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Applicability of Path Loss Prediction in Macrocellular Environment Using Artificial Neural Networks in Hyderabad City

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ABSTRACT:-*This paper investigates the applicability of Artificial Neural Networks in predicting the propagation path loss in the wireless environment. The proposed path loss prediction model composed of Feed Forward Neural Network trained with measured data using levenberg-marquardt algorithm.The system consists of a GUI application for predicting path loss using various models suitable for different environments.A comparative analysis of measured path loss and predicted path loss is done.*

Keywords: *-Path loss prediction, artificial neural networks, measured path loss, predicted path loss*

I. INTRODUCTION

Path loss is the degradation in received power of an Electromagnetic signal when it propagates through space. Path loss is due to several effects such as free space path loss, refraction, diffraction, reflection, coupling and cable loss, and absorption. Path loss depends on several factors such as type of propagation environments, distance between transmitter and receiver, height and location of antennas. Propagation models are used extensively in network planning, particularly for conducting feasibility studies and during initial deployment. Radio engineers carried out signal strength measurement for a specific area and compared the observed output with that of predicted outputs from different widely accepted propagation models so as to find out which model best predict the path loss for the given scenario. Many propagation models are available for path loss predictions.These models can be broadly classified into two models deterministic and empirical models. Deterministic models are based on the laws of electromagnetic wave propagation whereas Empirical models are based on extensive collection of data for specific case [1,2].

To encompass the benefits of both models Artificial Neural Network models are proposed. As ANN models can easily comply with different environments and it has high processing power. ANN models can be built according to the type of model depending on the scenario required. Artificial neural networks (ANNs) have also been proposed to obtain prediction models that are more accurate than standard empirical models while being more computationally efficient than deterministic models. ANNs have been shown to successfully perform path loss predictions in urban environments [4, 5, 6]. Therefore, to obtain an ANN model that is accurate and generalizes well, measurement data from many different environments had been used in the training process. The trained ANN model consist of inputs that contain information about the transmitter and receiver locations, surrounding buildings, frequency, etc. while the output gives the propagation loss for those inputs. The feasibility analysis of different models has been done for macrocellular propagation environments in Hyderabad city by taking four different areas namely: Amber Nagar, Osmania University, Vidya Nagar and Zamistanpur and Field Strength Measurements offers a better means to understand what path loss model to use in certain propagation environments. Field strength measurements were conducted on the existing GSM (948.2, 951.4, 949.8, and 948.8) MHz Network of BSNL Telecom on the locations of interest.

II. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks (ANNs) are relatively adaptive models based on the neural structure of the brain. The brain learns from experience. Artificial neural networks try to mimic the functioning of brain. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process.

The network is composed of a large number of highly interconnected processing elements (neurons) working in parallel to solve a specific problem. Neural networks learn by example. By examples ANN can create its own model [4,5].

In this work the ANN are trained using the measured field data to create its own model of behavior. Later on this model can be used for predicting path loss values by observing the measured values. With this generalization is achieved. There are many types of network architectures used. In this work feed forward network is used for simplicity. This network (Figure 1) consists of one or more hidden layers, whose computation nodes are called hidden neurons or hidden units. The function of hidden neurons is to interact between the external input and network output in some useful manner and to extract higher order statistics. The source nodes in input layer of network supply the input signal to neurons in the second layer (1st hidden layer). The output signals of 2nd layer are used as inputs to the third layer and so on. The set of output signals of the neurons in the output layer of network constitutes the overall response of network to the activation pattern supplied by source nodes in the input first layer [5,7].

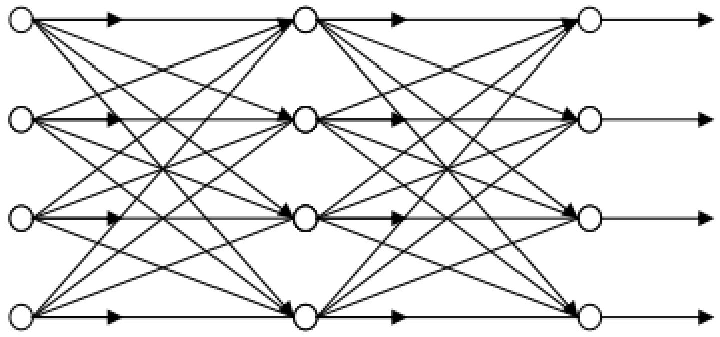

Figure 1: A Multi-layer feedforward network

Training of Artificial Neural Networks

Once a network has been structured for a particular application, it is ready for training. At the beginning, the initial weights are chosen randomly and then the training or learning begins using training algorithms. There are many algorithms available for training a neural network but the simplest one is gradient descent method. Levenberg Marquardt (LM) training algorithm is used for the project.

Levenberg Marquardt algorithm is one of the fastest training algorithm for moderate sized networks [5,8].

The LM algorithm is a combination of gradient descent method and the Gauss Newton method. LM algorithm was designed to approach 2nd order training speed without having to compute the hessian matrix. Hence the Hessian matrix is computed as,

$$H = J^T J \qquad (1)$$

Where the gradient is computed as,

$$g = J^T e \qquad (2)$$

Where,

J is the Jacobian matrix that contains first derivatives of the network errors

e is a vector of network errors

The LM algorithm uses this approximation to the Hessian matrix in the following Newton like update is given as,

$$X_{k+1} = X_k - [J^T J + \mu I]^{-1} J^T e \qquad (3)$$

When the scalar μ is zero, it will act like Newton's method using the approximate Hessian matrix. When μ is large, it acts like gradient descent with a small step size. Newton's method is faster and accurate near an error minimum, so the aim is to shift toward Newton's method as quickly as possible. Thus μ is decreased after each successful step and is increased only when a tentative step would increase performance function. In this way, the performance function is always reduced at every iteration of the algorithm [5,8].

LM algorithm was found to be one of the fastest algorithms that fits for the optimal configuration of the proposed ANN model.

III. METHODOLOGY

Measured data was collected to train and tune neural network model, so that it can create its own behavior of radio waves. GSM base station data was provided by the Bharat Sanchar Nigam Limited (BSNL) which is a telecom company owned by Government of India. The base station data sheet consists of the location, cell identity, transmitted power, height of all the base stations near the Osmania University where the experiments were done. GSM module was mainly used to capture received signal strengths from the base stations. GSM data sheet is in the form of +CCED format.

The receiving antenna was held on the top of the car. The experiment setup consists of GSM modem (Wavecom WM01-G900) and a laptop with suitable interface installed on it. The car was driven starting from the main base station to the neighboring base stations. At all instants Received signal strength were captured. Four parameters namely distance, frequency, mobile station height, base station height were considered as input parameters and a 4-4-1 network was created.

A set of path loss data recorded at distances of 100m to 1km for the three different base stations were taken and was used for training. 400 measurement samples of each were used. 75% of data was used for training, 15% was used for validation, and 15% was used for performance evaluation. Training was continued as long as it decrease the network's error on the validation samples.

During the training phase weights were adjusted and modified in order to obtain minimal error so that the error between the actual output and the desired output is minimized.

IV. RESULTS

The main aim was to develop an ANN model that accurately predicts the propagation path loss. This paper presents the path loss prediction made using free space path loss, Egli, Hata, Cost-231, Walfisch-Ikegami and Neural network model. Path loss exponent is calculated for all the models and the neural network model was found to be the best suited prediction model. The path loss exponents computed for the prediction models of the three base stations are tabulated in Table1.

Table 1: Path loss exponent values of all the models.

Base Stations	Measured Path loss	Free Space Path loss	Egli	Hata	Cost 231	Walfisch Ikegami	Neural Network
Amber Nagar	5.3	2.0	4.0	3.6	3.6	2.6	5.0
Osmania University	4.7	2.0	4.0	3.5	3.5	2.6	4.6
Vidya Nagar	4.6	2.0	4.0	3.6	3.6	2.6	4.6

The performance of the ANN model was evaluated by making a comparison between expected and the measured values using error metrics. The error metric used here is mean square error (mse). The mse values computed for the ANN model are tabulated in Table 2.

Table 2: Mean square error values of the ANN model.

Distance	0.2km	0.4km	0.6km	0.8km	1.0km	Average
mse(dB)	2.77	2.73	2.68	2.63	2.58	2.67

Table 3 presents the mse values for all the models to show the better accuracy of the ANN model.

Table 3: Mean square error values of the ANN model.

Free space	Egli	Hata	Cost 231	Walfisch Ikegami	Neural Network
14.77	10.73	3.68	4.63	10.58	2.67

From the above statistics it is noted that the ANN model has an average of 2.67dB mse value. This value falls below 6dB which is better for good signal propagation [2].
Below figures show the best performance obtained during the training process and also regression plot.

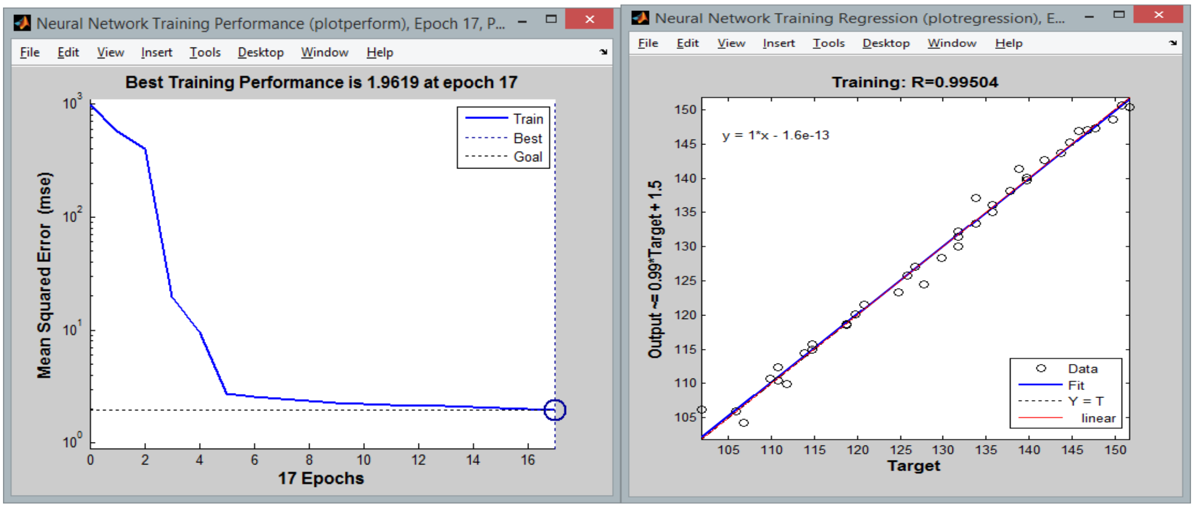

Figure 2 : Training performance and regression ploft of the proposed ANN model.

V. CONCLUSION

The proposed ANN model for path loss prediction gives better performance compared to the empirical models. As ANN's are capable of best function approximation they are useful for the propagation loss modeling. ANN model was found to be more accurate than empirical models and computationally efficient than deterministic models. A test bed is provided for validating the loss for each scenarios by considering different models. The GUI system developed makes easier to plan the best value of parameters for the specified path loss based on the need. ANN model can be used to take account of various types of environments based on measured data taken in the desired environment.

VI. RECOMMENDATIONS

The ANN model provides transcription for new models. For better path loss prediction, by introducing of additional parameters during the training process such as buildings, trees, mountains, road orientation makes it more feasible and efficient. This is to make sure that the path loss calculated indicates overall obstacles. The outcome of this model can be used for interference estimation and frequency assignment planning for new network. Telecommunication companies in Hyderabad can use this model for realistic planning of GSM networks, intelligent placement of base stations, link budget analysis, and frequency re-use, better coverage predictions and interference reduction. Path loss and received signal strength can be used to estimate user position.

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