h_{rx}/3), & 3m < h_{rx} < 10m \end{cases}$$
..... (5)

IV. OKUMURA-HATA MODEL

This model empirically formulates Okumura model by utilizing the graphical information retrieved by Okumura.Just like in the Okumura model, the applicable frequency range for the Okumura-Hata model is also 150 to 1500MHz, provides three separate formulae for each type of environment, namely: Urban area, Suburban areas and open area

For urban area, Okumura-Hata formulated the path loss as follows

$L_{urban} = 69.55 + 22.16log_{10}(f_c$)- 13.82 $log_{10}(h_{tx}) - a(h_{rx}) + (44.9 - 6.55log_{10}(h_t)$) $log_{10}d$ .... (6)

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Where

$a(h_{rx})$ *city*

= correction factor for mobile antenna length. This Factor depends upon the coverage are. If the city is small to medium sized, this factor in dB can be given as

$$a(h_{rx}) = (1.1log_{10}f_c - 0.7)h_{rx} - (1.56log_{10}f_c - 0.8) \quad \text{........} \quad (7)$$

Whereas for large cities at f_c >300MHz, the factor is given as

$$a(h_{rx}) = 3.2(log_{10}(11.75))^2 \text{-}4.97 \quad \text{......} \quad (8)$$

For Suburban area, Okumura-Hata model gives path loss as

$$L_{suburban} = L_{urban} - 2[log_{10}\left(\frac{fc}{28}\right)]^2 - 5.4 \quad \text{.........} \quad (9)$$

For open area, the formulation is

$$L_{open} = L_{urban}(d) - 4.78[log_{10}f_c]^2 + 18.33log_{10}f_c - K \quad \text{..........} \quad (10)$$

V. COST-231 HATA MODEL

The COST-231 Hata radio propagation model is an extension of the Hata-Okumura model. The path loss for the COST-231 Hata Model is mathematically given as

$$PL_{dB} = 46.3 + 33.9log_{10}f - 13.82log_{10}h_{tr} - a(h_m) + (44.9 - 6.55log_{10}(h_{rx})log_{10}(d) + C_{[dB]} \quad \text{......} \quad (11)$$

Where,

L=Median Path loss in decibel (dB)

f= frequency of Transmission (MHz)

h_{tr}=Base Station antenna effective height (metre)

D=link distance (distance between transmitter and receiver)

h_{rx}= Mobile Station antenna height

$a(h_{rx})$= Mobiles station antenna height correction factor as described in the Hata model for urban areas

C_{dB}= 0dB for suburban or open environment

NOTE: This model is limited to cases where the base station antenna is placed higher than the surrounding building.

$$1500MHz < f_c < 2000MHz\,;\ 30m < h_{tx} < 200m;\ 1000m < d < 200m$$

The COST-231 Hata's model proposed the following formula to extend the Hata's model to 2GHz.The parameter C_{dB} is defined as 0dB for suburban or open environment and 3dB for urban environment

COST-231 Hata model contains corrections for urban, suburban and rural (flat) environment.

The term $a(h_{rx})$ is defined for urban and suburban environment respectively as

$$a(h_{rx}) = 3.2(log11.75h_a)^2$$

$$4.97 \quad f \geq 400MHz \text{..}(12)$$

$$a(h_{rx}) = 1.1(logf)h_r - (1.56log - 0.8) \quad \text{.............} \quad (13)$$

Where

h_a=receiving antenna height above ground level

VI. RESULTS

A simulation was done in Mathlab to compare the path loss between the Okumura-Hata and the COST-231 Hata models for three different frequencies (1000MHz, 1500MHz & 2000MHz) and for different base station antenna heights, and the following results were obtained.

The vertical axis represents the Path loss in dB, the horizontal axis represent the link distance in km.

A = large urban htr =30m, B = large urban htr =100m, C = suburban htr =30m, D = large urban htr =200m, E = suburban htr =100m, F = suburban htr =200m G= rural htr =30m, H= rural htr =100m, I= rural htr 200m,

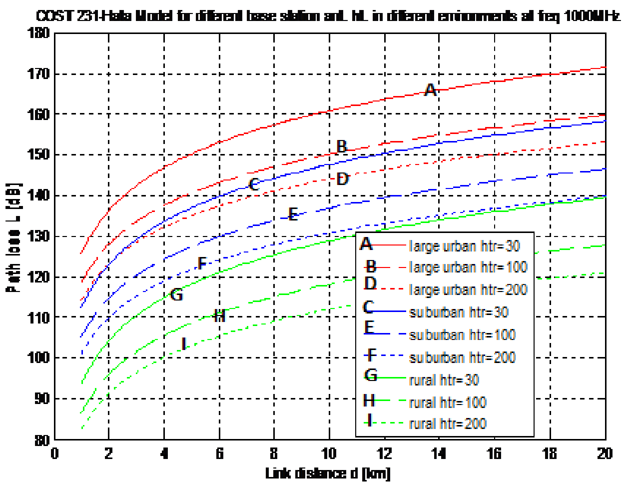

Fig.1, COST-231 Hata model for frequency 1000MHz

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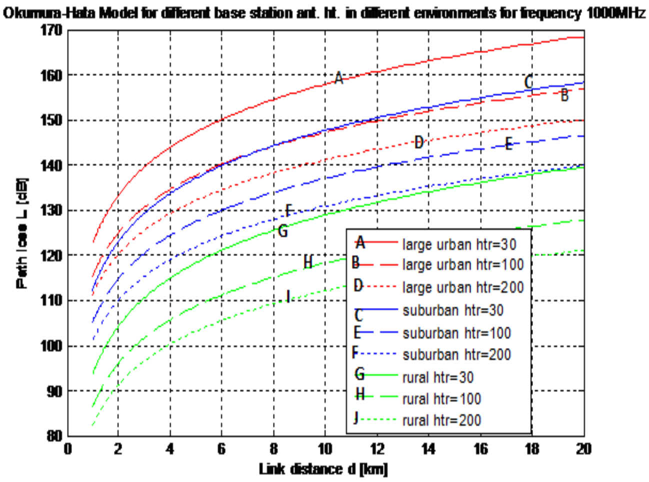

Fig.2, Okumura model for frequency 1000MHz

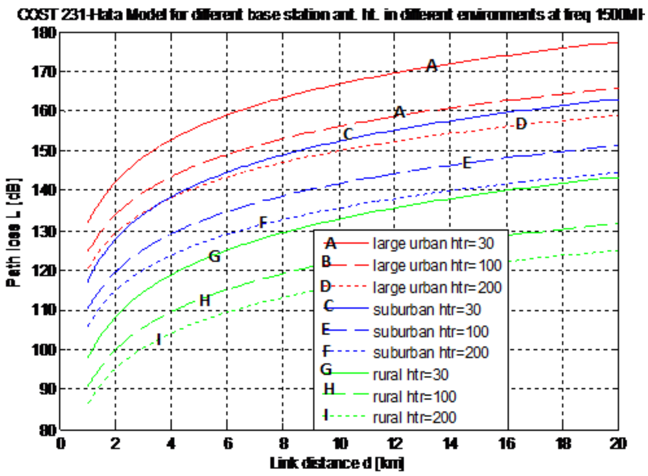

Fig.3, COST-231 Hata model for frequency 1500MHz

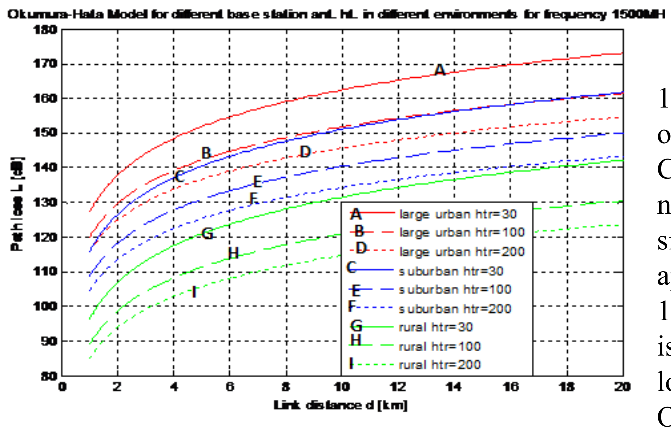

Fig.4, Okumura model for frequency 1500MHz

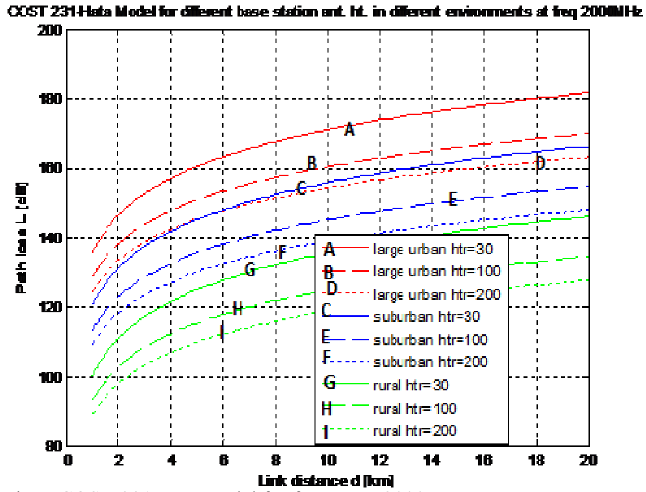

Fig.5, COST-231 Hata model for frequency 2000MHz

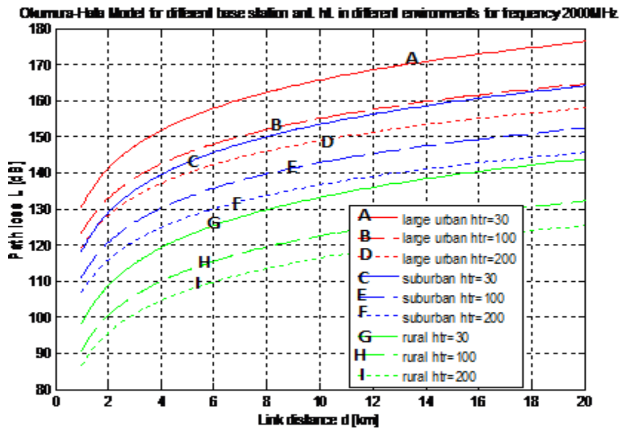

Fig.6, Okumura model for frequency 2000MHz

VII. CONCLUSION

The simulations were done for frequencies of 1000MHz, 1500MHz & 2000MHz, and link distances of 30m, 100m & 200m. For both Okumura-Hata and COST-231, the path loss is lowest when the mobile is nearest to the base station. From the result of the simulation, it can be seen that the path loss graphs apparently look similar especially for frequencies 1000MHz and 1500MHz, but on a keener inspection it is noticed that for antenna height of 200m, the path loss for COST-231 Hata model is lower than Okumura-Hata model in urban environment than other environment. It can be seen from the plot that the higher the antenna base station height, the better the path loss in both COST-231 Hata Model

The Path loss model for COST-231 Hata gives a better path loss value for the urban environment, which is the most realistic of the three terrains since the practical propagation environment is the urban.

The simulation shows that for a good radio propagation, where path loss will be minimized, the COST-231 Hata model should be used in LTE since the frequency range extends to 2000MHz.The result shows that the higher the height of the base station antenna, the lower the path loss expected, especially in the urban

In LTE deployment, for better performance, high antennas should be used, while COST-231 Hata model should be used as the radio propagation model since it presents better results. The model does not give a good result for antenna height less that 50m as is seen from the graphs above

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