Comparative Study on Radio Wave Propagation Models for 4G Network

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***Abstract* - This paper is about comparative study on the radio wave propagation models for the Fourth Generation Mobile Network known as Long Term Evolution Advanced (LTEAdvanced). The selection of radio wave propagation model is essential as the propagation model is able to estimate and predict the radio wave propagation path loss value between the transmitter and receiver for different types of environments. From the preliminary results, it shows that COST-231 Hata model produce higher path loss value due to it is only applicable for LOS situation and macro cell environment as the model does not consider radio wave propagation reflections and shadowing. In contrast, COST-231 Walfisch-Ikegami is applicable for both LOS/NLOS situations and both macro and micro cell environments because the model considers radio wave propagation reflections and shadowing.**

Keywords*- *4G, COST-231 Hata, COST-231 Walfisch-Ikegami, propagation model.

I. INTRODUCTION

Mobile network was first introduced as Global System for Mobile Communication (GSM) before it being replaced by General Packet Radio Service (GPRS), Enhanced Data Rates for GSM (EDGE), Universal Mobile Telecommunication System (UMTS), High Speed Downlink Packet Access (HSDPA), Long Term Evolution (LTE) and Long Term Evolution Advanced (LTE-Advanced). Figure 1 shows the types of mobile network from its first generation to the fourth generation. Long Term Evolution Advanced (LTE-Advanced) is the next generation of Long Term Evolution (LTE) mobile network services developed to comply with the requirements on IMT-Advanced and Fourth Generation (4G) standards that being defined by International Telecommunication Union (ITU) and 3rd Generation Partnership Project (3GPP). LTE is often defines as 4G services because of its major performance enhancements, however the 3rd Generation Partnership Project (3GPP) and the International Telecommunication Union (ITU) are still not considered LTE as a 4G services [1]. LTE-Advanced has a download peak rates at over 1Gbps and the uplink peak rates greater than 500 Mbps [2]. LTE-Advanced is developed to have backwards compatibility to ensure that it would not give any effect on the existing LTE terminals when deploying the LTE-Advanced on spectrum that already been occupied by LTE [3].

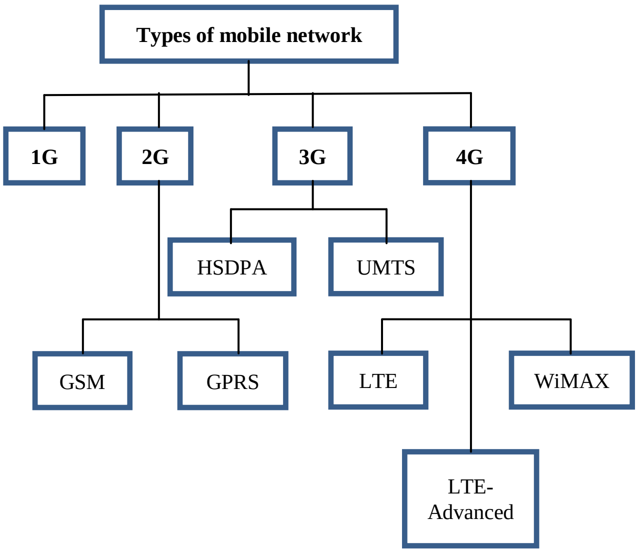

Figure 1: The types of mobile network

In general, the radio wave propagation models can be classified into two major categories, which are empirical models and deterministic model [4]. There are a large numbers of radio wave propagation models created to predict the path loss between transmitter and receiver for different types of environments. Some of the propagation models are Ericsson 9999 model, Lee model, Egli model, COST-231 Hata model, Okumura Hata model, COST-231 Walfisch-Ikegami model, Walfisch-Ikegami model and Stanford University Interim (SUI) model. Figure 2 shows types of radio wave propagation models.

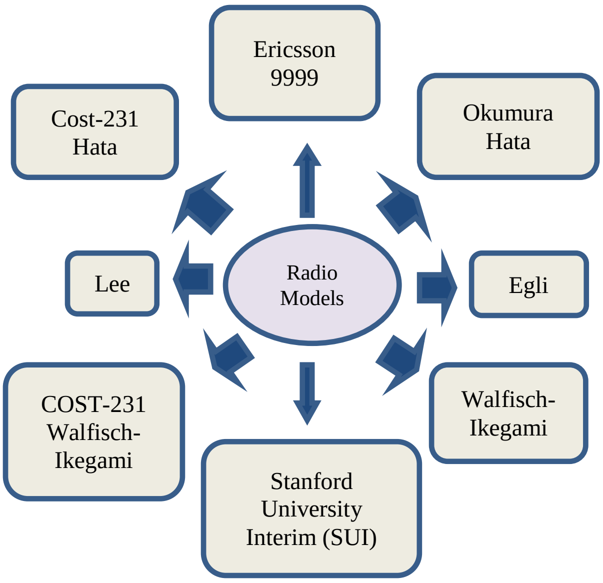

Figure 2: Types of radio wave propagation models

The selection of an appropriate radio wave propagation model for LTE-Advanced mobile network is necessary as it is capable to estimate predict the radio wave propagation path loss value between the transmitter and receiver for different types of environments. However, the study presented here only focuses on the comparison of two radio wave propagation models which are COST-231 Hata Model (Advanced Okumura-Hata) and COST-231 Walfisch-Ikegami Model (Advanced Walfisch-Ikegami).

The structure of the paper is organized as follows: Section I covers the introduction and general view on LTE-Advanced, and radio propagation models. Section II describes on the two radio wave propagation models; COST-231 Hata Model and COST-231 Walfisch-Ikegami. Section III is on comparison, and discussion on the two propagation models; COST-231 Hata Model and COST-231 Walfisch-Ikegami Model. Section IV concludes on the paper and future work.

II. COST-231 HATA MODEL

The COST-231 Hata model is an extended version of well-known Okumura-Hata propagation model. It has extended frequency range of 1500 MHz to 2000 MHz compared to the Okumura-Hata model which is only valid in the range of 100 MHz to 1500 MHz [5]. The COST-231 Hata Base Station (BS) antenna height range is from 30 to 200 meters, the mobile antenna height range is between 1 to 10 meters and the distance of Base Transceiver Station (BTS) and Mobile Station (MS) ranges between 1 to 20 kilometers which are similar with the ones in Okumura-Hata Model [6].

Equation (1) below is the equation for path loss prediction using the COST-231 Hata model:

$$L = 46.3 + 33.9 \log_{10}(f) - 13.82 \log_{10}(H_b) - a(H_m) + [44.9 - 6.55 \log_{10}(Hb)] \log_{10}(d) + C. \quad (1)$$

Where: f is the frequency (MHz), H_b is the base station antenna height (m), $a(H_m)$ is the mobile antenna correction factor (meters), d is the distance between the BTS and MS (kilometers), C is a constant factor (C = 0 dB for medium and suburban macro and C = 3dB for urban macro and metropolitan areas).

There are two types of correction factor for $a(H_m)$, one is for medium sized city, equation(2):

$$a(H_m) = [1.1 \log_{10}(f) - 0.7]\, H_m - [1.56 \log_{10}(f) - 0.8] \quad (2)$$

one is for large city, equation (3):

$$a(H_m) = \begin{cases} 8.29\,[\log_{10}(1.54\, H_m)]^2 - 1.1 : & f \leq 200 \text{ MHz} \\ 3.2\,[\log_{10}(11.75\, H_m)]^2 - 4.97 : & f \geq 400 \text{ MHz} \end{cases} \quad (3)$$

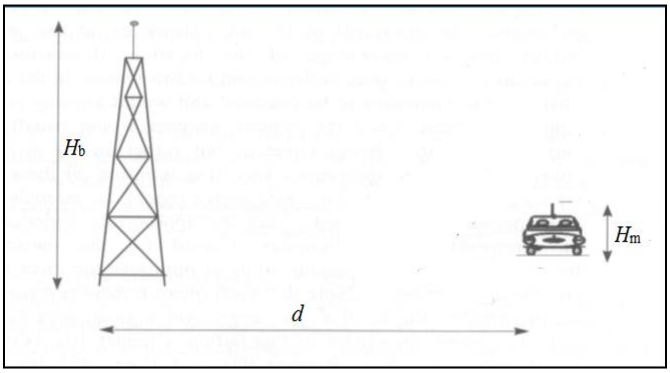

Figure 3: Illustration of COST-231 Hata Model

III. COST-231 WALFISCH-IKEGAMI MODEL

The COST-231 Walfisch-Ikegami Model is an improved version of Walfisch-Ikegami Model which improved the prediction of path loss by considering more data such as heights of buildings (h_{roof}), widths of roads (w), building separation (b) and road orientation with respect to the direct radio path (φ) for the urban environment character description [7].

The COST-231 Walfisch-Ikegami share the same characteristics in terms of frequency range, mobile antenna height range, base station antenna height range and transmitter and receiver distances range with the Walfisch-Ikegami model. Both of them have usable frequency ranges of 800-2000MHz. The range for mobile antenna height is between 1 to 3 meters, base station antenna height is between 4 to 50 meters and the distances of transmitter and receiver ranges from 0.02 to 5 kilometers [6].

The COST-231 Walfisch-Ikegami models are separated into two types of cases, which are the line-of-sight (LOS) and non-line-of-sight (NLOS) situations [7]. Equation (4) is for path loss prediction in the LOS situation.

$$L = 42.6 + 26 \log_{10} d + 20 \log_{10} f. \quad (4)$$

Where: *d* distance (kilometers), *f* frequency (MHz)

Equation (5), (6) and (7) is for non-line-of-sight situations that are divided into three components; free space loss (5), rooftop-street diffraction and scatter loss (6), and multiscreen diffraction loss (7).

$$L_0 = 32.4 + 20 \log_{10} d + 20 \log_{10} f \quad (5)$$

Where: L_0 is the free space loss, *d* is distance (kilometers), *f* is frequency (MHz)

$$L_{rts} = -16.9 - 10 \log_{10} w - 10 \log_{10} f - 20 \log_{10} (h_{roof} - h_{RX}) - L_{Ori} \quad (6)$$

Where: L_{rts} is the rooftop–street diffraction and scatter loss, *w* is the mean value for street widths (meters) h_{roof} is the mean value for building heights (meters)

$$L_{msd} = L_{bsh} + k_a + k_d \log_{10} d + k_f 10 \log_{10} f - 9 \log_{10} b \quad (7)$$

Where: L_{msd} is the multiscreen diffraction loss, k_d and k_a is the dependence controller of the multiscreen diffraction loss versus distance and radio frequency, *f* is the frequency(MHz), *b* is the building separation (meter).

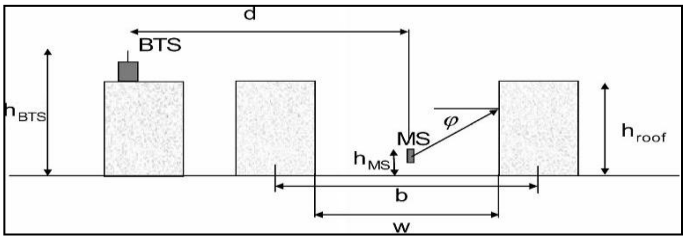

Figure 4: Illustration of COST-231 Walfish-Ikegami Model

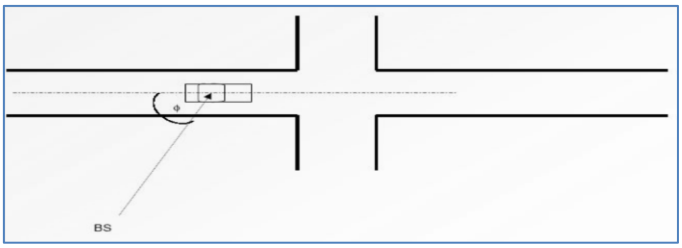

Figure 5: Definition of road orientation

IV. Propagation Model Comparison

This research is based on the frequency bands of 1900 MHz as this frequency bands are frequently used by many parts of the world for TDD LTE-Advanced. Comparison between two radio wave propagation models is made to find out the best suitable in particular terrain like urban, suburban and rural. The comparison is made on the basis of path loss, antenna height and transmission frequency.

Parameter of the simulation is shown in Table 1.

TABLE 1. Parameters

Parameter	Value
Transmitter Antenna Height	30 m urban and suburban 20 m rural
Receiver Antenna Height	3 m
Frequency	1.9 GHz
Distance between Antennas	5 km
Buildings Distance	50 m
Average Buildings Height	15 m
Road Width	25 m
Road Angle	30^o urban and 40^o suburban

V. PRELIMINARY RESULTS

Results in Table 2 is only a preliminary results for the research based on frequency bands of 1900 MHz with a distance between antenna is 5 km, base antenna height of 30 m and receiver antenna height of 3 m.

TABLE 2. Preliminary Results

Model	Frequency (MHz)	Distance (km)	Base Antenna Height (m)	Receiver Antenna Height (m)	Urban Path Loss (dB)
COST 231 Hata	1900	5	30	3	194.03
COST 231 WI	1900	5	30	3	150.20

V. Conclusion and Future Work

From the preliminary results in Table 2, it shows that COST-231 Hata model has a higher path loss value compare to the path loss value produced by COST-231Walfisch-Ikegami model when all the parameter used are the same for both models. This is due to COST-231Hata model does not consider radio wave propagation reflections and shadowing. The model also only based on quasi-smooth terrain or LOS situation. Therefore, COST-231Hata model is only applicable for macro cells environment. On the other hand, COST-231 Walfisch-Ikegami model does consider radio wave propagation reflections and shadowing. In other word, the model is applicable on LOS and NLOS situations which mean it takes the effects of individual buildings and many propagation paths into account. Therefore, COST-231 Walfisch-Ikegami model is applicable for both micro and macro cells environment. In future, we are going to resume the simulation on MATLAB GUI with the other parameter based on the two models mentioned above. A further analysis of the results and plotted graph would give better details and accurate results.

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