Field Measurement and Empirical Models for Radio Signal Propagation Prediction in Baghdad

Dina J. Jabbar
Electrical Engineering Technical Collage
Middle Technical University
Baghdad Iraq
Dina.dinaa89@gmail.com

Aseel H. Al-Nakkash
Electrical Engineering Technical Collage
Middle Technical University
Baghdad Iraq
Aseel_Alnakkash@eetc.mtu.edu.iq

***Abstract*— Mobile communications businesses have grown rapidly through recent years. In front of this development, quality of services may consider as a big challenge. Accordingly, the need for optimization in all mobile networks' aspects is essential. The optimization starts from good planning which provides a good coverage area and hence the best signal quality. An important factor that playing the fundamental's role in characterizing accurately the environment is the appropriate propagation model. In this work, an empirical model is being selected to characterize two regions, urban and suburban areas. The selected model will be adapted to analyze the performance of 2G and 3G mobile networks that are currently operated in Baghdad city. An extensive drive and walk test are conducted to collect the field measurement data. After comparative analyses between the simulated and the measured data, the results clarify that; Cost231-Hata model is the most suitable propagation model for the 2G network in all environment. Cost231-Hata model achieves the least Root Mean Squared Error (RMSE) equals to 3.37dB and 2.24dB for urban and suburban respectively. For the 3G network, Cost231-Hata model achieves the least RMSE equals to 8.17dB in an urban environment, while the ITU model is determined to be the suitable model for the suburban environment with RMSE equals to 4.45dB.**

Keywords*— Drive test, Propagation models, 2G, 3G, Urban, Sub-urban.

I. INTRODUCTION

Since1980's, mobile communications growth rapidly until becoming an essential demand in our daily life and investment in this field become profitable. Accordingly, commercial mobile communications companies compete with each other to provide the best services in order to attract more subscribers [1]. Best mobile communications services means providing a good connection between the mobile station and the cellular network everywhere and at any time. This requires an optimal network design that provides the best coverage and less interference. The Path Loss (PL) is used as a metric to evaluate the network performance by determining the amount of power attenuation [2]. PL can be estimated based on the propagation model which characterizes the propagation of the radio waves in a different environment; indoor, outdoor, urban, suburban and rural [3]. Propagation models are mathematical formulas that take into account all the important parameters that affect the radio waves such as; frequency, distance and antenna height…etc. On the other hand, each environment has its' specific clusters. Accordingly, the researchers' efforts have employed to find the appropriate propagation model that fit their environment properties. Some of the researchers' works will be illustrated below:

Several propagation models were discussed in [4]. The study includes a wide range of frequencies. The effects of an environment such as; fading, shadowing…etc. were also considered.

In [5], several propagation models were adopted in the simulation that was performed using Atoll software for two GSM band frequencies (900MHz and 1800MHz). The author concluded that Standard Propagation Model and Stanford University (SUI) was the best-fitted model to the environment of Makurdi City in Nigeria. The author based on the comparison between the simulation results and the experimental results from the driving test.

The author in [6] made a comprehensive investigation for the three major operators' mobile networks in Iraq. A drive test through a route has conducted to quantify experimentally their quality of services.

The Okumura-Hata model was adopted in [7] for planning a 3G cellular network in Palestine based on radio network planning tools. Okumura-Hata model is the one adopted by Wataniya Company (the main Mobile network operator) and it was proved the best-suited propagation model for the area of interest.

A suburban study area in Edo State in Nigeria was investigated to quantify the strength of a GSM signal in [8]. Three GSM operators' networks were evaluated by conducting a driving test for outdoor and indoor environments. The effects of buildings' materials were also discussed in term of penetration loss. In addition, the path exponent for each environment was calculated.

Three major routes in a campus of Covenant University, Ota, Nigeria were selected in [9] in order to conduct a field measurement. 1800 MHz GSM radio signal was measured using TEMS software and then was compared with the empirical models in terms of mean square error, standard deviation, and other statistical tools.

Network planning is an analytic and pragmatic approach implemented via a complicated procedure to meet the main objective. Accordingly starting with accurate propagation model reduces the error cost by assisting the network designer to evaluate the network performance accurately before the network is really deployed over the field. Although, there are extensive research are performed discussing different environment as above mentioned, it still cannot be depended due to the specifications and the geographical nature of each target area to be covered. Hence, in this work, data were collected from the field in two environments (urban and suburban) in Baghdad city. Then a comparative analysis is performed with the simulated data (based on different empirical models) in order to have a judicious decision about the appropriate model for the 2G and 3G mobile networks. The rest of this paper is organized as; section two will introduce several propagation modes. Materials and methods will be explained in section three. Results will be discussed in section four and finally the main concluded points will be illustrated in section five.

II. EMPIRICAL PROPAGATION MODELS

Propagation models are a mathematical expression that characterizes the behavior of the electromagnetic waves through the medium. Usually, many parameters are included within the models in order to materialize the environmental effects and the system configuration. Predicting the PL from these models are essential in every network planning procedure since it can be depended to determine the number of sites and their coverage. Therefore, propagation models help the engineers to configure their network and predict the performance before deployment. In general, there are three types of propagation models as below [10]:

1. Empirical Model: which represents several mathematical expressions derived from field measurement data. There are different universal empirical models such as; Okumura's Model, COST231 - Hata Model…etc.
2. Deterministic Model: This model is based on Maxwells' theorems and employs reflection and diffraction laws. It is assumed to give an accurate prediction.
3. Statistical models: which is based on the probability theory and it is the less accurate one with least computational processing.

This work aims to compare the field measurements collected data with the predicted results from empirical models. The appropriate model is the one that achieves the least mean error, some of these empirical models are listed below:

A) Hata model

It is derived from Okumura model to predict the median PL and can be represented by the following [10]:

$$P_{L(urban)}(dB) = 69.55 + 26.16\log_{10}(f_c) - 13.82\log_{10}(h_b) - a(h_m) + (44.9 - 6.55\log_{10}(h_b))\log_{10}(d) - - - - - (1)$$

Where f_c is the carrier frequency in MHz and it is proved valid in the range of 150MHz - 1500 MHz, h_b is the antenna height of the base station in a meter, h_m is the antenna height of mobile station in meter. d is the distance between the base station and the mobile station in Km. $a(h_m)$ is the correction factor which indicate the cell coverage. For a small to medium size city, $a(h_m)$ is given by [10]:

$$a(h_m) = (1.1\log_{10}(f_c) - 0.7)h_m - (1.56\log_{10}(f_c) - 0.8) - - - - - (2)$$

While for large cities and for $f_c \geq 300$MHz

$$a(h_m) = 3.2[\log(11.75h)] - 4.97 \quad (3)$$

To obtain the path loss in suburban area, eq. 1 is modified to be:

$$P_{L(suburban)}(dB) = P_{L(urban)} - (2\log_{10}(\frac{fc}{28}))^2 - 5.4 \quad (4)$$

B) Cost 231 Hata Model

The frequency band identified by Hata model was extended to 1500 MHz ≤ fc ≤ 2000MHz by Cost 231 Hata Model and can be represented as below [11]:

$$P_L(dB) = 46.3 + 33.9\log_{10}(h_b) - a(h_m) + [44.9 - 6.55\log_{10}(h_b)]\log_{10}(d) + C_m \quad (5)$$

For large city:

$$a(h_m) = 3.2[\log(11.75h_m)]^2 - 4.97 \quad (6)$$

C_m=0 dB for suburban areas

C_m=3 dB for metropolitan areas

Where f_c, h_b, h_m and d ,is the carrier frequency in (MHz), the base station antenna height in (m), the mobile station antenna height in (m), the distance between base station and the mobile station in (Km) respectively.

C) ITU-R Model

The ITU-R model is being used for the outdoor, indoor environment in an urban and suburban area. The path loss is given as [7]:

$$P_L(dB) = 40\log_{10}(d) + 30\log_{10}(f_c) + 49 \quad (7)$$

Where: d is the distance between the base station and the mobile unit in (km), f_c is the frequency to 2000 MHz. The model is usually used for Non-Line of Sight (NLOS) case.

II" MATERIALS AND METHODS

There are three major cellular network operators in Iraq; Zain, Asiacell, and korek. In this work, the cellular network of Asciacell was adopted for the research's analyses. Two areas were selected in Baghdad as cases studies; Al-Amreya quartier at the west of Baghdad is selected as an urban area, while Al-Radwaniya quartier is selected at the west boundaries of Baghdad city as a suburban area. It is worthy to note that, the selected network is currently employing the Enhanced Data Rates of GSM Evolution (EDGE). Even EDGE is considered as the 2.9G, it will be referred to it as 2G network in this work. In addition to 2G, this operator company is also employing 3G services materialized by the Universal Mobile Telecommunication System (UMTS), which in some sites overlaid the 2G sharing the same infrastructure.

In this work, the most accurate propagation model will be determined for authors' future works and simulations. The judicious decision is based on the comparison results between the field measurement and the predicted data from the simulation. Moreover, the deviation between these two sets of data can be evaluated based on RMSE, which can be determined as below:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} (P_{mi} - P_{si})^2}{N}} \tag{8}$$

where, P_m and P_s are the power measured and simulated respectively, N is the data set size.

A. Field Measurements

The author exploits the capabilities of modern Android software in operating the modern available applications based smartphones for signal quality measurements. "Network Cell Info Lite", "Cell Coverage Map" and "Cell Tower Locator" software are used to collect data in terms of a signal-received power for 2G and 3G. The number of test points was determined which is sufficient to predict the coverage area of a base station in all direction as depicted in figs 1, 2, 3, and fig.4. This software with the aid of Global Positioning System (GPS) determines the distance between the test point and the base station. Then, the PL of that area can be estimated and the coverage of the specified cell can be determined.

B. Simulation Method

Hata model, Cost231-Hata model, and ITU model were selected to predict the behavior of propagation signal through simulation using MatLab. The PL as a function of distance for each test point was investigated. The simulation is carried on the three models when the base station parameters were adopted as; 900MHz for the 2G network, and 1800MHz for 3G network.

Fig. 1: View of the propagation environment study area (2G cell - urban area)

Fig. 2:View of the propagation environment study area (2G cell - suburban area)

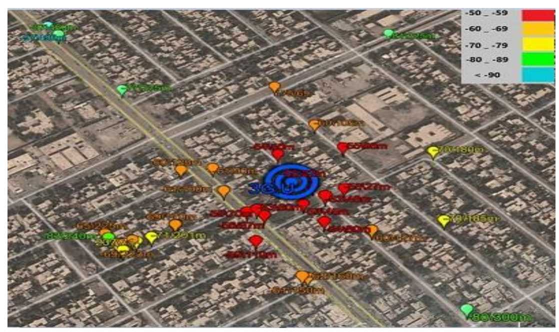

Fig. 3: View of the propagation environment study area (3G cell -urban area)

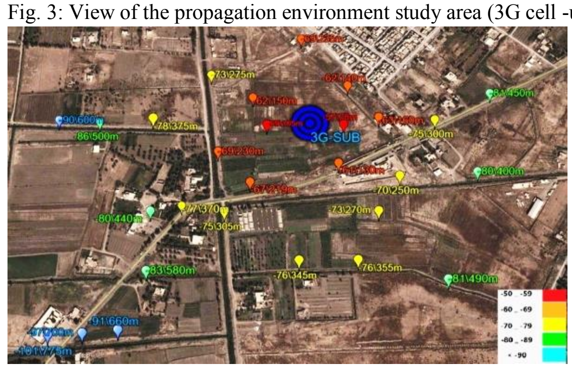

Fig. 4: View of the propagation environment study area (3G cell-suburban area)

III" RESULTS AND DISCUSSION

The cell coverage is governed by the power received at the cell edge. Accordingly, the coverage of the 2G and 3G networks are compared in terms of received power versus distance as shown in fig. 5 and fig.6, where the logline represents the logarithmic based fitness. It can be notice that for the 2G cell, the maximum power can be measured equals to -51dBm, -54dBm at 37m and 75m for urban and suburban area respectively. For the 3G cell, the minimum power can be measured equals to -93dBm, -97dBm at 490m and 690m for urban and suburban area respectively. Although the drive test condition is not the same for all the study cases, it can be concluded that wider coverage can be achieved for the 2G cell in a suburban area. The results that are obtained from this works seems to be logical since a wider coverage is gained at suburban areas as expected due to fewer obstacles in the area. In addition, increasing the frequency (3G) results in increasing the PL as proofed by the free space model. Accordingly, a wider cell coverage area can be notice for 2G network.

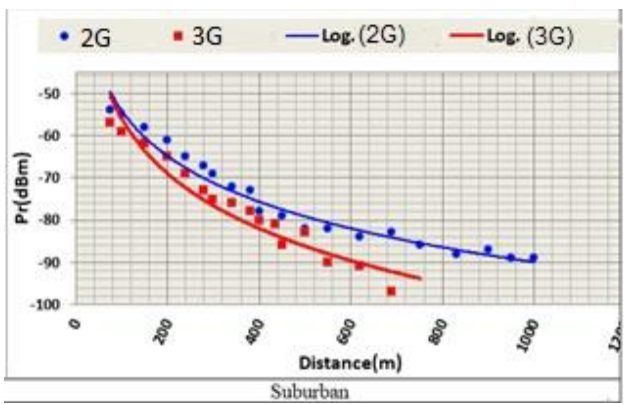

Fig. 5: Measured power at suburban verse distance

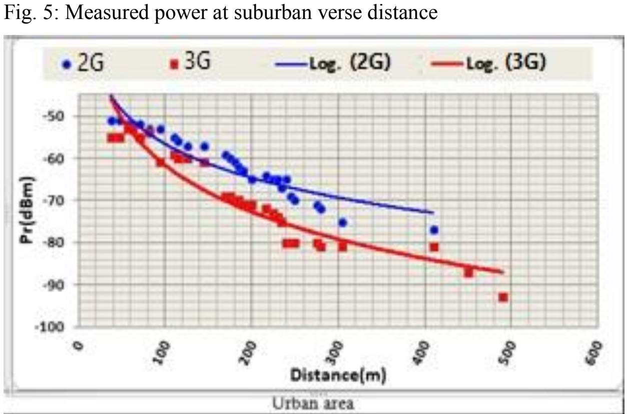

Fig. 6: Measured power at urban verse distance

In order to determine the most appropriate propagation model for the study area, the measurement results were compared with the simulation of three empirical models as shown in figs. 7, 8, 9, and fig.10. The results show a reasonable behavior of the propagated signal, where the PL increases as the distance and the frequency increased. Almost 10 dB is the PL reduction at 2G for urban area compared to 3G at the same distance. Moreover, for a suburban area, almost 13 dB is the PL reduction at 2G compared to 3G at the same distance.

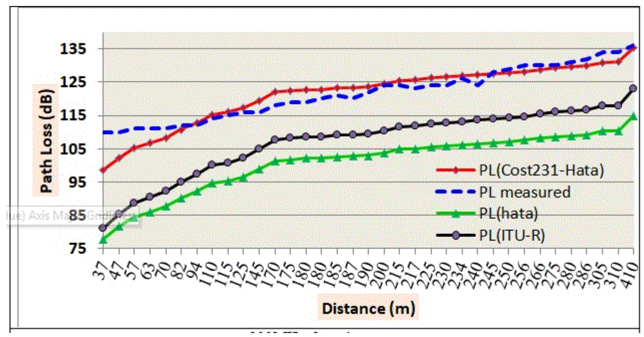

Fig. 7: Measured and simulated signal PL (2G for an urban area)

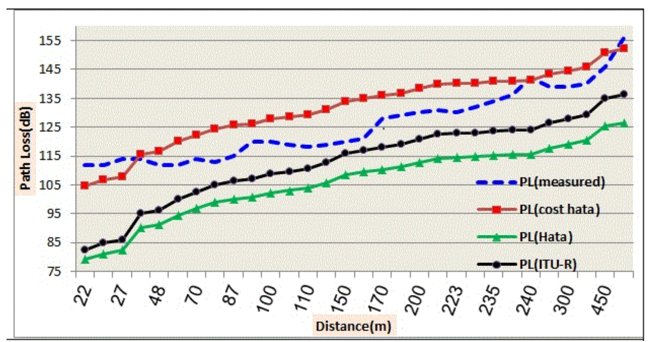

Fig. 8: Measured and simulated signal PL (3G for an urban area)

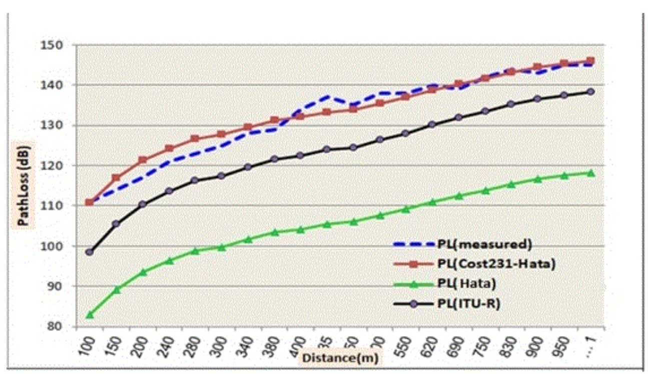

Fig. 9: Measured and simulated signal PL (2G for a suburban area)

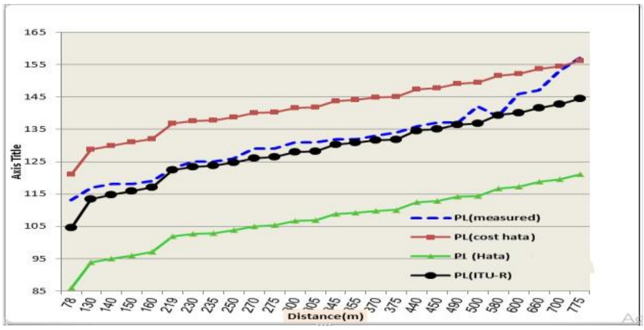

Fig. 10: Measured and simulated signal PL (3G for a suburban area)

In order to determine the appropriate empirical models for the study area, a comparison is performed in terms of RMSE as depicted in figs. 11, 12, 13, and fig. 14. It is obvious that Cost 231-Hata model is the most suitable propagation model for an urban area. It achieved the least RMSEs equals to 3.4dB, 8.2dB for 2G and 3G network respectively. On the other side, for a suburban area, Cost231-Hata achieved the least RMSEs equals to 2.24dB 2G network, while ITUR achieved the least RMSEs equals to the 4.45dB 3G network.

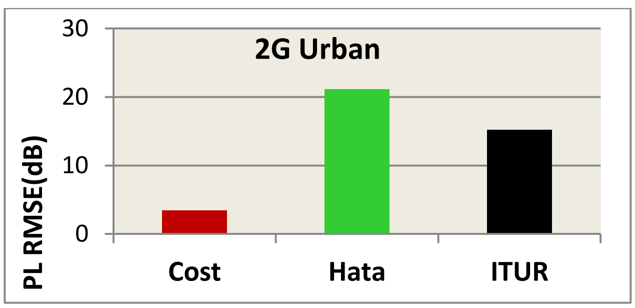

Fig. 11: Root mean squared error between the field measurement and empirical models

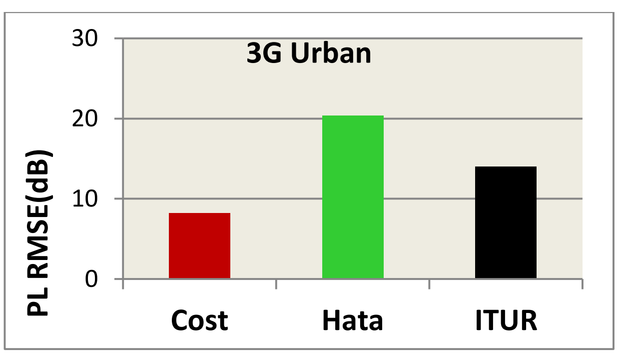

Fig. 12: Root mean squared error between the field measurement and empirical models

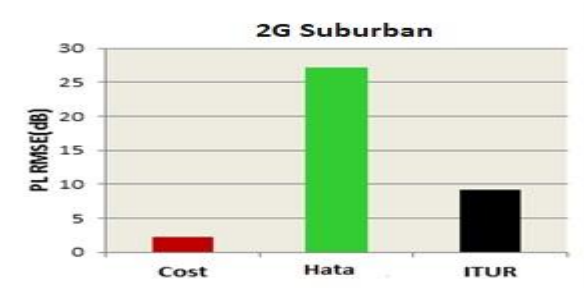

Fig.13: Root mean squared error between the field measurement and empirical models

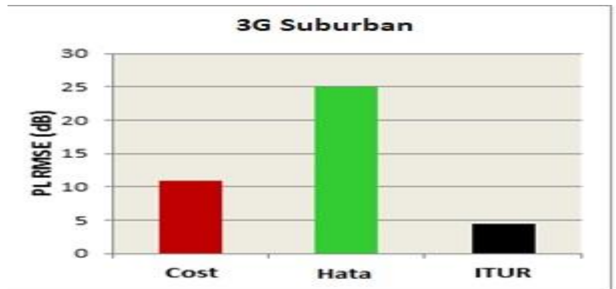

Fig.14: Root mean squared error between the field measurement and empirical models

IV" CONCLUSIONS

In this work, the performance of 2G and 3G networks evaluated, where UMTS and GSM Edge propagated signals are investigated in a real outdoor environment in Baghdad city. Two regions were selected that materialize urban and suburban areas. Experimental field measurements are conducted to measure the received power at the two networks frequency bands 900MHz and 1800MHz. The field-collected data were compared to three empirical propagation models to determine the accurate model that verifies the least RMSE. The comparison results show that Cost231-Hata model is the most suitable propagation model for 2G networks in all environments, besides 3G networks in urban area. Other ITU model is verified to be more suitable to a suburban environment for 3G network.

REFERENCES

[1] H. K. Hoomod , I. Al-Mejibli, A. I. Jabboory, "Analyzing Study of Path loss Propagation Models in Wireless Communications at 0.8 GHz" IOP Conf. Series: Journal of Physics: Conf. Series 1003, 2018.

[2] V. O. A. Akpaida1, F. I. Anyasi, S. I. Uzairue, A. I. Idim, O. Alashiri, "A Review Investigation on Outdoor and Indoor Propagation Models V. O. A. Akpaida1," Journal of Materials Science Research and Reviews 1(1): pp. 1-11, 2018.

[3] M. S. Mollel, M. Kisangiri, "An Overview of Various Propagation Model for Mobile Communication," Pan African International Conference on Information Science, Computing and Telecommunications, 2014.

[4] Z. Naseem, I. Nausheen, Z. Mirza, "Propagation Models for Wireless Communication System", International Research Journal of Engineering and Technology (IRJET), Vol. 05, Jan-2018.

[5] S. I. Popoola, O.F. Oseni, "Empirical Path Loss Models for GSM Network Deployment in Makurdi, Nigeria," International Refereed Journal of Engineering and Science (IRJES), pp. 85-94, 2014

[6] Kassim Mohammed, "Performance Measurements and Analysis of the Existing Wireless Communication Technology in Iraq" Ph.D. dissertation, Brunel University, U.K, 2013.

[7] Saed Tarapiah, ,Shadi Atalla, ,Kamarul Faizal Bin Hashim & Motaz Daadoo, " Mobile Network Planing Process Case Study - 3G Network ", Computer and Information Science; Vol. 9, No. 3; 2016.

[8] V. O. A. Akpaida1 , F. I. Anyasi1 , S. I. Uzairue, A. I. Idim, "Determination of an Outdoor Path Loss Model and Signal Penetration Level in Some Selected Modern Residential and Office Apartments in Ogbomosho, Oyo State, Nigeria," Journal of Engineering Research and Reports (JERR), pp. 1-25, 2018.

[9] S. I. Popoola , A. A. Atayero, O. A. Popoola, " Comparative assessment of data obtained using empirical models for path loss predictions in a university campus environment," Elsevier, Vol. 18, pp. 380-393, June 2018.

[10] P. K. Sharma, R.K.Singh, " Comparative Analysis of Propagation Path loss Models with Field Measured Data," International Journal of Engineering Science and Technology. Vol. 2(6), pp. 2008-2013, 2010.

[11] a. k. al-samarrie, h. alyasiri , a. h. al-nakkash, " Design and analysis of wimax e-government network for the city of Baghdad," International Journal of Scientific & Engineering Research, Vol. 6, Issue 1, January-2015.