Location Estimation in Cellular Networks Using Artificial Neural Networks

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Abstract- Location estimation provides information about the location of cellular phones of the users. Some of the existing techniques such as those used in GPS, Satellite, and Navigation systems require non standard features either at cellular phone or network. The prediction of mobile location using propagation path loss (signal strength) is a complex task. Various propagation models are used to predict location. These models are studied for the estimation of received power. This paper proposes an Artificial Neural Network (ANN) model for the prediction of location estimation for the propagation models which is having better power received capability.

Key Words-Artificial Neural Network, Global Positioning System, Global System for Mobile Communication, Location Estimation, Propagation Models

1. INTRODUCTION

The Radio wave propagation model or Path loss model plays a very significant role in planning of any wireless communication system. Radio propagation model is a mathematical formulation for the characterization of radio wave propagation as a function of parameters like frequency, transmitter –receiver separation, heights of the transmitter, receiver and density [1].

Calculation of path loss is usually called Prediction [1]. The prediction of mobile location using propagation path loss (signal strength) is a complex task. The accuracy depends on environment (Multipath, NLOS, Shadowing) , path loss model used, number of base stations and techniques such as Enhanced Observed Time Difference(E-OTD) , Global Positioning System (GPS) , Cell ID , Timing Advance (TA),Time Of Arrival (TOA) and signal strength based techniques are used for estimating the cellular location. Location estimation provides users of cellular telephones with information about their location. Some of the existing techniques such as those used in GPS, Satellite, and Navigation systems require non standard features either at cellular phone or network. It is possible to use existing GSM technology for location estimation. An Approach based on Artificial Neural Network (ANN) is proposed in this paper.

Neural networks are particularly effective for predicting events when the networks have a large database of prior examples to draw on. Strictly Speaking, a neural network implies a non-digital computer, but neural networks can be simulated on digital computers.

Section 2, covers different Radio propagation models like Stanford University Interim (SUI), Cost231 (Walfish Ikegami), Okumurahata, Costhata, Ercission, Comite Consultatif International des Radio-Communication (CCIR). All these models are studied based on propagation path loss equations and a comparison is made by using different terrains e.g. urban, suburban and rural area [2]. Section 3 describes about the location determination with ATOLL software. Section 4 covers ANN.

2. PROPAGATION MODELS

The mathematical formulation for various propagation models are as follows:

2.1 SUI MODEL

This model is characterized by three set of terrains namely A,B&C, where terrain A represents urban area, terrain B represents suburban area and C represents rural area[2,3]. The equation for Path loss is given by

$$L=A+10\gamma log_{10}[d/d_0]+X_f+X_h+s \quad \text{for } d>d_0 \qquad (1)$$

Where

$$A=20log_{10}(4\pi d_0/y)$$

$$\gamma = a - bh_b + c/h_b$$

TABLE 1: TERRAIN PARAMETERS FOR SUI MODEL

Model Parameter	Terrain A	Terrain B	Terrain C

a	4.6	4.0	3.6
b(1/m)	0.0075	0.0065	0.005
c(m)	12.6	17.1	20

The correction factors for the Operating Frequency are

$X_f = 6.0 log_{10}(f_c/2000)$ and

x_h= -10.8log_{10} (h_r/2000) for terrain A&B

= -20.0log_{10}(h_r/2000) for terrain C

Where f is operating frequency ,h_b is the height of base station antenna, h_r is the height of mobile antenna, s is the log normally distributed factor accounting for the shadow fading owing to trees and other clutter and has a value between 8.2 dB and 10.6 dB, d_0 is the reference distance(100m).

2.2 COST HATA MODEL

The equation for path loss is given by

L= 46.3+ 33.9log_{10}(f) - 13.02log_{10}(h_b) - a(h_r)+ [44.9-6.55log_{10}(h_b)] log_{10}(d) +c (2)

where

For urban areas

a(h_r)= 3.2$(log_{10}(11.7h_r))^2$- 4.97

For suburban and rural areas

a(h_r)=(1.1$log_{10}(f) - 0.7h_r - (1.58f - 0.8)$

c is a terrain factor and it is 0 for suburban and rural areas, c=3 for urban area. f is a frequency of operation, d is the distance between transmitter and receiver, $h_b$is the height of the base station antenna, $h_r$is the height of mobile antenna[2,3].

2.3 OKUMURA HATA MODEL

The equation for path loss is given by

For urban area,

L=69.55+26.16$log_{10}(f)$- 13.82$log_{10}(h_b)$ +[44.9-6.55$log_{10}(h_b)$]log_{10}(d)- a(h_r) (3)

Where a(h_r)=3.2($log_{10}(11.75h_m))^2$- 4.97

For suburban area,

L=69.55+26.16$log_{10}(f)$- 13.82$log_{10}(h_b)$ +[44.9-6.55$log_{10}(h_b)$]log_{10}(d)-a(h_r)- a_1 (4)

Where a_1=2($log_{10}(f/28))^2$+5.4

For Rural area,

L=69.55+26.16log_{10}(f)-13.82$log_{10}(h_b)$ +[44.9-6.55$log_{10}(h_b)$]log_{10}(d)- a(h_r)- a_2 (5)

Where a_2=4.78$(log_{10}(f))^2$ -18.33($log_{10}(f)$) + 40.94

$h_b$is the height of the base station antenna, $h_r$is the height of mobile antenna, f is the frequency of operation, d is the separation between transmitter and receiver[2].

2.4 CCIR MODEL

The equation for path loss is given by

L= 69.55+26.16$log_{10}(f) - 13.82(log_{10}(h_b))$ +[44.9-6.55$log_{10}(h_b)$]log_{10}(d)-a(h_r)-B (6)

Where a(h_r)=(1.1$log_{10}(f)$-0.7)h_r- (1.56$log_{10}(f)$-0.8)

B=30- 25log_{10}(% of area covered by buildings)

B is the correction factor and is 0 for urban propagation. f is the frequency of operation , d is the separation between transmitter and receiver, $h_b$is the height of the base station antenna, $h_r$is the height of mobile antenna[3].

2.5 ERICSSON MODEL

The equation for path loss is given by

L=a_0+$a_1 log_{10}$(d)+$a_2 log_{10}(h_b)$+$a_3 log_{10}(h_b)log_{10}$(d) - 3.2($\log_{10}(11.75))^2$+g(f) (7)

Where g(f)=44.9$log_{10}(f)$- 4.78$(log_{10}(f))^2$

The values of a_0 , a_1, a_2, and a_3 can be changed according to environment. By default they are 36.2, 30.2, 12.0 and 0.1 respectively. F is the frequency of operation, d is the separation between transmitter and receiver [2].

2.6 WALFISH IKEGAMI MODEL

This is also called as COST 231 with the acronym of Cooperation in the Field of Science and Technology Research under the name of project 231[2, 3]. The equation for path loss is given by

L = l_{fs}+l_{rts}+l_{msd} l_{rts}+l_{msd}≥0

= l_{fs} $l_{rts} + l_{msd}$<0 (8)

where

l_{fs} =32.45+20$log_{10} d + 20 log_{10} f$, is free space loss

l_{rts}= -16.9-10$log_{10} w$ +10$log_{10} f + 20 log_{10} d_2 + l_{ori}$,Roof to street diffraction & scattering loss

l_{ori} = -10+0.345Ø, 0≤Ø ≤35^0

= 2.5+0.075(Ø −35^0), 35^0≤ Ø ≤55^0

$$= 4.0\text{-}0.114(\emptyset - 55^0), \quad 55^0 \leq \emptyset \leq 90^0$$

$$l_{msd} = l_{bsh} + k_a + k_d \log_{10} d + k_f \log_{10} f - 9\log_{10} b$$

$$shadowing\ Gain,\ l_{bsh} = -18\log_{10}(1 + d_1) \quad d1 > 0$$
$$= 0 \quad d_1 < 0$$

$$k_a = 54, \quad d_1 > 0$$
$$= 54+0.8|d_1|, \quad d_1 \leq 0\ \&\ d \geq 0.5$$
$$= 54+0.8|d_1|\left(\frac{d}{0.5}\right), d_1 \leq 0\ \&\ d < 0.5$$

Distance Factor,

$$k_d = 18, \quad d_1 > 0$$
$$= 18+15\frac{|d_1|}{h_B}, \quad d_1 \leq 0$$

Frequency Correction factor, for suburban & rural areas

$$k_f = -4+0.7(f/925-1)$$
$$= -4+1.5(f/925-1) \text{ for urban area}$$

Where h_b is the base station antenna height(meters)

h_m is the mobile station antenna height(meters)

h_B is the buildings height(roof)

$d_1 = h_b - h_B\ \&\ d_2 = h_B - h_m$

b is the building separation in meters

w is the width of the street in meters

Ø is the angle of incidence

d is the separation between transmitter and receiver

The Path loss is obtained using MatLab simulator with following specifications: Frequency of Operation =900MHz, Distance upto 7000m, Height of Base Station Antenna =50m, Height of Mobile Antenna=3m.

The simulated Results are obtained for the above mentioned models for Rural, Suburban and Urban models are shown in figures 1, 2 and 3.

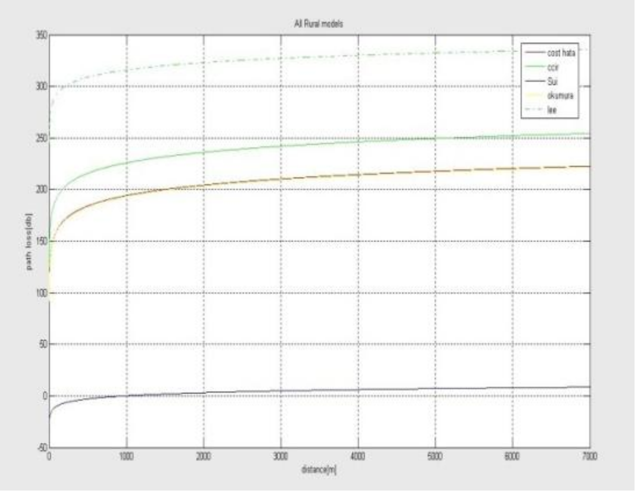


FIG 1: GRAPHICAL RESPONSE IN RURAL AREAS

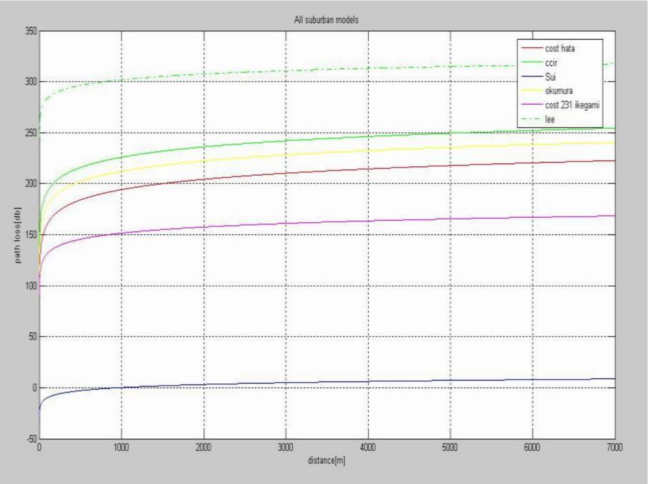


FIG 2: GRAPHICAL RESPONSE IN SUBURBAN AREAS

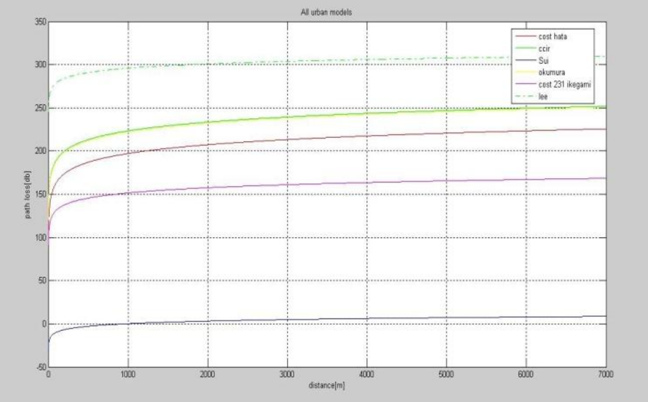


FIG 3: GRAPHICAL RESPONSE IN URBAN AREAS

From the above graphs, it has been observed that *SUI model has least Propagation Path Loss in Urban, Rural and Suburban areas.*

3 LOCATION DETERMINATION USING ATOLL

The determination of received power is discussed in this section. The error between the measured and the predicted data was used to calibrate the model. First, the clutter information was obtained from ATOLL planning tool. This information was then loaded in the MATLAB work space [5].

3.1 MODELLING MOBILE POSITIONING SYSTEM

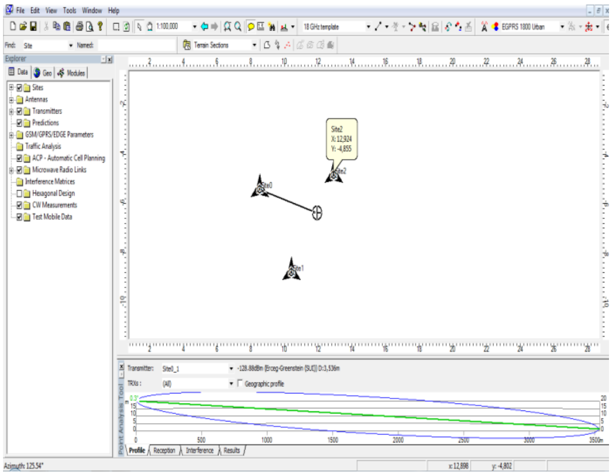
A mobile positioning using nonlinear least square approach, the calculation of mobile position (x,y) involves solving a nonlinear least squares is given by

$$\text{Error}=\sqrt{(X_i - x)^2 + (Y_j - y)^2} - d_{i,j} \qquad (9)$$

Where (X_i, Y_j) are the BTS coordinates, $d_{i,j}$ is the computed distance from BTSs to the approximate mobile position using the propagation prediction model. This method minimizes the difference between distance calculated from the BTS coordinates to the estimated mobile position and the same distance calculated using the modeled propagation prediction model. Ideally this difference in distance should be equal to zero for very accurate MS positioning. The MATLAB isqnonlin function in the optimization toolbox is used to implement this algorithm as it solves nonlinear least squares. The program utilizes coordinates of three Base Transceiver Stations and the distances from the prediction model to compute the mobile position [5].

To obtain the received power at particular BTS, total path loss was calculated using the SUI model of propagation.

3.2 OVERVIEW OF ATOLL



Transmitter: Site0_1 -128.88dBm (Erceg-Greenstein (SUI)) D:3,536m

TRXs : (All) ☐ Geographic profile

Azimuth: 125.54°

x: 12,898 y: -4,802

FIG 4: CALCULATION OF POWER RECEIVED AT A PARTICULAR BTS

The Mobile Station (Unit) is assumed at a default location then the respective power received is calculated at the three Base stations (as shown in FIG 4), now by taking the mean of those values the original position of MS is calculated. Hence the existing methods take lot of time for processing, this paper introduces a Artificial Neural Network(ANN) which gives the location with high speed parallel processing and accuracy.

4 ARTIFICIAL NEURAL NETWORK (ANN)

An alternative approach based on artificial neural networks which offers the advantages of increased flexibility to adapt to different environments and high speed parallel processing [6].

An ANN is an information Processing paradigm that is inspired by the way biological nervous systems, such as the brain process the information. The Key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs like people, learn by example.

An ANN can be configured for a specific application through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. The organization and weights of the connections determine the output. An artificial neuron is a device with many inputs and one output. The neuron has two modes of operation; the training mode and the testing mode. In training mode, neuron can be trained to be fire (or not), for particular input patterns. In the testing mode taught input pattern is detected at the input, its associated output becomes the current output. If the input pattern does not belong in the taught list of input patterns, the firing rule is used to determine whether to fire or not [7]. The Modeling of neural network is as per the Fig 5

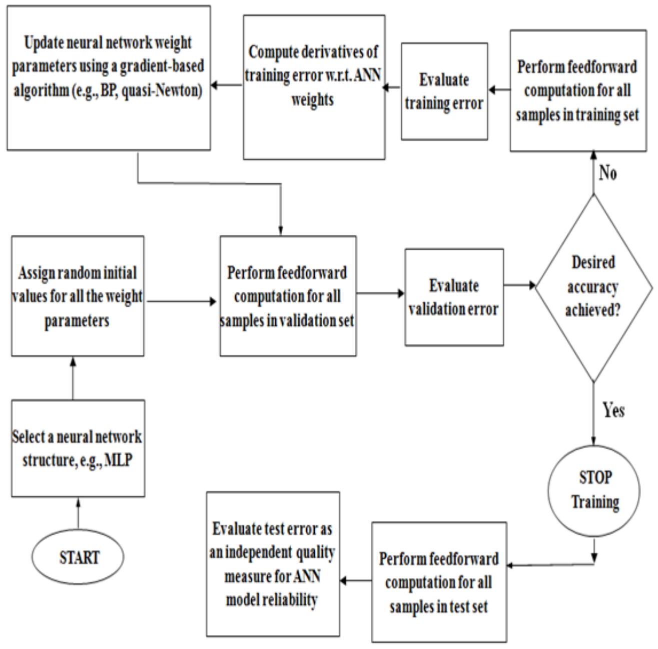


FIG 5: FLOW CHART REPRESENTING NEURAL NETWORK MODELING

The Neural Network model used in this paper is Multi Layered Perceptron (MLP). It is the universal method of approximation Network with inputs x and outputs y respectively, and network comprise one or more hidden layers [8]. The General Architecture of MLP is shown in Fig 6.

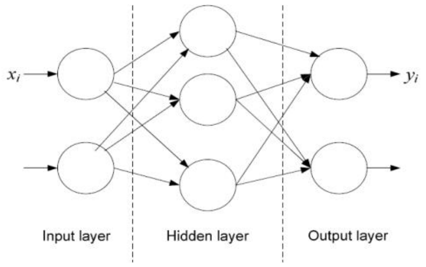


FIG 6: GENERAL ARCHITECTURE OF MLP

4.1 NEURON ACTIVATION FUNCTIONS

- Input layer Neurons simply relay the external inputs to the neural network.
- Hidden layer neurons have smooth switch – type activation functions.
- Output layer neurons can have simpler linear activation functions.

The output y_i of each neuron of the n-th layer is defined by a derivable nonlinear function F, represented as

$$y_i = F\left(\sum_j w_{ji}\, y_j \right) \qquad (10)$$

Where F is the nonlinear activation function, w_{ji} are the weights of the connection between the neurons N_j and N_i, y_j is the output of neuron of the (n-1)th layer.

4.2 THREE LAYER PERCEPTRON (WORKING MODEL)

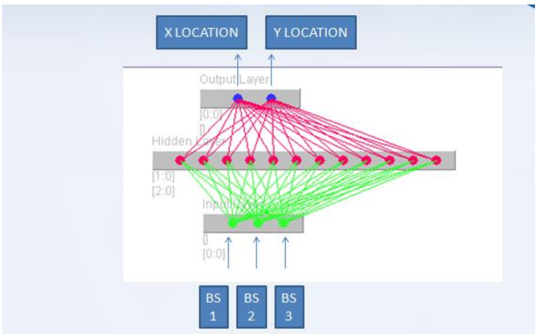


FIG 7: WORKING MODEL

The working model implemented is shown in Fig 7, the Inputs are namely; Three Inputs, they are Input 1: Received Power at the Base Station 1, Input 2: Received Power at the Base Station 2 and Input 3: Received Power at the Base Station 3. Two outputs X and Y give the location of the Mobile Unit. The Attempted Working Parameters here are Max no of epochs=1000 and Learning Rate =0.2. The Neural Network is trained and tested as per above mentioned Parameters. In our application neural networks are trained and tested with following set of algorithms:

- Back Propagation.

- Sparse Training.
- Conjugate Training.
- Adaptive Back Propagation.
- Quasi Newton(MLP)

4.3 RESULTS FROM VARIOUS ALGORITHMS

The various Testing and Training Errors are tabulated in the following table

TABLE 2: ERRORS OBTAINED THROUGH SIMULATION

ALGORITHM	TRAINING(FINAL ERROR)	TESTING
BACK PROPAGATION	0.02605294	AVG ERROR: 2.3834767
		WORSTCASE: 24.62174
		CORR COEFF: 0.916141
		AVG ERROR:

SPARSE TRAINING	0.0378339	2.383443
		WORSTCASE: 24.21647
		CORR COEFF: 0.853821
CONJUGATE TRAINING	0.0269463	AVG ERROR: 2.4929543
		WORSTCASE: 24.47148
		CORR COEFF: 0.9032254
ADAPTIVE BACK PROPAGATION TRAINING	0.028037	AVG ERROR: 2.5048988
		WORSTCASE: 24.156002
		CORR COEFF: 0.896921
QUASI NEWTON(MLP)	$2.5647749*10^{-4}$	AVG ERROR: 30.001652
		WORSTCASE: 27.207
		CORR COEFF: 0.962474

Hence from the above results Quasi Newton (MLP) is the best model for estimating Mobile Unit Location.

5 CONCLUSION

Localizing handset users within a mobile network has always been seen an important probability, since its successful incorporation would allow crucial services to the customers, these services include effective handling of emergency calls, location sensitive billing and intelligent transportation. Federal Communication Commission (FCC) made mandatory for network operators to be able to locate users on the location accuracy. There by using neural networks do not perform miracles but if used sensibly they produce some amazing results.

In future by increasing the number of samples, used for training and testing the correlation coefficient can be improved.

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