Hata Model Path Loss Optimization using Least Mean Square Regression

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doi: https://doi.org/10.21467/proceedings.114.34

Abstract

A stochastic approach based optimization technique to optimize the Hata model path loss equation is presented in this paper. In this paper, the existing Hata model equation for determining path loss in medium urban city is optimized using Least Mean Square regression method. Out of various path loss models available, Hata model was chosen due to its accuracy and reliability in an urban propagation environment. The optimization technique proposed is applied to get the optimum coefficients of Hata propagation model equation. This stochastic approach is based on reducing the mean square difference between the measured and predicted path loss by adjusting the error coefficients of MSE through regression. The MSE obtained after optimization is significantly lower than that obtained from the existing Hata model. For better planning and implementation of mobile cellular networks there is a need for modifying the existing path loss prediction models. This optimized model can be used to improve the quality of service in 900MHz band in a medium sized urban environment.

Keywords: LMS, Hata Model, MSE, Path Loss Optimization

1 Introduction

A wireless network plays an incredibly imperative role in our day to day life. The cellular mobile communication system is mainly the well-known network over the world. So, before designing a wireless communication system, we have to achieve the essential factors that are: the quality of service (QoS) for the users, antenna height of the base station, full coverage in a particular area, power received, cost, transmitted power and the frequency of the system [1]. These factors can be achieved, by selecting the correct and appropriate propagation path loss model. By making the use of an optimized model in the design phase will make sure the hand-picked communication performance of network and save the expenditure and time prior to the real system operation. [2]

The mobile communication systems are facing the degradation in signal due to a variety of barriers between base station and mobile stations [14]. So to avoid these problems Path loss models are used to predict the signal or to attain high signal quality in a particular area. The truthful forecast technique is necessary in order to resolve the factors of a radio system that will in turn raise the effectiveness of service quality, diminish the unwanted power loss, increase the coverage area, and decide the finest base stations activities of a particular region [6].

There are many models like Okumura, Egli, Hata etc. and every model is fitting for the particular area. These models approximate the path loss depends on the factors i.e. the height of the transmitting and Receiving antenna, distance among the transmitter and receiver etc. The Okumura Models are usually worn to calculate the path loss. But the main disadvantage of Okumura Model is that its response with respective terrain change is slow. Hata redefined a model in which Okumura's plots are adapted into an empirical model

Proceedings DOI: 10.21467/proceedings.114; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-8-8

and correction factors added which gives high-quality response when the clutter is having alterations [8]. The terrain conditions and the clutter density are decreased.

This paper shows the optimization of Hata model by using the least mean square regression Algorithm based on urban medium city dimensions at 900MHzto increase the accuracy of the system. The Hata model is largely used for outdoor propagation and is developed by Y. Okumura and M. Hata [4].

The main purpose of model optimization is to reduce the mean square error (MSE). The optimization of models formulates model extra accurate for signal received power calculations [5]. The LMS optimization helps to get improved signal coverage and high-quality signal in a particular area. The least mean square regression method works by reducing the sum of the square of the errors as small as possible. So the least mean square algorithms are used to perk up the system performance.

2 Hata Model

The Hata model covers frequencies between 150MHz and 1500MHz. with receiver (mobile) antenna heights ranging from 1m to 10m and base station (transmitter) antenna height between 30 and 200 meters.

The Hata model median path loss standard formula is given as:

$$L_{50}(urban)(dB) = 69.55 + 26.16\, log_{10}(f_c) - 13.82 log_{10}(h_t) + (44.9 - 6.55 log_{10}(h_t)) log_{10} D - a(h_r) \quad (2.1)$$

Where,

$$L_{50} = urban\ area's\ path\ loss\ (dB)$$
$$h_t = base\ station\ antenna\ height(m)$$
$$h_r = mobile\ station\ antenna\ height(m)$$
$$f_c = transmission\ frequency(MHz)$$
$$a(h_r) = mobile\ antenna\ correction\ factor$$
$$D = base\ and\ mobile\ station\ antenna\ distance\ (Km)$$

For medium sized urban city, $a(h_r)$ (dB) is given by:

$$a(h_r) = (1.1 log_{10}(f_c) - 0.7) h_r - (1.56 log_{10}(f_c) - 0.8) \quad (2.2)$$

3 Optimization Approach

An algorithm for any optimization process can be defined as a procedure which is executed repeatedly by comparing various solutions obtained from every particular iteration till an optimum result is obtained [3]. Such algorithm is required to create a suitable mathematical model of the optimal design project under consideration. Some of the optimization algorithms are Least Squares , Genetic algorithm, swamp optimization, and beecolony optimization [11].

Optimization process deals with recognition of variables that are changed during the setting and processing of various constraints like equality and inequality [3].

Statistical optimization approaches uses the predictors that are found by all environmental influences as well as by statistical analysis. In this optimization approach, the first step is formulation of a satisfactory statistical model. In Statistical optimization, drive tests are performed to collect network measurement data. Data analysis is done to find the errors which are converted into a proper format in such a way that the predictor coefficients can be obtained [3].

The stochastic processes in general terms are categorised as Stochasticmethods based on evolution and Stochastic methods based on Calculus,depending upon their properties. The Stochastic methods based on Calculus involve mathematical computations such as partial derivations, Weighted Least Square algorithm and Least Mean Squares algorithm[3].

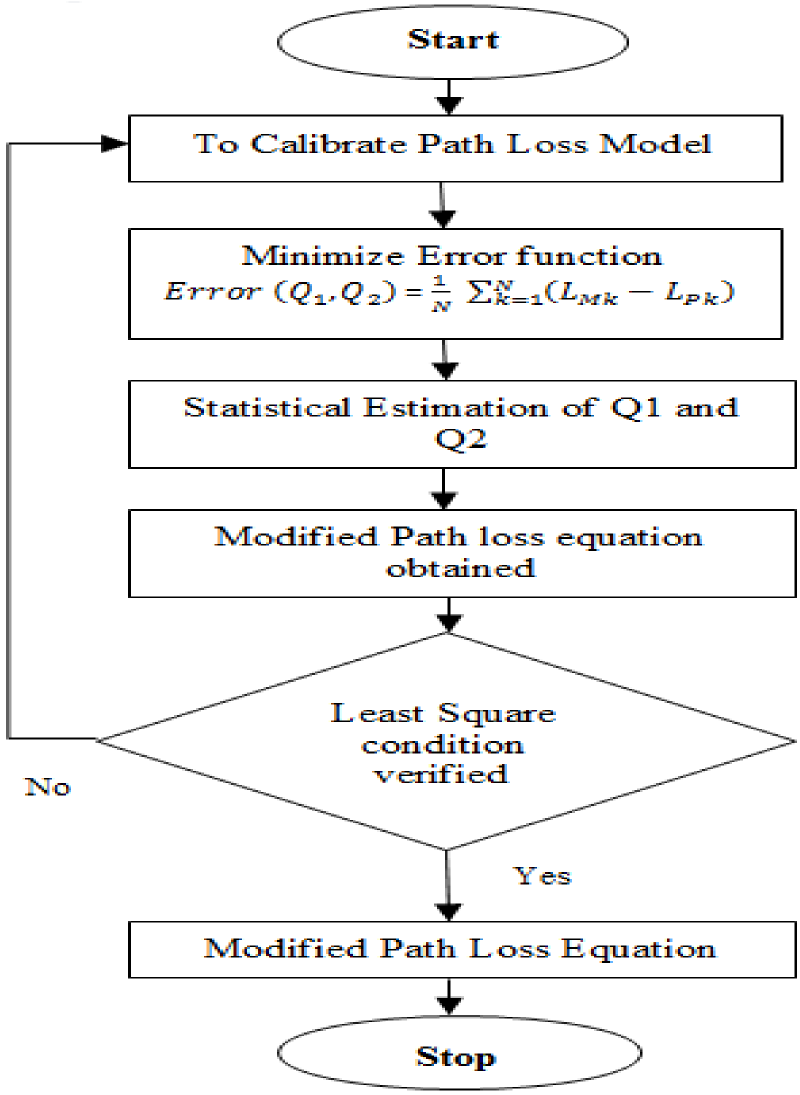
The Stochastic processes based on evolution are generally used to model population in which each particular individual of the particular generation produces a number of individuals randomly in succeeding generation to produce the best minimum value of the objective function [3].

The Least square method involvesthe adjustments based on the fitness function so as to obtain revised values which are closer to the measured values [11].

4 Hata Model Optimization Using Least Mean Square Algorithm

With increased congestion in urban areas the effect of multipath fading and other propagation losses have increased. Due to this the existing path loss models are not accurate enough for determining the path loss. This gives rise to the need for a suitable path loss model which has been optimized to predict path loss with improved accuracy. The main objective of optimization is to attain the finest design with respect to some constraints. These consist of maximizing features for example productivity, strength, reliability, durability, efficiency, and utilization. The optimization methods provide opportunities to introduce some new standards in order to improve the prevailing services.The preferred optimization method uses least mean Square method due to its simplicity [12].

Within the proposed paper, the information is fetched at 900 MHz frequency across the base stations, placed in the medium sizedurban city. The projected optimization technique is applied on Hata model[7].



Flow chart elaborating the least mean square optimization approachimplemented on Hata model

Proceedings DOI: 10.21467/proceedings.114
ISBN: 978-81-947843-8-8
Series: AIJR Proceedings
ISSN: 2582-3922

The measured path loss is given by:

$$L_M = P_t + G_t + G_r - P_r \quad (3.1)$$

Where,

$$P_r = strength\ of\ received\ signal\ in\ dB$$
$$P_t = strength\ of\ transmitted\ signal\ in\ dB$$
$$G_t = gain\ of\ transmitter\ in\ dBi$$
$$G_r = gain\ of\ receiver\ in\ dBi$$
$$L_M = measured\ loss\ in\ dB$$

Hata prediction model for medium urban city has been used and the equation is given as:

$$L_P(dB) = 69.55 + 26.16\,log_{10}(f_c) - 13.82 log_{10}(h_t) + 44.9 log_{10}D - 6.55 log_{10}(h_t) log_{10}D - a(h_r) \quad (3.2)$$

Rearranging the parameter of Equation 3.2 and the modified Hata model is given as

$$L_P = Q_1 + Q_2 Z_k + Y_k \quad (3.3)$$

Where,

$$Y_k = 26.16\,log_{10}(f_c) - 13.82 log_{10}(h_t) - 6.55\,log_{10}(h_t) log_{10}D - a(h_r)$$
$$Z_k = log_{10}D_k$$

If the mean squared error function is minimized, then the condition of an optimum Hata model for a medium sized urban area will be met. The error function is given as:

$$Error\ (Q_1, Q_2) = \frac{1}{N}\sum_{k=1}^{N}(L_{Mk} - L_{Pk}) \quad (3.4)$$

Where, N= number of data points

In order to minimize Error(Q_1,Q_2), the equation (3.4) is differentiated partially w.r.t Q_1 and Q_2. To satisfy the Least Square condition that optimizes Q_1 and Q_2, whole set of partial differential equations of the Error function must be equivalent to zero [7].

As a result, N equations are obtained which are given as follows;

$$\left.\begin{array}{l} Eq1:\ Q_1 + Q_2 Z_1 + Y_1 = L_{M1} \\ Eq2:\ Q_1 + Q_2 Z_2 + Y_2 = L_{M2} \\ \vdots \\ \vdots \\ EqN: Q_1 + Q_2 Z_N + Y_N = L_{MN} \end{array}\right\} \quad (3.5)$$

These equations can be represented in the form of matrices:

$$\begin{bmatrix} 1 & Z_1 \\ 1 & Z_2 \\ \vdots & \vdots \\ \vdots & \vdots \\ 1 & Z_N \end{bmatrix} \times \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} L_{M1} - Y_1 \\ L_{M2} - Y_2 \\ \vdots \\ \vdots \\ L_{MN} - Y_N \end{bmatrix} \quad (3.6)$$

This system ofequations can be rewritten as given in the following equation:

$$V \times K = J \quad (3.7)$$

Here,V = matrix of constraints coefficients

K = optimization variables

J = right hand constraints

The vector $K = [Q_1 Q_2]^T$

The finest tuned coefficients Q_1 and Q_2 that satisfy the least square condition are attained from the solution of the givenmatrix equation:

$$K = [V^T V]^{-1} V^T J \quad (3.8)$$

5 Results and Discussions

5.1 Comparison

Comparison for the path loss between the measured values, and the predicted values by urban Hata model without optimization and then with Least Mean Square regression technique has been done.The Mean Square Error has been evaluated for such comparison.

For $h_t = 50\ m$and $h_r = 1.5\ m$, the measured valuesof the path loss[13] are given in Table I.

MEASURED PATH LOSS IN MEDIUM URBAN CITY

D(km)	Measured value(dB)
0.0742	140.00
0.0877	140.50
0.1029	137.50
0.1236	138.20
0.1573	144.60
0.1843	134.45
0.2325	145.80
0.2714	141.40
0.3148	140.90
0.4031	145.40
0.4398	140.70
0.4750	149.30
0.5008	148.45
0.5331	143.90
0.5744	149.10
0.6077	145.60
0.6450	144.20
0.7061	142.70

The predicted un-optimized andoptimized path loss values and MSE are given in Table II.

PREDICTED PATH LOSS IN MEDIUM URBAN CITY

D(km)	Hata Model Path loss (dB)	
	Before Optimization	*After Optimization*
0.0742	85.189	138.26
0.0877	87.641	138.84
0.1029	89.985	139.39
0.1236	92.673	140.03
0.1573	96.209	140.86
0.1843	98.533	141.40
0.2325	101.940	142.21

ISBN: 978-81-947843-8-8
ISSN: 2582-3922

D(km)	Hata Model Path loss (dB)	
	Before Optimization	***After Optimization***
0.2714	104.209	142.74
0.3148	106.385	143.25
0.4031	110.011	144.10
0.4398	111.289	144.41
0.4750	112.419	144.67
0.5008	113.194	144.85
0.5331	114.111	145.07
0.5744	115.206	145.33
0.6077	116.032	145.52
0.6450	116.906	145.73
0.7061	118.233	146.04
MSE	**9.1680**	**0.73314**

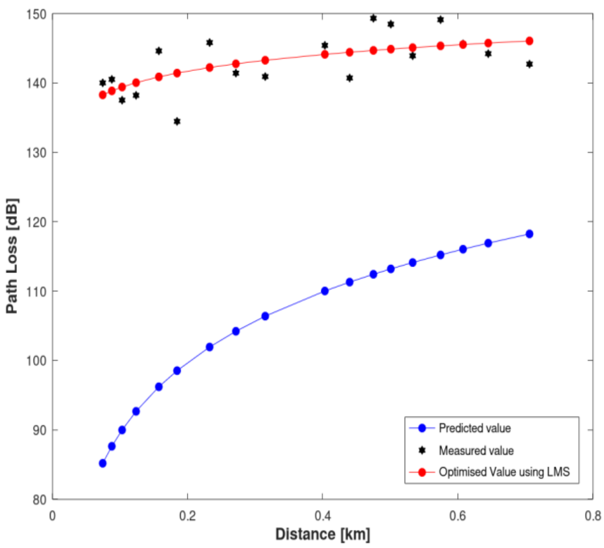
The optimised coefficients (from equation (3.8)) of the Hata model using Least Mean Square optimisation are:

$Q_1 = 93.452$

$Q_2 = -25.826$

The optimised Hata model for medium sized urban city results in a path loss equation, thus given by

$$L_{50}(urban)(dB) = 93.452 + 26.16\, log_{10}(f_c) - 13.82 log_{10}(h_t) + (19.074 - 6.55 log_{10}(h_t)) log_{10} D - a(h_r)$$



Optimized Hata Path Loss Model for Urban area

6 Conclusion

The MSE is thus reduced by a significant amount after applying the optimization technique as the existing Hata model prediction was not a reliable one. This optimized path equation can be used to improve network's quality of service, operating in 900 MHz band in a medium sized urban city.

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