ANALYSIS OF PROPAGATIONAL MODEL FOR 4G SYSTEM

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This Report Is Submitted In Partial Fulfilment Of Requirements For The Bachelor Degree of Electronic Engineering (Electronic Telecommunication)

Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer

Universiti Teknikal Malaysia Melaka

May 2017

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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PROJEK SARJANA MUDA II

Tajuk Projek : Analysis of propagation model for 4G system

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ABSTRACT

The objectives of this project are to compare and analyze various path loss models for different receiver antenna heights in urban, suburban and rural environment and to design a program to determine the most suitable propagation model for different parameters (height, environment and frequency). The overview of LTE and the principal of propagational models is reviewed. There is total of seven propagational model are review in this project. This project uses matlab and matlab gui as the designing tools. Matlab is used for design of the function while matlab gui is used for the interface design. The results are analyzed for the final product. The program is verified to be the same as the calculation result. Besides, the graphs plotted by the program are also verified to be the same as the graph plotted from the data. In conclusion, the project's objectives are achieved and the future work is discussed in the final chapter.

ABSTRAK

Projek ini bertujuan untuk membanding dan menganalisis tentang pelbagai model kehilangan lintasan untuk ketinggian penerima antenna yang berbeza di tempat bandar, pinggir bandar dan luar bandar. Selain itu, projek ini juga berobjectif untuk merekabentuk satu program yang boleh menentukan model propagasi yang paling sesuai untuk parameter yang berbeza (ketinggi, tempat dan kekerapan). Gambaran keseluruhan LTE dan model propagational telah dibincangkan. Terdapat sejumlah tujuh model propagational dikaji dalam projek ini. Projek ini menggunakan MATLAB dan MATLAB gui sebagai alat mereka bentuk. Matlab digunakan untuk reka bentuk fungsi manakala MATLAB gui digunakan untuk reka bentuk antara muka program. Keputusan telah dianalisis untuk produk akhir dan disahkan sama dengan kuputusan kiraan. Selain itu, graf diplot oleh program ini juga disahkan sama seperti graf diplot daripada data. Kesimpulannya, objektif projek tercapai dan kerja-kerja masa depan dibincangkan dalam bab terakhir.

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CHAPTER 1

INTRODUCTION

In this chapter, the details of the project which is the analysis of propagational model for 4G system is explained. Besides that, the objectives, problem statement, scope of project and chapter organization are also explained in this chapter.

1.1 PROJECT BACKGROUND

Without a doubt, mobile phone has become our daily necessity right now. Mobile network plays an important role to connect people around. Mobile network was first starting as Global System for Mobile Communication (GSM) and then it's being replaced by General Packet Radio Service (GPRS), Enhanced Data Rates for GSM (EDGE), Universal High Speed Downlink Packet Access (HSDPA), Mobile Telecommunication System (UMTS), Long Term Evolution (LTE) and Long Term Evolution Advanced (LTE-Advanced)[1]. 4G network often also known as Long Term Evolution (LTE) is continue growing bigger and better throughout the years. 4G services is currently available in 146 countries and 11 countries in schedule to have 4G services[2]. Due to these, it has become important to design an efficient 4G telecommunication system. There are plenty of propagation model available to predict the path loss of the system. Hence, selecting a suitable propagation model is crucial in the early phase of network planning process. Our main concentration in this thesis is to find out a suitable model for different environments to provide guidelines for cell planning of 4G LTE.

1.2 PROBLEM STATEMENTS

Nowadays, 4G LTE is such an established technology. There are numerous types of propagation model to predict path loss. Different propagation models are used in different terrain are used in the world nowadays. Due to the different types of models, all of them have different path loss depending on the parameters. Selecting a suitable propagation model is important in the initial network planning phase as selecting wrong propagation model will lead to inefficient overall system. The engineers would have to decide the most suitable propagation model to use to get the least path loss. Therefore, this project is needed to help the user to decide the most suitable propagation model to use.

1.3 OBJECTIVES

The objectives of this thesis are as follow:

1. To compare and analyse various path loss models for different receiver antenna heights in urban, suburban and rural environment.
2. To design a program to determine the most suitable propagation model for different parameters (height, environment and frequency).

1.4 SCOPE OF THE PROJECT

This program of this project is created by using MATLAB while the interface of the program will be created by using MATLAB GUI. This project is focused on the path loss of these propagation models including: Free Space Path Loss Model (FSPL), Okumura Model, COST 231 Hata Model, Stanford University Interim (SUI) Model, Hata-

Okumura extended model or ECC-33 Model, COST 231 Walfish-Ikegami (W-I) Model and Ericsson Model in three different environments which are urban, suburban and rural.

1.5 CHAPTER ORGANIZATION

This thesis consists of 5 chapters. Generally, chapter one is more to introduction of project. In this chapter, the project background, objectives, problem statements, scopes of project and chapter organization are discussed. Chapter 2 is the literature review of the project. the overview of LTE and the targets of LTE are researched. Besides that, the propagational models are analyzed and compared. Chapter 3 is the overall of methodology of project. The project flowchart and method that used to complete this project are explained in this chapter. Chapter 4, the result obtain from the project should present clearly and neatly. The results are clearly explained and will compared between current results and the calculated result. Chapter 5, report concludes with the overall summary of the studies based on the objectives and achievement. Furthermore, suggestion and improvement approach concerned with the topic.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the overview of LTE, target of LTE and benefits of LTE are discussed. Besides, the principal of propagational models and the various types of propagation model is discussed also in this chapter.

2.1 Long Term Evolution(LTE)

2.1.1 Overview of LTE Networks

Long Term Evolution (LTE) is a mobile broadband access technology founded due to the increasing demand of high data rate and it's based on the GSM/EDGE and UMTS/HSPA technologies. The Standard for LTE is based and developed by 3GPP (3rd Generation Partnership Project)[3]. 3GPP is a collaboration agreement, established in December 1998 that brings together a number of telecommunications standards bodies, known as 'Organizational Partners'. The ARIB, CCSA, ETSI, ATIS, TTA and TTC are current Organizational Partners. The joint LTE radio access standardization effort are participated by engineers all around the world especially Researchers and development engineers representing more than 60 operators, vendors and research institutes[4].

2.1.2 Targets for LTE

The LTE's targets include improving the peak data rate/user throughput by increasing the bandwidth to 20Mhz, download speed to 100Mbps and upload speed to 50Mbps. LTE also targets to be able to reduce the delay or latency to lower than 5ms. Besides, it also improving the spectrum efficiency to up to 200 active users in a cell at 5Mhz bandwidth. LTE also targets to be able to support multimedia broadcast and multicast services and the spectrum flexibility for allocation. Table 2.1 shows the targets or the requirement of LTE and the specific parameters and the spectrum[5].

Table 2.1 LTE performance requirement

Metric	Requirement
Peak data rate	DL: 100Mbps UL: 50Mbps (for 20MHz spectrum)
Mobility support	Up to 500kmph but optimized for low speeds from 0 to 15kmph
Control plane latency (Transition time to active state)	< 100ms (for idle to active)
User plane latency	< 5ms
Control plane capacity	> 200 users per cell (for 5MHz spectrum)
Coverage (Cell sizes)	5 – 100km with slight degradation after 30km
Spectrum flexibility	1.25, 2.5, 5, 10, 15, and 20MHz

2.1.3 Benefits of LTE

LTE provides several crucial advantages for consumers and operators:

• Performance and capacity –LTE has a crucial impact on the advantages due to the channel bandwidth supported. LTE can accommodate multiple channel bandwidths— 1.4, 3, 5, 10, 15, or 20 MHz due to its flexibility. However, when bandwidth goes over

5MHZ the performance of LTE in terms of user data rates, sector data rates, and higher spectral efficiency (bps/Hz) is significantly better[6]. LTE enables high quality video uplink and downlink applications due to its support of high peak data rates in uplink and downlink.

• Simplicity –LTE's flexibility allows it to support bandwidth from 5MHz up to 20Mhz. Besides that, it also supports both FDD (Frequency Division Duplex) and TDD (Time Division Duplex). Ten paired and four unpaired spectrum bands have so far been identified by 3GPP for LTE. And there are more band to come. This means that an operator may introduce LTE in 'new' bands where it is easiest to deploy 10MHz or 20MHz carriers, and eventually deploy LTE in all bands. Besides that, the building and management of next-generation networks can be simplified by LTE radio network products. For example, features like plug-and-play, self-configuration and self-optimization will simplify and reduce the cost of network roll-out and management. Lastly, LTE will be deployed in parallel with simplified, IP-based core and transport networks that are easier to build, maintain and introduce services on[7].

• Wide range of terminals – LTE embedded modules is widely in mobile phones, many computer and consumer electronic devices, such as notebooks, ultra-portables, gaming devices and cameras. These devices will incorporate since LTE supports hand-over and roaming to existing mobile networks, all these devices can have ubiquitous mobile broadband coverage from day one. In summary, operators can introduce LTE flexibly to match their existing network, spectrum and business objectives for mobile broadband and multimedia services. All these enhancements to the quality of service will allow more revenues[8].

2.1.4 Overall Network Architecture

LTE is the Radio Access Network (RAN) of the Evolved Packet System (EPS). The network core component of EPS, called Evolved Packet Core (EPC) or System Architecture Evolution (SAE), is designed to be a completely IP-centric network that provides QoS support and ensures revenue and security. Figure 1 below shows the basic overall architecture components of LTE. The architecture RAN consists of enhanced nodeBs (eNBs), and at the core have Mobility Management Entities (MMEs) and Serving Gateways (S-GW). The eNBs communicates with other eNBs through an interface called the X2 interface, while they are connected to entities at the core (MMEs and S-GWs) using the S1 interface[9].

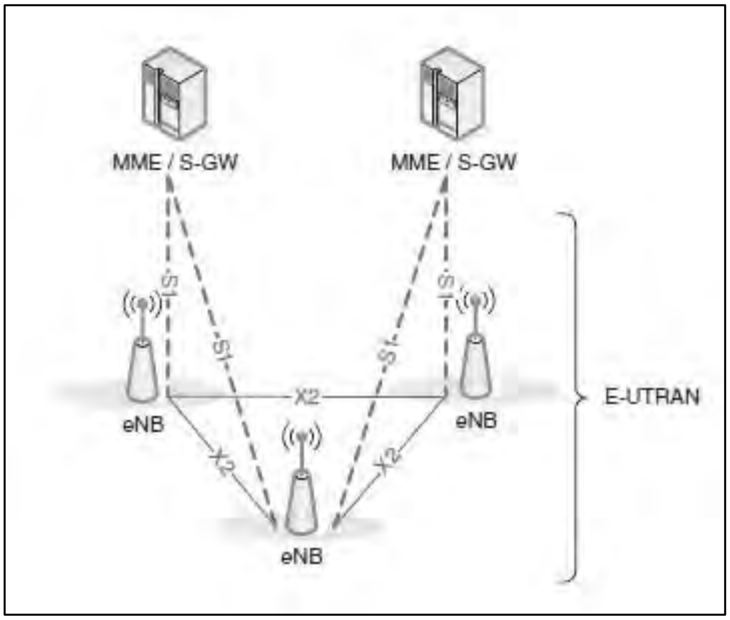

Figure 2.1 Overall Architecture[10]

2.2 Principal of Propagation Model

A propagation model describes the behaviour of the signal when it is transmitted from the transmitter to the receiver. The distance of transmitter and the receiver is related with the path loss are related by the propagation model. From this relation, the allowed path loss and the maximum cell range are can be calculated. Different types of propagation model will have different path loss which will be discussed[11].

2.2.1 Types of Propagation Model

There are three categories for model for path loss which are Empirical Model, Deterministic Models and Stochastic Models, where Empirical models can divided into Non-time-dispersive and Time-dispersive as shown in Figure 2.2[12]. The empirical Models is not based on mathematical model but using the observations and measurements for the prediction. The empirical models are mainly used to predict path loss[13]. The Deterministic model use the law of governing electromagnetic wave propagation in order to determine the received signal power in a particular locations. Lastly, the Stochastic model uses random variables to model the environment. It required the least information but the accuracy is not guaranteed[12].

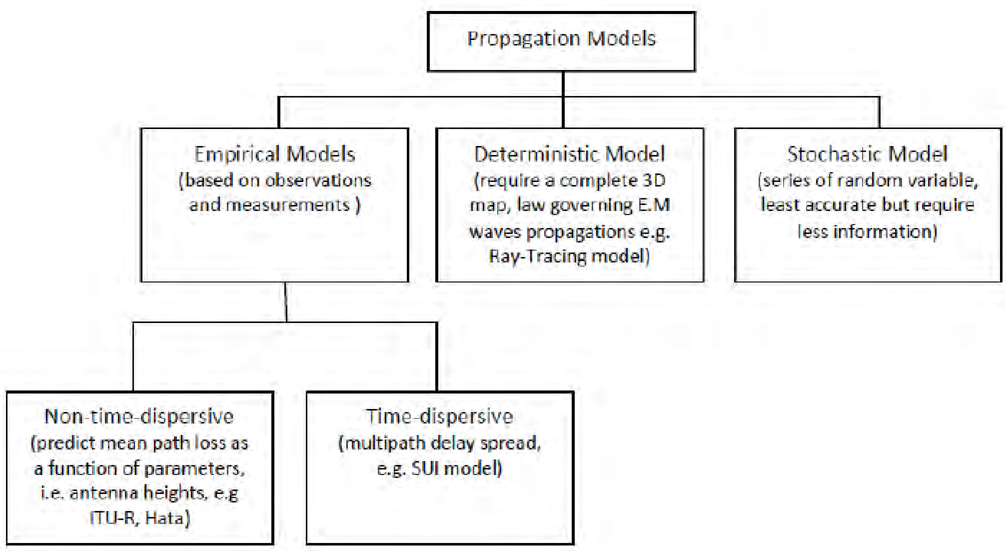

Figure 2.2 Categories of Propagation Models[12]

2.2.2 Basic Propagation Mechanism

The basic propagation mechanism can be categorized into four categories where the electromagnetic wave propagates by reflection, scattering and refraction. Reflection occurs when a signal is transmitted but some of the signal power may be reflected to the origin instead of being carried all the way. Diffraction is the apparent bending of waves around small obstacles and the spreading out of waves past small openings while Scattering is a general physical process where light, sound, or moving particles, are forced to deviate from a straight trajectory, by one or more localized non-uniformities, in the medium through which they pass. Figure 2.3 shows the basic propagation model where reflection is representing by R, scattering by S and Diffraction by D.

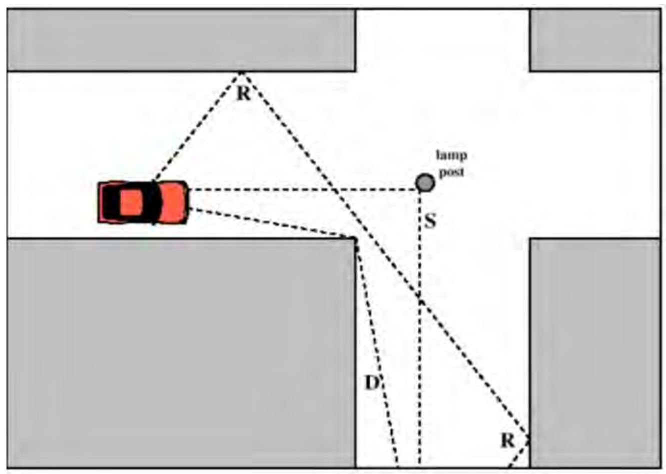

Figure 2.3 Sketch of Three Important Propagation Model[14]

2.3 Path Loss Model

There are many types of path loss model. In this review, seven path loss model are analyzed. There are three types of prediction area/environment which are open area, suburban area and urban area. Open area normally refers to open space with no tall tree or building in path while suburban area refers to Village Highway scattered with trees and house and some obstacles near the mobile but not very congested. Urban area is referring to build up city or large town with large building and houses and village with close houses and tall[15].

2.3.1 Free Space Path Loss Model (FSPL)

Free-space path loss (FSPL) is the loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space, with no obstacles nearby to cause reflection or diffraction. Free-space path loss is directly proportion to the square of the distance between the transmitter and receiver, and also directly proportional to the square of the frequency of the radio signal[16]. The calculation for path loss is done by using the following equations:

$$PL_{FSPL} = 32.45 + 20\log_{10}(d) + 20\log_{10}(f) \tag{2.1}$$

Where: *f* is the signal frequency (MHz) and *d* is the distance from the transmitter (km).

2.3.2 Okumura Model

Okumura model is one of the most commonly used models[11]. It is based on the measurements and data made in Tokyo in 1968. It can operate for frequencies up to 3000MHz. The distance between transmitter and receiver can be around 100km while the receiver height can be 3m to 10m[17]. This model is most suitable to use in the cities that have dense and tall structure which is the urban area. Okumura model is quite accurate in path loss prediction in cluttered mobile radio system environments. However, it is slow to response to rapid changes in terrain and not as good in rural areas[12]. The path loss in Okumura model can be represent by this calculation[15]:

$$L_{50}(dB) = L_F + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA} \tag{2.2}$$

$$G(h_{te}) = \begin{cases} 20log\,\frac{h_{te}}{200} & 100m > h_{te} > 10m \\ 10log\,\frac{h_{re}}{3} & h_{re} \le 3m \\ 20log\,\frac{h_{te}}{3} & 10m > h_{re} > 3m \end{cases} \tag{2.3}$$

$L_{50}(dB)$: median path loss

L_F: free space propagation loss

$A_{mu}(f,d)$: median attenuation relative to free space

$G(h_{te})$: base station antenna height gain factor

$G(h_{re})$: mobile antenna height gain factor

G_{AREA}: gain due to the type of environment

h_{te} : base station antenna height (m)

h_{re} : mobile antenna height (m)

Figure 2.4 shows the values of $A_{mu}(f,d)$ and G_{AREA}.

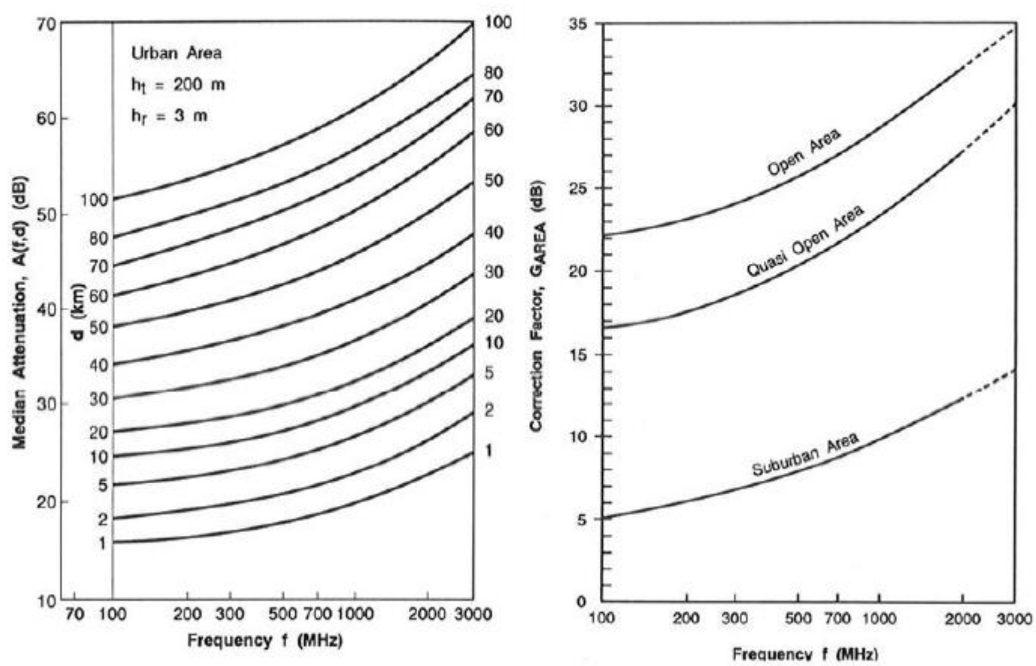

Figure 2.4 Median attenuation and area gain factor [16]

2.3.3 COST 231 Hata Model

Cost 231 Hata Model is an extended version of Okumura model[18]. Its frequency range is extended to 150Mhz to 1500Mhz to predict the median path loss for the distance from the transmitter to receiver 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. To predict the path loss in the frequency, range 1500 MHz to 2000 MHz[16]. This model can be used to calculated path loss in urban, suburban and rural. The path loss equation is shown as[14]:

$$PL = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - ah_m + (44.9 - 6.55\log_{10}(h_b))\log_{10}(d) + c_m \tag{2.4}$$

where

d: Distance between transmitter and receiver antenna [km]

f: Frequency [MHz]

h_b: Transmitter antenna height [m]

The c_m is a constant factor where:

$$c_m = \begin{cases} 0db, & suburban \\ 3db, & urban \end{cases} \tag{2.5}$$

The value of ah_m has different formula in different environment, for urban area[1]:

$$ah_m = 3.20(\log_{10}(11.75h_r))^2 - 4.79 \qquad for\ f > 400Mhz \tag{2.6}$$

And the value of ah_m for suburban and rural areas are:

$$ah_m = (1.1\log_{10} f - 0.7)h_r - (1.56\log_{10} f - 0.8) \tag{2.7}$$

where the h_r is the receiver antenna height in meter.