Comparison of radio propagation models in five LTE coverage cells in Riobamba

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Abstract— This article makes a comparative analysis of the power intensity levels measured with the Network Cell Info Lite application and the performance of the different Log-Normal, Okumura Hata, COST 231, Wolfish Bertoni and SUI propagation models in the Frequency Band 4G LTE. The study was carried out in 5 LTE coverage cells located in the southern area of the City of Riobamba and the model that best fits each cell is limited using absolute error analysis, obtaining an empirical correction factor for the proposed models. For the analysis of the absolute error, 3 measurement campaigns were carried out with 50 samples where the mean value was obtained. The analysis carried out will be suspended because the Log-Normal model is the one that best fits the Riobamba environment considering that it is a residential area, and that the power levels vary from (-80 dBm to -106 dBm) and that the coverage areas were determined up to 200m.

Keywords: Cover cells, frequency band, multiscreen diffraction los, MICROCELLS and open spatial propagation model, Friis.

I. INTRODUCTION

The growing demands on mobile services have encouraged many researchers toward achieving multi-services with low latency. To illustrate that, Lingchen Zhang in 2012 [1] pointed out the LTE (Long Term Evolution) is a standard for high-speed wireless data communications which is maintained as a project of the 3rd Generation Partnership Project (3GPP). In addition, to cover the requirements of the mobile migrations of Internet applications, such as VOIP, video streaming, music downloading and mobile TV, LTE networks offer the capacity to tolerate the throughput explosion for the connection from mobile devices customized to those new mobile applications. A propagation model is a set of mathematical expressions, diagrams, and algorithms used to represent the radio characteristics of a given environment [2].

In 2004, an initial study of long-term evolution (LTE) was introduced and viewed as a path for migration to 4G networks [3]. With the rapid development of LTE (4G) technology in recent years, 4G terminals like mobile phones have been widely used for communication and LTE (4G) signals have covered both indoor and outdoor environments in modern cities. Inspired by the advances in wireless sensing that have enabled a large variety of new applications such as indoor localization [4].

The goal of LTE is to increase the speed and capacity of wireless networks by utilizing signal processing techniques and modulations [5]. 4G technology is supported by the 3GPP (third generation) standard, which bases its system on IP, that is, it is a system of systems and a network of networks, and is subsequently overcome in the convergence between cable networks or wireless networks, computers, electrical devices -electronic, ICT among others to provide access speeds between 100Mbps in movement and 1Gbps at rest, but the most important thing is to maintain the quality of service (QoS) from point to point (end-to-end), with a high security in order to massify the number of additional services in any place betting on having the lowest possible cost [6].

Path loss models are sophisticated tools for predicting coverage area, interference analysis, frequency assignments and cell parameters which are the basic elements for network planning process in mobile radio systems [7].

The Okumura-Hata model is the most widely used empirical propagation prediction model. In 1980, Hata introduced an empirical formula for propagation loss that was derived from Okumura's report to put the propagation prediction method into computational use in system planning software. The propagation loss is presented in the simple form A + B log(R), where A and B are functions of frequency and height of the antenna and R is the distance [8]. This simplicity of the model has made it the most widely used propagation prediction model and it is even standardized for international use [9].

The European Cooperative for Scientific and Technical Research (Euro-Cost) developed the Cost 231 model, in which the Hata model is extended to the 2 Ghz range, covering the VHF and UHF band. CM is a correction factor to fit the model by extending the frequency range for which the Hata model operates; CM (0 dB) for medium cities and suburban areas; CM (3 dB) for metropolitan centers; and a(he) corresponds to the equations presented in the Hata model. One of the contributions of this model is to consider losses due to dispersion [10].

Stanford University Interim (SUI) model derived from Hata, with corrections for frequencies above 1900MHz. It includes the path loss exponent, it proposes three different types of terrain, urban, suburban and rural. The height of the antenna of the proposed base station is between 10 and 80
meters, that of the mobile from 2 to 10 meters and the extension of the cell from 0.1 to 8 km [11].

The model, proposed by Joram Wallfisch and Henri Bertoni, takes into account the losses produced by the diffractions that occur on the roofs of buildings [12]. It is a model that does not consider the existence of line of sight between the transmitter and the receiver, it uses the phenomenon of diffraction to describe the losses suffered by the signal before reaching the receiver located low above the street. The contribution of the rays that penetrate the buildings and of those that suffer multiple diffractions is neglected. The separation between the buildings must be less than their height and they are supposed to be arranged in parallel rows. The frequency range in which this model is applicable is from 300 to 3,000 MHz, with a separation between transmitter and receiver of 200 to 5,000 m. It is not applicable when the base station antenna is below the average height of buildings [13].

The log-normal distribution is a function distributing a dependent variable in a normal or Gaussian fashion on a logarithmic scale of the independent variable. This function has been used for a long time to describe size distributions of particle properties in atmospheric aerosols. Foitzik (1964) used this functional relationship for the description of optical aerosol properties. Later, Whitby (1974) built a general concept for the multimodal nature of the atmospheric aerosol on this approach by fitting measured particle size distributions in a combination of three log-normal distributions [14].

To determine the performance of the previously proposed propagation models, a comparative analysis of the power intensity levels measured with the Network Cell Info Lite application in the 4G Frequency Band was carried out at 5 LTE coverage cells located in the southern zone of the city of Riobamba and the model that best adapts to the conditions of the area will be extinguished by applying an empirical correction factor to the proposed models. The document details the absolute error for the calculation of this correction factor, considering 3 measurement campaigns with 50 samples where the mean value was obtained. From the study carried out, it was concluded that the model Log-Normal is the best estimator of power levels considering the environment of the city, which is a residential area. And that the power levels varied from -80 dBm to -106 dBm and that the coverage areas were determined up to 200m.

II. THEORETICAL FRAMEWORK

A. Log Normal Model

It is an empirical model based on a reference of the losses at a pre-established distance, and applicable in closed environments by factors of correction. It is expressed in an equation as a function of the distance between transmitter and receiver as:

\[ PL(d) = PL(d_0) + 10 \log \left( \frac{d}{d_0} \right) + X_\sigma \]  

(1)

Where \( n \) is the path loss variable due to the multiple trajectories; \( PL(d_0) \) is the loss to one near reference distance \( d_0 \) and it is calculated using the space propagation model open, Friis formula, or taking measurements field; \( X_\sigma \) is a random variable expressed in dB and experimentally validated and statistically. The model is simple but absorbs the random effects of shadows and multipaths that occur for different measurement locations with the same distance between the Tx-Rx, but with different obstructions in the path of propagation comparing with a reference value [15].

B. Okumura Hata Model

The Hata model is an empirical formulation of the graphical path loss data provided by Okumura, and is valid from 150 MHz to 1500 MHz. Hata presented the urban area propagation loss as a standard formula and supplied correction equations for application to other situations. The standard formula for median path loss in urban area is given by:

\[ L_{50}(dB) = 69.55 + 26.16 \log f_c - 13.82 \log h_{te} - a(h_{re}) + (44.9 - 6.55 \log h_{te}) \log d \]  

(2)

where \( f_c \) is the frequency (in MHz) from 150 MHz to 1500 MHz, \( h_{te} \) is the effective transmitter (base station) antenna height (in meters) ranging from 30 m to 200 m, \( h_{re} \) is the effective receiver (mobile) antenna height (in meters) ranging from 1 m to 10 m, \( d \) is the T-R separation distance (in km), and \( a(h_{re}) \) is the correction factor for effective mobile antenna height which is a function of the size of the coverage area. For a small to medium sized city, the mobile antenna correction factor is given by

\[ a(h_{re}) = (1.1 \log f_c - 0.7)h_{re} - (1.56 \log f_c - 0.8) dB \]  

(3)

and for a large city, it is given by

\[ a(h_{re}) = 8.29(\log 1.54h_{re})^2 - 1.1 \ dB \]  

for \( f_c \leq 300 \ MHz \)  

(4)

and

\[ a(h_{re}) = 3.2(\log 11.75h_{re})^2 - 4.97 \ dB \]  

for \( f_c \geq 300 \ MHz \)  

(5)

The predictions of the Hata model compare very closely with the original Okumura model, as long as \( d \) exceeds 1 km. This model is well suited for large cell mobile systems, but not personal communications systems (PCS) which have cells on the order of 1km radius [16].

C. Cost 231 Walfish-Ikegami Model

The COST 231 model is a semi-empirical path loss prediction model. It is recommended for macro-cells in urban and suburban scenarios, with good path loss results for transmitting antennas located above average rooftop height. However, the error in the predictions increases considerably as the transmitter height approaches rooftop height, leading to very poor performance for transmitters below that level. Compared to previous models such as Okumura-Hata, the COST 231 model includes a series of additional parameters to the calculation process, in addition to expanding the frequency range in which it can be used (800 - 2000 MHz). The model performs a more detailed calculation of the attenuation, based on four additional parameters:

- Height of buildings.
- Width of streets.
- Separation between buildings.
- Orientation of the street with respect to the direction of propagation.

For LOS scenarios, the propagation loss considers only the free space loss, \( L_b = L_{0(LOS)} \) where:

\[
L_{0(LOS)} = 42.6 + 26 \log(d) + 20 \log(f) \tag{6}
\]

where \( d \) is expressed in km and \( f \) in MHz.

The typical NLOS path described in the COST 231 model is shown in Figure 1 and Figure 2.

![Fig. 1. Typical NLOS Propagation Scenario Profile view.](Image)

![Fig. 2. Typical NLOS Propagation Scenario Top view.](Image)

The parameters defined in the COST 231 model are the following:
- \( h_s \): average height of buildings (m)
- \( w \): width of the street (m)
- \( b \): average distance between buildings (m)
- \( \phi \): angle formed by the direction of propagation and the axis of the street (degrees)
- \( h_b \): base station antenna height (m)
- \( h_m \): height of the mobile device antenna (m)
- \( \Delta h_m = h_r - h_m \) (m)
- \( \Delta h_b = h_b - h_r \) (m)
- \( l \): total distance between the first and the last building on the path (m)
- \( d \): distance between base station and mobile device (km)
- \( f \): frequency (MHz)

The basic propagation loss for the NLOS scenario is given by:

\[
L_b = \begin{cases} 
L_0 + L_{rts} + L_{msd} & \text{for } L_{rts} + L_{msd} > 0 \\
L_0 & \text{for } L_{rts} + L_{msd} \leq 0
\end{cases} \tag{7}
\]

The propagation loss in free space conditions, \( L_0 \), is obtained according to the expression:

\[
L_0 = 32.4 + 20 \log(d) + 20 \log(f) \tag{8}
\]

The term \( L_{rts} \) considers the width of the street and its orientation with respect to the direction of ray propagation.

The expression for the calculation of \( L_{rts} \) is given by:

\[
L_{rts} = -8.2 - 10 \log(w) + 10 \log(f) + 20 \log(\Delta h_m) + L_{ori} \tag{9}
\]

where:

\[
L_{ori} = \begin{cases} 
-10 + 0.35\phi & \text{for } 0^\circ \leq \phi < 35^\circ \\
2.5 + 0.07(\phi - 35) & \text{for } 35^\circ \leq \phi < 55^\circ \\
4.0 - 0.11(\phi - 35) & \text{for } 55^\circ \leq \phi < 90^\circ
\end{cases} \tag{10}
\]

The \( L_{ori} \) term is a correction factor that quantifies losses due to street orientation. In case the value of \( L_{rts} < 0 \), \( L_{rts} = 0 \) should be considered.

The multiscreen diffraction loss, \( L_{msd} \), is a function of the frequency, the distance between the mobile device and the base station, as well as the height of the base station and the height of buildings. Like \( L_{rts} \), if \( L_{msd} \) is negative, \( L_{msd} = 0 \) is considered. Its value is calculated using the expression:

\[
L_{msd} = L_{bsh} + k_a + k_d \log(d) + k_f \log(f) - 9\log(h) \tag{11}
\]

where:

\[
L_{bsh} = \begin{cases} 
-18\log(1 + \Delta h_b) & \text{for } h_b > h_r \\
0 & \text{for } h_b \leq h_r
\end{cases} \tag{12}
\]

Is a term that depends on the height of the base station. In addition, the following parameters are defined:

\[
k_a = \begin{cases} 
54 & \text{for } h_b > h_r \\
54 - 0.8\Delta h_b & \text{for } h_b \leq h_r, y d \geq 0.5 \text{ km} \\
54 - 0.8\Delta h_b \frac{d}{0.5} & \text{for } h_b \leq h_r, y d < 0.5 \text{ km}
\end{cases} \tag{13}
\]

\[
k_d = \begin{cases} 
18 & \text{for } h_b > h_r \\
18 - 15 \frac{\Delta h_b}{h_r} & \text{for } h_b \leq h_r
\end{cases} \tag{14}
\]

\[
k_f = \begin{cases} 
-4 + 0.7 \left( \frac{f}{925} - 1 \right) & \text{for } \text{metropolitan centers} \\
-4 + 1.5 \left( \frac{f}{925} - 1 \right) & \text{for } \text{medium – sized cities}
\end{cases} \tag{15}
\]

The \( k_a \) term presents the increase in path loss for the case of base stations located below the average height of the buildings. The terms \( k_d \) and \( k_f \) control the dependence of \( L_{msd} \) on distance and frequency, respectively. If there is no data on the buildings on the route, the COST 231 model recommends using: \([17]\).

\[
h_r = 3 \text{ m} \ast (\text{No. of floors}) + \text{ceiling height} \tag{16}
\]

\[
\text{ceiling height} = \begin{cases} 
3 \text{ m} & \text{sloping roof} \\
0 \text{ m} & \text{flat roof}
\end{cases} \tag{17}
\]

D. Walfish-Bertoni Model

It is valid when there is no line of sight between the base station and the mobile. Buildings are modeled as a set of diffraction and absorption screens buildings of a uniform height and width are considered, requires that the transmitting antenna be above the highest ceiling.

The path loss is given by:
\[ L_p = 89.55 + 21 \log f + 38 \log d - 18 \log H \]

\[ + A - 18 \log \left( 1 - \frac{d^2}{17H} \right) \]  

(18)

where:

- \( f \): frequency (MHz)
- \( d \): distance between transmitter and receiver (km)
- \( H \): average height of the antenna with respect to the height of the buildings (m)
- \( A \): variable that expresses the influence of buildings on the signal

The influence of buildings on the signal

\[ A = 5 \log \left( \frac{b^2}{2} + (h_b - h_r)^2 \right) - 9 \log b \]

\[ + 20 \log \left\{ \tan^{-1} \left[ \frac{2(h_b - h_r)}{b} \right] \right\} \] 

(19)

where:

- \( h_b \): height of buildings (m)
- \( h_r \): receiver height (m)
- \( b \): distance between buildings (m)

In a real environment, the geometry of the buildings is irregular, causing this model to have less certainty in predicting the received power, however this model is applicable in radio propagation simulation software (Cell View) if adaptations are made to the equations or if an average density and height of buildings is obtained [18].

E. SUI Model

Stanford University Interim (SUI) model is developed for IEEE 802.16 by Stanford University. It is used for frequencies above 1900 MH. In this propagation model, three different types of terrains or areas are considered. These are called as terrain A, B and C. Terrain A represents an area with highest path loss, it can be a very densely populated region while terrain B represents an area with moderate path loss, a suburban environment. Terrain C has the least path loss which describes a rural or flat area. In Table 1, these different terrains and different factors used in SUI model are described.

The path loss in SUI model can be described as

\[ PL = A + 10 \gamma \log \left( \frac{d}{d_0} \right) + X_f + X_h + S \] 

(20)

where PL represents Path Loss in dBs, \( d \) is the distance between the transmitter and receiver, \( d_0 \) is the reference distance, \( X_f \) is the frequency correction factor, \( X_h \) is the correction factor for base station height, \( S \) is shadowing and \( \gamma \) is the path loss component and it is described as

\[ \gamma = a - bh_b + \frac{c}{h_b} \] 

(21)

where \( h_b \) is the height of the base station and \( a, b \) and \( c \) represent the terrain for which the values are selected from the above table.

\[ A = 20 \log \left( \frac{4 \pi d_0}{\lambda} \right) \] 

(22)

where \( A \) is free space path loss while \( d_0 \) is the distance between Tx and Rx and \( \lambda \) is the wavelength. The correction factor for frequency and base station height are as follows:

\[ X_f = 6 \log \left( \frac{f}{2000} \right) \] 

(23)

\[ X_h = -10.8 \log \left( \frac{h_r}{2000} \right) \] 

(24)

where \( f \) is the frequency in MHz, and \( h_r \) is the height of the receiver antenna. This expression is used for terrain type A and B. For terrain C, the blow expression is used.

\[ X_h = -20 \log \left( \frac{h_r}{2000} \right) \] 

(25)

\[ S = 0.65(logf)^2 - 1.31log(f) + \alpha \] 

(26)

Here, \( \alpha = 5.2 \) dB for rural and suburban environments (Terrain A & B) and 6.6 dB for urban environment (Terrain C) [19].

III. METHODOLOGY

The comparative analysis was carried out on 5 LTE coverage cells in the South Zone of the city of Riobamba in 3 different campaigns, taking 50 reference samples from which the arithmetic mean of said measurements was taken to have an estimate of the reception power of each cell.

### Table 1: Different Terrains and Their Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Terrain A</th>
<th>Terrain B</th>
<th>Terrain C</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a ) (1/m)</td>
<td>4.6</td>
<td>4</td>
<td>3.6</td>
</tr>
<tr>
<td>( b ) (1/m)</td>
<td>0.0075</td>
<td>0.0065</td>
<td>0.005</td>
</tr>
<tr>
<td>( c ) (m)</td>
<td>12.6</td>
<td>17.1</td>
<td>20</td>
</tr>
</tbody>
</table>
Figure 4: Location of LTE coverage cells.

Figure 4 shows the southern area of the city of Riobamba taken by the Google Maps application where the 5 cells were located, which the power data was collected for the study of the propagation models that can be applied in said area. Each antenna works with different operators.

The applicability of this document was carried out by means of 2 software programs: Microsoft Excel for the development of mathematical operations and obtaining numerical data, and Matlab for the management of graphs and the statistical study of results.

To determine which model best fits, we apply the equations of the different propagation models considering the correction factor and the parameters that each model requires.

A. Coverage Cell 1

The first cell is located on José Orozco and Bernardo Darquéd streets, it belongs to Tuenti operator and works with an operating frequency of 1900MHz. Next, the considerations for the use of propagation models are detailed.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base station antenna height (m)</td>
<td>30</td>
</tr>
<tr>
<td>Mobile device height (m)</td>
<td>1.5</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>47 – 170</td>
</tr>
<tr>
<td>Street width (m)</td>
<td>4</td>
</tr>
<tr>
<td>Elevation angle</td>
<td>14.47° - 40.79°</td>
</tr>
<tr>
<td>Buildings height (m)</td>
<td>9</td>
</tr>
<tr>
<td>Distance between buildings (m)</td>
<td>4</td>
</tr>
</tbody>
</table>

B. Coverage Cell 2

The second cell is in the Sabú Sports complex, belongs to Tuenti operator and works with an operating frequency of 1900MHz. Next, the considerations for the use of propagation models are detailed.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base station antenna height (m)</td>
<td>32</td>
</tr>
<tr>
<td>Mobile device height (m)</td>
<td>1.5</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>48.62 – 205.02</td>
</tr>
<tr>
<td>Street width (m)</td>
<td>4</td>
</tr>
<tr>
<td>Elevation angle</td>
<td>20° - 63°</td>
</tr>
<tr>
<td>Buildings height (m)</td>
<td>9</td>
</tr>
<tr>
<td>Distance between buildings (m)</td>
<td>3.5</td>
</tr>
</tbody>
</table>

C. Coverage Cell 3

The third cell is located at Celso Rodríguez avenue and París street, it belongs to Tuenti operator and works with an operating frequency of 1900MHz. Next, the considerations for the use of propagation models are detailed.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base station antenna height (m)</td>
<td>18</td>
</tr>
<tr>
<td>Mobile device height (m)</td>
<td>1.5</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>49 – 211</td>
</tr>
<tr>
<td>Street width (m)</td>
<td>4</td>
</tr>
<tr>
<td>Elevation angle</td>
<td>25° - 63°</td>
</tr>
<tr>
<td>Buildings height (m)</td>
<td>9</td>
</tr>
<tr>
<td>Distance between buildings (m)</td>
<td>4.5</td>
</tr>
</tbody>
</table>

D. Coverage Cell 4

The fourth cell is located at Leopoldo Freire avenue and Lisboa street, it belongs to CNT operator and works with an operating frequency of 1900MHz. Next, the considerations for the use of propagation models are detailed.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base station antenna height (m)</td>
<td>30</td>
</tr>
<tr>
<td>Mobile device height (m)</td>
<td>1.5</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>49 – 226</td>
</tr>
<tr>
<td>Street width (m)</td>
<td>4</td>
</tr>
<tr>
<td>Elevation angle</td>
<td>25° - 72°</td>
</tr>
<tr>
<td>Buildings height (m)</td>
<td>9</td>
</tr>
<tr>
<td>Distance between buildings (m)</td>
<td>3.5</td>
</tr>
</tbody>
</table>

E. Coverage Cell 5

The fifth cell is located at 9 de Octubre avenue and Noruega street, it belongs to Claro operator and works with an operating frequency of 1700MHz. Next, the considerations for the use of propagation models are detailed.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base station antenna height (m)</td>
<td>25</td>
</tr>
<tr>
<td>Mobile device height (m)</td>
<td>1.5</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>48.62 – 205.02</td>
</tr>
<tr>
<td>Street width (m)</td>
<td>4</td>
</tr>
<tr>
<td>Elevation angle</td>
<td>17° - 70°</td>
</tr>
<tr>
<td>Buildings height (m)</td>
<td>9</td>
</tr>
<tr>
<td>Distance between buildings (m)</td>
<td>4</td>
</tr>
</tbody>
</table>

Finally, the losses obtained by each of the models mentioned above are replaced in the general formula that is given by:

\[
Pr(dBm) = Pt + Gt + Gr - L_{pm} \tag{27}
\]

where:
- \( Pt \): transmission potency
- \( Gt \): transmission gain
- \( Gr \): reception gain
- \( L_{pm} \): propagation models lost

The received power obtained was plotted against the distance around each of the base stations for each propagation model and compared to the measured field average power value.
F. Adjusting the Propagation Model

Since the propagation models were taken in cities whose conditions are very different from the study area, it is necessary to adjust the model. For this, the absolute error that will represent the empirical correction factor was used to determine with what range of power the values are far from the real ones measured. To do this, the average of the measured values and the average of each of the propagation models that required adjustment are used.

\[ \epsilon_{abs} = |v_{real} - v_{measured}| \]  

where:
- \( \epsilon_{abs} \): absolut mistake
- \( v_{real} \): average power value
- \( v_{measured} \): power value for each propagation model

IV. RESULTS

The following graphs obtained show the approximate curves of the propagation models without a correction factor in each of the five LTE coverage cells with respect to the average power whose data was collected in the southern zone of the city of Riobamba.

Figure 5 shows cell 1. It is possible to observe that without the corrections to the different propagation models, the samples obtained resemble the Log Normal model, in addition to the other models such as Okumura-Hata and the Walfish-Bertoni model, giving results very far from the values measured. In the first 100 meters many powers were collected, finally it was visualized that at a greater distance the samples suffer an attenuation that is caused by the presence of different infrastructures.

Figure 6 shows us cell 2 in which it is possible to observe that the samples obtained are similar to the Log Normal model within 100 meters, which is where there is a great concentration of powers, so it can be said that it is where it is best has been coupled to the prediction model, taking into account that the different attenuations are due to being in an area full of vegetation. On the other hand, the other models do not coincide with the powers collected due to the fact that the area where the samples were taken does not meet the characteristics of the different models, which is why it is seen that both the Okumura-Hata, Cost 231 and Walfish-Bertoni are far apart with respect to the powers obtained and compared with the data obtained in the other radio bases, it is observed that these 3 models are much further away from each other.

Figure 7 shows cell 3. It is observed that the data collected is very similar to the Log Normal model, especially between 80 and 118 meters there is a coupling with respect to this model, but at the same time it is possible to observe that the powers collected at from 130 to 190 meters they resemble the SUI model, these power losses are due to the fact that the area where the data was collected was an area where there are many houses between 2 and 3 floors.
Figure 8 shows cell 4 where it is observed that it resembles two models, firstly, the collected data tend to have a coupling with the SUI model between 47 to 78 meters and from 83 to 140 meters they are coupled to the model. Log Normal, taking into account that from 140 meters these tend to suffer more attenuations, therefore they move away from the results of the models, this is because the data obtained were in a place full of buildings within the main street.

Figure 9 shows cell 5 in which it is observed that it resembles the Log Normal model within 50 to 96 meters of distance, where there is a great concentration of powers between 70 to 94 meters, in addition to that manages to observe that there is an intersection between the SUI model and Log Normal, so that within 130 to 135 meters the data collected resembles the SUI model.

Next, the graphs of the propagation models are presented with a correction factor so that they are coupled to the power measurements of the 5 different LTE coverage cells located in the southern zone of the city of Riobamba, in this way having a prediction of attenuation in that area.

Figure 10 shows cell 1 where a correction factor was applied to 3 propagation models: Okumura-Hata, Cos 231 and the Walfish-Bertoni model, the correction values were: -20.69 dBm, -13.34 dBm, -21.23 dBm respectively. When applying the correction factor, the graphs of the propagation models are better coupled to the power samples taken with the mobile, however, the model that is more coupled in cell 1 is the Log-normal model.

Figure 11 shows cell 2 in which a correction factor was applied to 3 propagation models: Okumura-Hata, Cos 231 and the Walfish-Bertoni model, the correction values were: -30.35 dBm, -19.40 dBm, -26.20 dBm respectively. When applying the correction factor, the graphs of the propagation models performed better to the power samples taken with the mobile, however, the model that best fits cell 2 is the Log-Normal with variations less than 5dBm.
Figure 12 shows cell 3 in which a correction factor was applied to 4 propagation models: Okumura-Hata, Cos 231, the Walfish-Bertoni model and the SUI model, the correction values were -34.20 dBm, -27.28 dBm, -34.42 dBm and -6.69 dBm respectively. When applying the correction factor, the graphs of the propagation models performed better to the power samples taken by the mobile, however, we see that almost all the models fit correctly, being the one that stands out the most the Cos 231 model and the Cos 231 model. Log-Normal with differentiation between the measured value and that of the power of the models not greater than 6 dBm.

Figure 13 shows cell 4 in which a correction factor was applied to 3 propagation models: Okumura-Hata, Cos 231, the Walfish-Bertoni model, the correction values were: -31.84 dBm, -14.43 dBm, -20.64 dBm, respectively. When applying the repair factor, the graphs of the propagation models are better coupled to the power samples taken by the mobile, however, the one that best fits is the normal Log model curve with a differentiation between the measurements taken and the model less than 5dBm.

Figure 14 shows cell 5 in which a correction factor was applied to 3 propagation models: Okumura-Hata, Cos 231, the Walfish-Bertoni model, the correction values were: -30.29 dBm, -21.97 dBm, -29.48 dBm, respectively. When applying the correction factor, the graphs of the propagation models are better coupled to the power samples taken by the mobile, however, the one that best fits is the normal Log model curve with a differentiation between the measurements taken and the model less than 5dBm.

V. CONCLUSIONS

This article has presented a correction to the different propagation models so that they can be applied to the conditions presented in the southern zone of the city of Riobamba, where the Log Normal model as the best predictor of power in this zone taking into account the different locations and scenarios where there were propagation losses due to topographical causes.

The implementation of the adjustment to the propagation models was carried out successfully, in such a way that the graphs were close to the average of samples obtained in each of the cells, in addition two types of results were analyzed, the first only with the general application of the propagation models where it was observed that there was a considerable dispersion of data that did not agree with the study area, then with the respective correction, where it was possible to observe that there is a similarity in the graphs of both the measured samples and the Models.

REFERENCES


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