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Comparison of Propagation Models for WiMAX networks in suburban and rural areas (Wadi-Ashati)

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Abstract WiMAX is a wireless access system that offers fixed, nomadic, portable and mobile wireless broadband services. The problem of dimensioning large scale broadband wireless systems is a vital confront in radio network planning. A perfect knowledge of path loss performance is an essential requirement for primary deployment of wireless network and cell planning. This paper presents a simulation study of different path loss empirical propagation models (Cost 231 hata Model, Ericsson Model, Stanford University Interim (SUI) Model) with measured field data in suburban and rural environment, where The field measurement data is taken in suburban (medium density region) at 3500 MHz frequency.

Keywords: WiMAX, Ericsson Model, SUI Model, Cost 231 Hata.

مقارنة نماذج الانتشار لشبكات WiMAX في الضواحي والمناطق الريفية (وادي الشاطئ)

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الملخص شبكات النطاق العريض (WiMax) هو نظام وصول لاسلكي يقدم خدمات النطاق العريض اللاسلكية الثابتة والمحمولة. تمثل مشكلة تحديد أبعاد الشبكة والنظام بشكل عام مشكلة اساسية في تخطيط لبناء شبكات النطاق العريض او الجيل الرابع. المعرفة الكاملة للتوهين الناتج عن فقد المسار وتأثيره على الأداء بشكل عام هي مطلب أساسي للتحضير والاعداد للتأسيس الأولي للشبكة اللاسلكية والتخطيط الخلوي. تقدم هذه الورقة دراسة محاكاة لنماذج الانتشار التجريبي المختلفة لفقدان المسير (Cost 231 hata Model, Ericsson Model, Stanford University Interim (SUI)) مع بيانات المجال المقاسة في المدينة و الضواحي والبيئة الريفية. تم اخذ القياسات الحقيقية والقراءات بشكل عام من شبكة النطاق العريض بمنطقة وادي الشاطئ حيت تتطابق مواصفات المدن الضواحي والمناطق الريفية.

الكلمات المفتاحية: شبكة الواي ماكس ، نموذج اريكسون ، نموذج Cost 231 Hata ، نموذج SUI .

1. Introduction

Presently, the use of Internet and mobile communication has increased tremendously, the statistics in Libya shows that there are more than 2.5 million internet and mobile users in Libya in May 2015 . Libya has one of the highest number of internet and mobile users (comparison with population) in Africa and ranks top 60 in the world, with a population of about 6 million people, the internet penetration ratio in Libya is about 27%, which is still low. Major population in Libya resides in remote areas where access to basic amenities like telephony, internet etc are difficult to provide. Broadband wireless access have become the best way to meet the demand for rapid Internet connection and integrated data, voice and video services in remote and rural areas, Broadband wireless access can extend fiber-optic networks and provide more capacity than cable networks or digital subscriber line [1] .The free license band spectrum (IEEE 802.11b, 2.4 GHz Band) of Wi-Fi, the easy availability of Wi-Fi devices, and very good QoS features of WiMAX, makes it suitable to provide long range communications for rural areas such as (Wadi-Ashti) and can satisfy bandwidth requirement at proper price that suits rural people, The benefits of this integration include cost- effective backhaul with long range, interference-free, licensed WIMAX and the cost effective access of Wi-Fi clients[1]. In wireless communication systems, transfer of information between the transmitting antenna and the receiving antenna is achieved by means of electromagnetic waves, Furthermore, the interaction between the electromagnetic waves and the environment reduces the signal strength which is sent from transmitter to receiver, that causes the path loss[2]. There are several propagation models which can precisely calculate the path loss. In this paper various propagation models (COST 231 Hata Model, Stanford University Interim (SUI) Model and Ericsson Model) are compared and analyzed.

2. Propagation modules

2.1. COST 231 Hata Model

This model is widely used for predicting path loss in wireless system , and COST 231 project is the development of the outdoor propagation models for application in urban areas at higher frequencies [3] . Cost 231 Hata model is initiated as an extension of Hata-Okumura model, It is designed for 500MHz to 2000MHz frequency range, The main advantage is that it contains corrections for urban, suburban and rural (flat or open area) environments, Its simplicity and the availability of correction factors have seen it widely used for path loss prediction at 3.5 GHz frequency band [4].The basic path loss equation for this COST-231 Hata Model can be expressed as [5]:

$$PL = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b) - ah_m + (44.9 - 6.55\log_{10}(h_b))\log_{10}(d) + C_m \quad (1)$$

Where:

f : the operating Frequency ($500 \le f \le 2000$)MHz

d : Distance between transmitter and receiver antenna (1 - 20 km).

h_b : Height of transmitter antenna (AP) (30 - 200m)

The parameter C_m is correction factor, its value is 0dB for suburban and rural area and 3dB for urban area.

The parameter ah_m is defined for urban environments as:

$$ah_m = 3.20(\log_{10}(11.75h_r))^2 - 4.97 \quad , \; for \; > 400MHz \quad (2)$$

And for rural or suburban (small –to- medium) environments

$$ah_m = (1.1\log_{10}(f) - 0.7)h_r - (1.56\log_{10}(f) - 0.8) \quad (3)$$

Where :

h_r : the CPE antenna height above ground level (1 - 10m).

2.2. Stanford University Interim (SUI) Model

Working group of IEEE 108.16 proposed this standard for the frequency range below 11GHz, and, for prediction of path loss in urban, suburban and rural environments, The proposed standards for frequency range below 11GHz contain the channel models developed by Stanford University, namely the SUI models [6] . Novelty of this model is the introduction of the path loss exponent, γ , and the weak fading standard deviation, S, as random variables obtained through a statistical procedure. This model has been derived as an extension to Hata model with 1900 MHz frequency band and above, and proposed in the literature as a solution for the planning of WiMAX/LTE network on a 3.5 GHz band[5]. This model is defined for the Multipoint Microwave Distribution System (MMDS) for the frequency band from 2.5 GHz to 2.7 GHz; the correction parameters allowed extending it up to 3.5 GHz band [7]. The base station antenna height of SUI model can be used from 10 m to 80 m, Receiver antenna height is from 2 m to 10 m, the cell radius is from 0.1 km to 8 km , The SUI models are subdivided into three different types, namely A, B & C, Terrain A can be used for hilly areas with moderate or very dense vegetation, and This terrain presents the highest path loss , considered terrain A as a dense populated urban area ,Terrain B is characterized for the hilly terrains with rare vegetation, or flat terrains with moderate or heavy tree densities , and considered this model for suburban environment, and this terrain presents the intermediate path loss scheme , Terrain C is suitable for flat terrains or rural with light vegetation, here path loss is minimum[5]. The fundamental path loss expression for the SUI model along with correction factors is as[8]:

$$PL = A + 10\gamma\log_{10}(\frac{d}{d_0}) + X_f + X_h + S \; , \quad for \; d > d0 \quad (4)$$

Where:

d: Separation of transmitter and receiver [km]

$d0$:100 [m]

X_f : Correction factor for frequency [MHz] > 2GHz

X_h : Correction factor for receiving antenna height [m]

S : the Correction factor , and defined as log normally distributed that is used to account the effect for the shadow fading owing to trees and other obstacles , and it has values depends on the environment type, 8.2 dB in Rural , 9.6 in suburban , and 10.6 dB in urban.

The parameter A is the intercept parameter and defined as:

$$A = 20\log_{10}(\frac{4\pi d_0}{\lambda}) \quad (5)$$

Where:

λ: the wave length [m]

The path loss exponent γ is given by:

$$\gamma = a - bh_b + \frac{C}{h_b} \quad (6)$$

Where:

h_b: the base station antenna height [m]

The constants a, b, and c depend upon the types of terrain, that are given in Table 1.

Table 1: The parameter values of different terrain for SUI model

The parameter	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	17.1	20

The value of parameter γ depends on the environment type, for urban area, the path loss component γ=2, in urban NLOS environment: 3< γ>5, and for indoor propagation γ>5.

The correction factors for the operating frequency and for the receiver antenna height for the model are:

$$X_f = 6\log_{10}(\frac{f}{2000}) \quad (7)$$

$$X_h = -10.8\log_{10}(\frac{h_r}{2000}) \quad , \; \text{for Terrain A and B} \quad (8)$$

$$X_h = -20\log_{10}(\frac{h_r}{2000}) \quad , \; \text{for Terrain C} \quad (9)$$

Where:
hr: the receiver antenna height (CPE) [m]

2.3. Ericsson Model

To predict the path loss, the network planning engineers are used a software provided by Ericsson company is called Ericsson model, This model also stands on the modified Okumura-Hata model to allow room for changing in parameters according to the propagation environment[3] . It using for higher frequencies (i.e. higher than 3GHz), Sometimes, it is called 9999 model, Path loss according to this model is given by [5]:

$$LP = a_0 + a_1 \log_{10}(d) + a_2 \log_{10}(h_b) + a_3 \log_{10}(h_b)\log_{10}(d) - 3.2(\log_{10}(11.75h_r)^2) + g(f)$$

(10)

Where:

$$g(f) = 44.49\log_{10}(f) - 4.78(\log_{10}(f))^2 \quad (11)$$

f: the operating Frequency [MHz]
h_b: Transmission antenna height [m]
h_r: Receiver antenna height [m]

The Parameters (a_0, a_1, a_2 and a_3) are constants, which can be changed for better fitting specific propagation conditions; the default values of these parameters for different terrain are given in Table 2.

Table 2: Values of parameters for Ericsson model

Environment	a_0	a_1	a_2	a_3
Suburban	43.20	68.63	12	0.1
Rural	45.95	100.6	12	0.1

3. The Simulation of Models and Analysis of results

In this paper, COST 231 Hata Model, Stanford University Interim (SUI) Model and Ericsson Model was simulated and analyzed in suburban and rural environments by applying receiver antenna height its length 3m. Table 3 shows values of the parameters which were applied at this research.

Table 3 : Parameters of the Simulation

The Parameters	The values
The operating frequency	3.5MHz
The Receiver antenna height	3 m
The Transmission antenna height	57m
The Distance between transmitter and receiver antenna	(1 - 8) km

3.1. Experimental Results

WiMAX is a Fixed Wireless Access (FWA) network suitable for broadband services on areas without adequate cable infrastructure, This system is based on the Orthogonal Frequency Division Multiplex (OFDM) and realizes broadband data transmission by using a radio-frequency range of 2-11 GHz and 10-66 GHz , An important feature of an OFDM system is a possibility of successful communication even under non-line-of-sight (NLOS) propagation condition, WiMAX uses adaptive modulation which is dependent on the signal to noise ratio (SNR), In a difficult propagation condition with a high level of interference or with a weak signal on the receiver antenna, the system chooses a more robust and slower modulation and ensures transmission[9]. In an ideal condition, WiMAX offers a bit rate of up to 75 Mbps, within the range of 50 km, which depends on radio- optical visibility between the transmitter and the receiver, So far, measurements on the field, under real conditions show significant degradation of declared characteristics, i.e. the coverage range between 5 and 8 km and the bit rate of up to 2 Mbps [8]. Experimental measurements of radio propagation characteristics are made in suburban and rural areas for a WiMAX system working at 3.5GHz, Measurements are carried out in the Wadi Ashati area and its suburban region, (Brak, Gurda and Gera) are a medium-sized city in Wadi Ashati, (Zewaya and Gagum) are small sized and rural, with a high percent of residential areas . Transmitting antenna height, h_b, is 57 m, and receiving antenna height, h_r, is 3 m. Receiver power is measured at 14 locations, which are selected to reflect two distinctive propagation scenarios : LOS propagation path with direct visibility between antennas, and NLOS propagation path without direct visibility. At each location 13 measurements were taken, i.e. every 20 cm along with the line connecting the base station and receiver antennas, as well as every 20 cm perpendicular to that line. The mean value of measurements at each location is compared with results obtained with three statistical models: SUI for C terrain type, COST 231 Hata, Model 9999.

3.2. Results of measurements

Results of measurements as well as predictions of the receiver power obtained by models are given in Fig. 1. for NLOS propagation condition, In this case, the best prediction model is SUI with the prediction error standard deviation бNLOS=3.5dB. The COST231 Hata model underestimates receiver power while the Model 9999 and the SUI Model overestimate receiver power . Fig. 2 shows measurement and prediction results for LOS propagation conditions, The best prediction model in this case is the Model 9999 the , and COST 231 Hata is the worst . For LOS propagation condition the SUI model gives бNLOS =13.15 dB . Prediction error standard deviations for LOS and NLOS measurement are given in Table 4.

Table 4. Error standard deviation

Error Standard deviation (б)	SUI Terrain type C	Cost 231 Hata	Ericsson Model (Model 9999)
б $_{NLOS}$ (dB)	3.5	5.6	8.8
б $_{LOS}$ (dB)	13.15	17.81	6.36

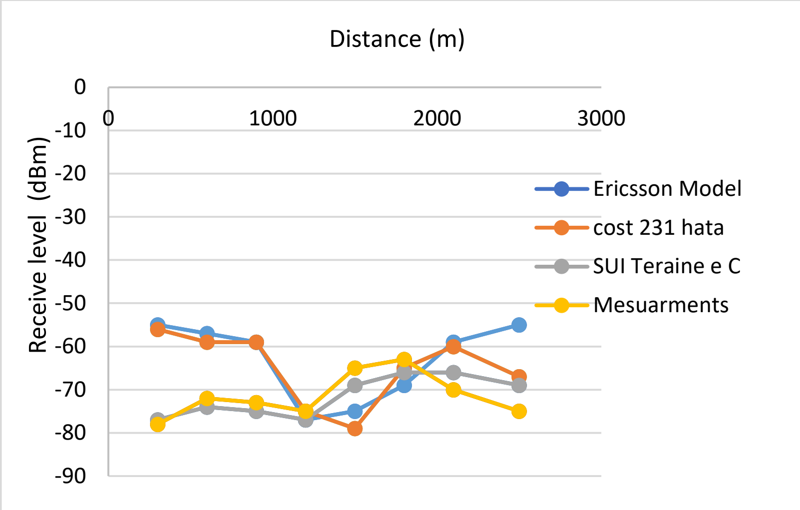

Fig. 1. Under NLOS propagation condition

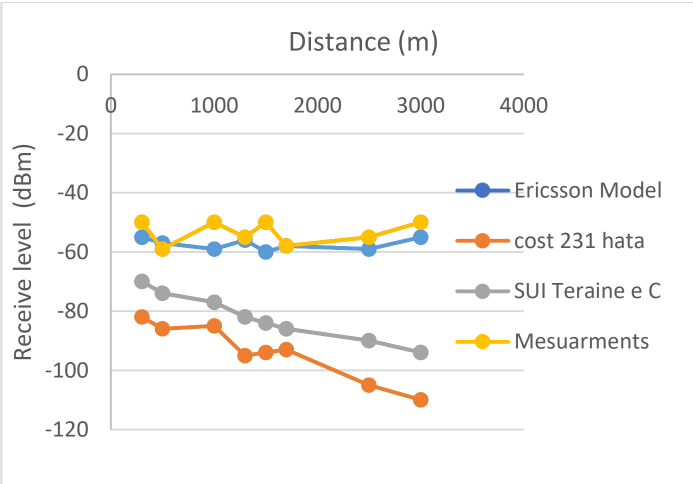

Fig. 2. Under LOS propagation condition

Measurements show a very interesting feature that receiver power does not decrease with the distance, This phenomenon can be explained existence of multipath components reaching the receiver antenna The OFDM system can effectively use them because of the guard period incorporated in the signal.

4. Conclusion

The goal of this paper is a comparison of propagation model accuracy under different propagation conditions in a 3.5 GHz frequency band. Measurements are taken for an installed WiMAX system in Wadi Ashati, South of Libya. The SUI model gives most accurate results for NLOS, but with a high level of prediction error for the location with LOS propagation. Although this model adapts different parameters to a specific propagation condition, its main shortcoming is the lack of distinguishing suburban and rural environments, In the SUI model terrains are divided into three categories, A, B, C, which may be chosen arbitrarily and therefore it is a source of an additional error. The Model 9999 show worse performance for NLOS propagation, while the results for LOS propagation condition obtained with this prediction model are better than the results obtained with the SUI and the COST 231 Hata model. Neither of the prediction models used has been suitable for both NLOS and LOS propagation in our experiment. Experimental results show that separation of prediction for NLOS and LOS conditions improves prediction accuracy if the most suitable model is chosen for a given location.

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