A Predictive Optimization Model for Path Loss Minimization for GSM Based Network Using Neuro-Swarm Intelligence

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Abstract

Path Loss is the reduction in power density of an electromagnetic wave as it travel, through space. It is a major component in the analysis and design of the telecommunication system. This study presents a predictive optimization model for minimizing path loss in GSM network using Neuro-Swarm Intelligence. Experiment performed include training data collected from GSM network provider using a feed forward propagation algorithm in a system with IPv4 network configuration. Simulation and determination of path loss (signal strength) based on distance, frequency and propagation speed of the data parameters whose termination criteria met the Mean Square Error (MSE). The program was coded in MATLAB. The result obtained was compared favourably with the best two (free space path loss and log normal shadowing model)

Keywords: *Path Loss, Minimization, GSM Network, Optimization, Prediction, Neuro-Swarm Intelligence.*

I. Introduction

GSM Network performance and service quality are essential steps for mobile operators as this will be about customer's perception is necessary to evaluate the network performance and maintain service quality standards. Path loss is one of the main component When it comes to analysis and design of the link budget of a telecommunication system, path loss is one of the main. Path loss is mostly used in wireless communications and signal propagation. Free-space loss, scattering, refraction, diffraction, reflection, aperture-medium coupling loss and absorption are some of the causes of path loss. Terrain contours, environment (urban or rural vegetation and foliage) propagation medium (dry or moist air) the distance between the transmitter and the receiver and the height and location of antennas can also influence path loss [6].

Path loss normally includes propagation losses caused by the natural expansion of the radio wave front in free space (which usually takes the shape of an ever-increasing sphere) absorption losses (sometimes called perpetration losses) when the signal passes through media not transparent to electromagnetic waves, diffraction losses occurs when part of the radio wave front is obstructed by an opaque obstacle, and losses caused by other phenomena. The signal radiated by a transmitter travels concurrently to a receiver along many and different paths; this effect is called multipath. Multipath waves converge at the receiver antenna, resulting in a received signal that can vary widely depending on the wave amplitude and relative propagation line distribution and the transmitted signal bandwidth. In a Rayleigh fading scenario, the total power of interfering waves varies rapidly as a function of space (known as small-scale fading) Small-scale fading refers to the rapid changes in radio signal amplitude in a short period of time or travel distance[9]. In Global system for Mobile Communications, path loss is highly inevitable in evaluating network quality and capacity as regards efficient and reliable coverage areas in the growth of communication [13]. Added to the increase in the number of GSM users, the need for connectivity everywhere has triggered the development of different generations of mobile communications standards over the past decades.

The demand for increased traffic capacity involving both voice and data transmission requires the planning of mobile communications networks consisting of smaller and smaller cells, thereby exponentially increasing the number of base stations and complicating the process of determining and optimizing the location of these stations. Because of this, precise and fast prediction models are needed to make predictions of received signal level / path loss before network deployment is realized. Path Loss estimation is a major part of large-scale fading analysis of the propagation electromagnetic waves. In the context of mobile radio signal, it ensures better data rates, identifies the optimum location base stations, overcomes various constraints such as limited band width, coverage, channel variability and provides better quality of service[12].

This study will focus on minimizing path loss in GSM networks using a prediction optimization model based on Neuro-swarm Intelligence. The importance of the swarm technique is to intelligently evolve an optimal solution space during network dynamics while the Neuro part is used to learn and memorize the best set of swam setting that gives the desire fitness or convergence to the GSM network. They will result to a very robust and efficient flow of signal scheme. It will address this problem by evaluating the potential of a promising hybrid Artificial Intelligence (AI) technique for minimizing of path loss in GSM network prediction and identifying the most suitable one to use.

Artificial Neural Network (ANN) Is used mainly to predict the loss of mobile radio paths in urban rural and indoor environments. Compared to the deterministic approach, the use of neural network models in path loss prediction provides better access to signal models and less computational complexity. ANN models have the advantages of processing large amounts of data at high processing speeds and ensuring greater flexibility to reflect the real-time environment in which measurements are carried out[11]. The ANN has been applied successfully in various fields of science, such as pattern recognition, fault identification, forecasting, prediction, path loss measurements and network model analysis, even in reducing path loss. Particle Swarm Optimization, and a combination of ANN like ABC-PLOSS has also been applied in minimizing path loss. Neuro-swarm intelligence (a combination of two Artificial Neural Networks) has been applied in power station. However, no research has been done on predicting optimization model for path loss minimization based on Neuro-swarm intelligence.

Path loss (Network failure) can pose a very serious risk to GSM subscribers (both the caller and the receiver). There can be a distortion of the communication of important information due to call drops, call fluctuations and even call failure and this can lead to loss of life, lost of several opportunities etc. Several researches have been done to reduce Path loss in GSM network but, we have to gotten there yet because we still experience network failures though minimized. The problem addressed here is how to develop a sophisticated hybrid artificial intelligence technique (Neuro-swarm) that can minimize excess fluctuations and call drops in GSM network. This research is aimed at developing a predictive optimization model for path loss minimization in GSM network based on Neuro-swarm intelligence. The objectives include: To measure signal strength and collect data parameters for GSM networks, to develop a model that will improve the quality of service (by minimizing call drops and fluctuations) using hybrid Neuro- swarm technique and compare the system with existing ones in place.

II. Related Works

Path Loss (or attenuation of the path) delineates a decrease in the density of power of any given electromagnetic wave as it propagates space. There are various causes of path loss ranging from natural expansion of the radio wave, loss of the path of diffraction due to obstruction, to loss of the path of absorption due to the presence of a medium that is not transparent to electromagnetic waves. It is important to note that the transmitted signal may travel along other paths to the intended destination even when there is a path loss, this process is called multipath. Since these waves or transmitted information travel along other routes, the wave can regroup at the destination point resulting in a significantly different received signal[5].

In a very recent work by [4] The "ABC-PLOSS" open-source software tool was presented, which was developed for use in optimisation processes. The tool uses a sequential processor architecture based on an artificial bee colony (ABC) swarm intelligence algorithm and cost-231 Hata Path-Loss model as cost function for path-loss minimization (PLM). Using the ABC-Loss framework, the ABC algorithm was compared with two other existing and popular artificial intelligent (A1) algorithms called the genetic algorithm (GA) and particle swarm optimization (PSO). Results of simulation studies show that the tool is indeed useful as it gives a competitive or lower path-loss estimate when compared with conventional techniques. It also shows that it is possible for the ABC to attain an estimated seven fold and two-fold path-loss improvement over the GA and the PSO techniques respectively.

III. Material and Methods

A. Path Loss Models for Prediction

Several path loss models have been used to predict path loss earlier, but the two used in this work are free space path loss and log-normal propagation model. Some calculations also performed with these models and outcome recorded.

a) Free Space Path Loss

The free space propagation model represents the simplest scenario for radio signal propagation. It was observed that the signal level falls as it is moving away from the transmission point. The rate at which it falls is proportional to the distance square inverse[12].

$$\text{Signal level} = \frac{k}{d^2} \qquad (3.1)$$

Where:

k = constant

d = transmitter distance

This means that a transmission's signal level will be a quarter of the force at a distance of 2 meters which it is at a distance of 1 meter. If a signal is subject to the effect of certain factors, the basic formula can be altered to take it into account.

The exponent is modified to more accurately represent the real-life scenario. In conditions such as the internality of a building, stadium and other indoor settings, the path loss exponent can reach within 4-6 range.

To calculate the path loss between the transmitter and receiver, the path loss is proportional to the square of the distance between the transmitter and the receiver and also to the square of the frequency in use.

In terms of wavelength

$$\text{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2$$

(3.2)

In terms of frequency

$$\text{FSPL} = \left(\frac{4\pi df}{c}\right)^2 \qquad (3.3)$$

Where:
FSPL = Loss of free space path
d = distance from the transmitter to the receiver (meter)
λ= signal wavelength (meter)
f = signal frequency (Hz)
c = light speed (meter per second)

Free space pass loss in deciBels

Normally, being able to express the path loss in terms of a direct loss in decibels is more convenient. In this way, elements including the expected signals can be calculated and antenna gain added[3].

$$\text{FSPL (dB)} = 20\log(d) + 20\log(f) + 32.44 - G_{tx} - G_{rx} \qquad (3.4)$$

Where:

d = distance of the receiver from the transmitter (km)

f = signal frequency (MHz)

G_{tx} = overall transmitter antenna gain including feeder losses

G_{rx} = overall receiver antenna gain including feeder losses

b) Log-Normal Propagation Model

The log-normal path loss model may be considered as a generalization of the Friis free-space equation where the power can be reduced at a rate of $(1/d)^n$.

This model is expressed as:

$$pr(d)_{dB} = \bar{p}r(d_0)_{db} - 10n\log\left(\frac{d}{d0}\right) + \chi, \; d > d_0$$

Where:
Log = base 10 logarithm
$pr(d)_{dB}$=received power at a distance d meters from the transmitter
n = the path loss exponent that defines the rate of decay of power with respect to distance
χ = Gaussian random variable with zero mean and variance σ^2_χ which is defined in dBs.
$\bar{p}r(d_0)_{db}$ = ensemble average of all possible power values received for a given reference distance denoted by d_0 meters.

B. Neuro-Swarm Intelligence

Neuro-Swarm intelligence is derived from the Swarm Optimization based on swarm intelligence. Neuro-Swarm intelligence is a combination of two models which are Particle Swarm Optimization (PSO) and Artificial Neural Network (ANN) and mostly used in Artificial Intelligence. The ANN and the PSO models were hybridized and used in conjunction with the separate ANN and PSO models as an alternative optimization process[8][1][2].

a) Neuro Swarm Algorithm

The PSO section comes after the ANN portion, in this way the fitness criterion is indistinguishable from the unadulterated PSO calculation. That is if during the execution of the program, the situation of the considerable number of particles combines to some steady esteem, no further advancement happens in the goal work, no requirements are broken, and all the choice factors are non-negative at that point, it can be

viewed as that the wellness measure is met. At that point, the arrangements are at its fittest, and along these lines, the program goes to an end.
The working Model of the hybrid ANN-PSO (Neuro-Swarm) procedure are as follow:
The main step of Neuro-Swarm Intelligence are listed below[8][4].

1. Setx_i as the data sources and introduce the neural network weights,w_{ij}
2. Compute output, y_j and, vitality difference, dE
3. Check differential threshold: if $(dE > 1)$, proceed with network recursion (Step 2) else, continue to stage 4.
4. Initialize no of particles,i and the modelparameters$w, c1, c2, r1, r2, no$
5. Set beginning position $x_i\ (n)$ and speed $v_i\ (n)$
6. Compute individual and social impact
7. Compute position $x_i\ (n+1)$and speed $v_i\ (n+1)$ at next cycle
8. If the swarm advancement time$n > n_o + T$, update position x_i and velocity v_i and go to Step 2, else, continue to stage 6, where n_o is some consistent, $n$is the swarm iteration,$m$is the system recursion, and T is the generally speaking program iterations
9. Initialize DG framework coefficients and plan parameters
10. Evaluate wellness of the plan parameters
11. If wellness standard is fulfilled, stop and print arrangements, else go to stage 3

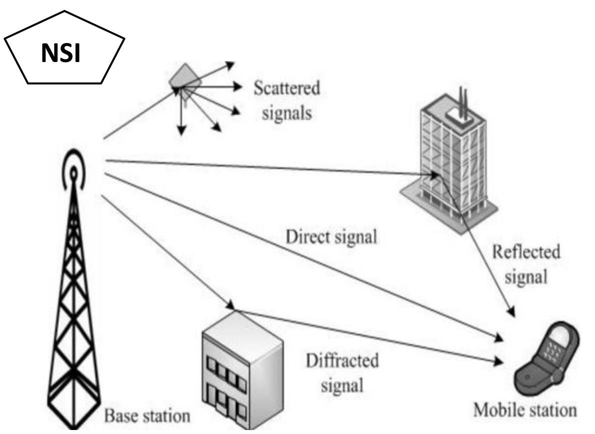


Figure 1: Overview of the Physical Environment Envir

C. Overview of the Physical Environment

The Physical Environment describes the overall view of the system, how system components interact with each other within the system. In this case, there are some main components which explain the architecture of this system. In figure 1 below base station sent the signal toward the mobile station in three different ways which are reflected, direct and diffracted.

D. Architectural Design

The architectural design basically defines the system structure and information flow between the main components of the system.

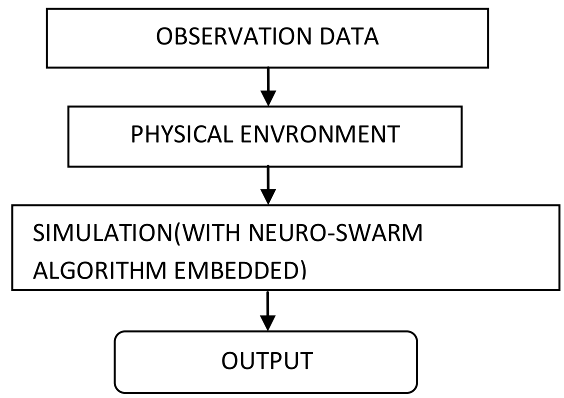


Figure 2: Architectural Design of Proposed System

1V. Results and Discussion

When there is a communication between two mobile devices, its power density decreases as signal propagates through space. Neuro-swarm intelligence has been used to reduce the path loss in GSM network. The demonstration of path loss model via communication from source to destination between 50M. It is an end to end wireless communication which is made up of sender (source), receiver (destination), radio medium and physical environment. Physical environment models suburban area with tall trees, rise building and moderate road traffic. The power loss is determined based on the distance, frequency and propagation speed. The system has used Ipv4 network configuration, packet is sent from one mobile device to another and the signal power is recorded. The sender (source) sent UDP packet and transmit with power of 20mW and propagation speed is 2.99792e+008. The simulation start time is 0.008714 seconds and end time is 0.009018 seconds, with a carrier Frequency of 1.5 GHz, bandwidth of 22 MHz and snir Threshold of 2.51189. The communication from source to destination between 340M was recorded. The destination returns a WLanAck signal back to sender. However, distance between sender (source) and receiver (destination) varies. The distance between the two hosts is 480M.

The distance used in the GSM network simulation ranges from 50 meter (m) to 500m. The received signal strength ranges from -65 decibel (dB) to -105dB. The lower the received signal strength, the stronger the signal and better the quality of service. A signal strength of -65dB indicates excellent signal and enhance good communication. Signal strength between -66dB to -79dB implies very good signal, between -80dB to -89dB entails good signal while signal strength of -90dB to -99dB implies poor signal strength, communication may fluctuate, thus, a signal strength of -100dB to -105dB indicates bad signal and terminates call.

The path loss result from the simulation of GSM network. The physical environment, distance between the sender and receiver, frequency of transmission greatly affects the result. Increase in distance led to increase in path loss. The area with 3dB, 3.92dB, 5.1dB, 5.2dB and 5.6dB falls within the suitable value for good signal propagation while the path loss of 7dB, 8.7dB, 9.6dB, 9.7dB and 14.1dB falls above the minimum range for a good signal propagation, thus, should be minimized. Path loss against distance in meter for 10 runs. The minimized path loss has been determined based on Neuro-swarm intelligence.

Neuro-swarm optimization has used a feed forward propagation in training the network. The main program file is conducted in MATLAB code (pathl_nnpso.m).The regression plot for the trained neural network is found in Figure B.5. Regression coefficient R is 0.85238.Elapsed time is 86.038406 seconds. A line graph of minimized path loss in Neuro-swarm model against distance in meter was recorded. Neural Network has used MSE to compare the inputs data with targets data. The input data is gotten from the GSM network simulation. Path Loss for all simulated paths have been minimized with values ranging from 0.061dB to 0.10dB

A. Systems Testing

The path loss minimization based on Neuro-swarm intelligence system (Artificial Neural Network (ANN) using Particle Swarm Optimization (PSO)) needed to be tested and verified for correct operation after program construction, in order to evaluate the performance of the system.

The testing procedure is outlined below:

1. Start MATLAB
2. Load the Main application file (pathl_nnpso.m)
3. Click the simulation button
4. Read and record the output as the case may be from the MATLAB workspace.
5. Record the generated figure plot regression
6. Exit the MATLAB application environment

B. Simulation Result

The physical environment, distance between the sender and receiver, frequency of transmission greatly affects the result. The power loss is determined based on the distance, frequency and propagation speed as shown below.

Table 4.1: Path Loss Simulation Results

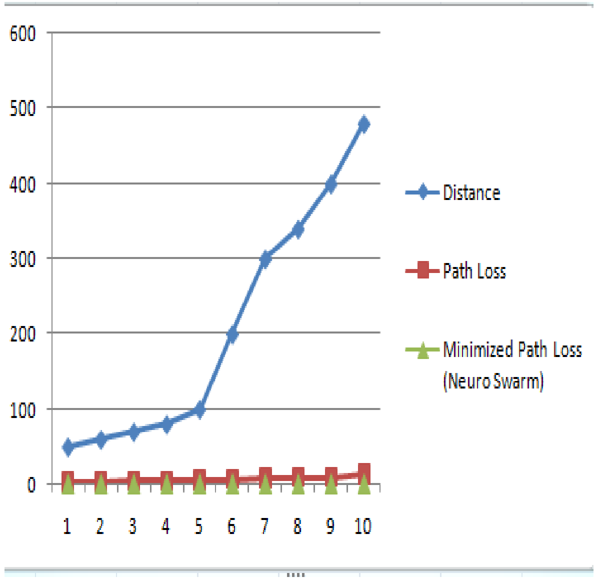
S/N	Distance (m)	Frequency	Path Loss Exponent	Path loss (dB
1	50	900MHZ	2.0	3.0
2	60	900MHZ	2.2	3.92
3	70	914MHZ	1.8	5.1
4	80	1.3GHZ	1.6	5.2
5	100	3.2 GHZ	2.5	5.6
6	200	1.5GHZ	3.0	7.0
7	300	1.9GHZ	2.1	8.7
8	340	1.4GHZ	2.4	9.6
9	400	4GHZ	2.1	9.7
10	480	1.8GHZ	2.6	14.1

The minimized path loss has been determined based on Neuro-swarm intelligence as shown in Table 4.2.Mean Square Error (MSE) has been used to check the performance of the system with the following equation:

$$MSE = \frac{(net\_f(inputs)-targets)^2}{length(net\_f(input))} \quad (5.1)$$

Table 4.3: Relationship between Distance, Path Loss and Minimized Path Loss (Neuro Swarm)

Distance(m)	Path Loss dB	Minimized Path Loss (Neuro Swarm) dB
50	3.0	0.0061
60	3.39	0.0069
70	5.1	0.0024
80	5.2	0.0024
100	5.6	0.0025
200	7.0	0.0039
300	8.7	0.0041
340	9.6	0.0049
400	9.7	0.0049
480	14.1	0.10



Relationship between Path Loss and Minimized Path Loss

V. Conclusions

In this research, the developed model has predictive abilities to minimize path loss in GSM network. The model has used Neuro-swarm intelligence (artificial neural network (ANN) using particle swarm optimization (PSO)) to minimize path loss. The power density decreases as the signal propagates through space. Path loss may be due to the combination of multiple effects such as loss of free space, refraction, diffraction, reflection, and absorption. This model explains power reduction as the signal spreads across space. It determines the factor of power loss based on the distance travelled, the frequency of the signal, and the rate of propagation. The calculation is useful in determining the maximum range of contact depending on the strength of transmission and sensitivity of reception.

Constructive research method was adapted to understand the problem associated with path loss in GSM network and by undergoing review of related work. The optimization of path loss in GSM network is of great importance as successful prediction may boost the spread of many telecommunication companies. Object-oriented design method has been used to design the interaction between system components; communication between source and destination in network simulation environment.

Zero path loss in GSM network was achieved.

Though we have successfully achieved path loss minimization in short distance ranging from 50m to 500m, there is need to extend work in long distance such as 10km and above.

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