Genetic Algorithm Based Pathloss Optimization for Long Term Evolution in Lagos, Nigeria

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Abstract

The signal strength in any wireless communication system is being governed by the environment. The strength of signal at any location depends on the distance, frequency of transmission and obstacles along the path. This makes the signal strength unpredictable and exact analysis so difficult to obtain in planning of any communication system. Subsequently, the attenuation of signals at different frequencies and distances depends on the environment and is being predicted by propagation path loss models which give different results in different environments. One of the most commonly used empirical model to predict the path loss is the Okumura-Hata model. In this paper, the suitability of Okumura-Hata model for Long Term Evolution (LTE) is investigated at 2.3 GHz in Lagos. The signal strengths are taken through drive test at different distances from the four (4) LTE stations in Lagos. The model is optimized using Genetic Algorithm Technique. The performances of the Okumura-Hata model and optimized model are evaluated through the path loss. The path loss results obtained show that the optimized model values are slightly above the measured values. This indicates that the optimized model has taken care of the future development of the environment.

Keywords: Genetic Algorithm, Empirical, Path loss, Models, Long Term Evolution

1. Introduction

Wireless environment plays an important role in the performance of communication systems. This environment is unpredictable because of the obstacles such as foliage, street signs and lamp posts along the signal path which cause signal from the transmitter to be scattered, reflected, refracted and diffracted. All these physical phenomena cause the signal to propagate in multipath, that is, multiple copies of the transmitted signal having different gains, different phase angles and different angle of arrivals are propagating. The three major effects of multipath propagation are signal fading, delay, and Doppler spreads of the channel. These effects are characterized as a non-additive signal disturbance in wireless channel which is one of the sources of signal degradation otherwise known as multiplication distortion. The multiplicative distortion was initially modeled for High Frequency (HF), Ultra HF and super HF. Extensive channel measurements are currently researched into, to develop the wireless channel models.

The fading phenomenon in wireless communication is classified into two types namely: Large and Small scales fading. Large-scale fading occurs as the mobile unit moves over a large distance (Yong *et al.,* 2010; Adeyemo and Raji, 2010; Rappaport, 2002). It is caused by path loss of signal as a function of distance and shadowing by objects such as terrain profile, vegetation and building. According to Yong *et al.,* (2010), large-scale fading is characterized by path loss and shadowing.

It is manifested by the mean path loss that decreases with distance and frequency. The received signal strength may vary even at a distance from a transmitter due to obstacles on the path. Obtaining the losses in the wireless channel at the receiver allows for predicting the received signal strength. Therefore, the mean path loss is a deterministic factor which can be predicted with the distance between the transmitter and receiver. Under large-scale fading, there are various path loss models for predicting the path loss, which in turn used for determining the signal strength at a location (Sklar 2003).

These path loss models include Log-normal, Okumura-Hata, Stanford University Interim (SUI) developed for IEEE 802.16d model, Cost-231 Hata propagation model and Ericsson model. Some of these empirical models depend on the frequency of operation, terrain profile of an environment, and distance from the base station, atmospheric condition, and transmitter and receiver heights. Out of all these, Okumura model is one the most commonly used models, all other propagation models are enhanced forms of Okumura model. The Okumura model is applicable to frequency range of 150-1500MHz and covers 100km. This model is used for the investigation because extensive measurements of base station-to-mobile station attenuation are carried out in irregular terrains to develop it (Akpado *et al.,* 2013; Jadhar and Kale, 2014; Mardeni and Lee, 2012; Sharma and Singh, 2010; Gbenga Ilori and Obiyemi, 2011; Isabona and Azi, 2012).

In this paper, Long Term Evolution signal which often describes as 4G service but it is not fully compatible to 4G standards is investigated in Lagos, Nigeria, where there is recent deployment of the network. The LTE is being developed by the 3rd Generation Partnership Project (3GPP) and it is also known as Evolved Universal Mobile Telecommunication Service Terrestrial Radio Access (E-UTRA). According to Noman et al., (2011), LTE has downlink and uplink of 100 Mbps and 50 Mbps respectively, scalable bandwidth from 1MHz to 20MHz, support multitude of user types and high spectra efficiency (Cox, 2012; Kale and Jadhar, 2013; Nkordeh, *et al.*, 2014; Noman *et al.*, 2011; Aderemi *et al.*, 2011; Chris and Myasar, 2013).

The modification of the existing propagation path loss models depends on whether the path loss model values are in agreement with the path loss obtained by measurements. The modification of the existing path loss models is referred to as optimization. When the measured path loss values are greater than the existing propagation path loss models values, optimization is needed for their suitability. A lot of researches have been carried out on optimization of these existing models, but some of them are based on Least Square method. Though, other optimization methods such as Genetic Algorithm, Particle Swarm Optimization, Ant-colony Algorithm have not been commonly used to the best of Author's knowledge. In this paper, signal strength from four (4) LTE stations are measured at different distances from each of the station using the drive test. The site ID parameters and the frequency of transmission are used to obtain the path loss from propagation model. The difference is then optimized to make it suitable for the environment at 2.3GHz.

2. Large-scale Fading: General Propagation Path loss Model

In ideal situation, where there is no obstacle between the transmitter and receiver, the free-space propagation model is used for predicting the received signal strength. The level of the received signal power governs the quality of message at the destination (Rappaport, 2002; Sklar, 2003).

Therefore, the received power density 'R_{pd}' at distance 'd' meters away is

$$R_{pd} = \frac{P_s}{4\prod d^2} w/m^2 \qquad (1)$$

where:

P_s = transmitted power from the isotropic antenna

Using the non-isotropic antenna of gain 'G_t'

$$R_{pd} = \frac{P_s G_t}{4\prod d^2} w/m^2 \qquad (2)$$

$P_s G_t$ is known as the Effective Isotropic Radiated Power (EIRP) of the transmitter

Equation (2) can be written as

$$R_{pd} = \frac{EIRP}{4\prod d^2} w/m^2 \qquad (3)$$

Equation (3) can be expressed in logarithmic form due to large numerical values as

$$R_{pd} = 10\log(G_t) + 10\log(P_s) - 10\log(4\Pi d^2) dB\, w/m^2 \quad (4)$$

The received power 'γ' at the destination with an antenna area 'A_d' is given by Yong *et al.*, (2010) as

$$\gamma = R_{pd} A_d \;\; watts \quad (5)$$

Assuming there is inherent losses in an antenna system

The received power $\gamma = \eta R_{pd} A_d \;\; watts$ (6)

where: η is antenna efficiency,

$$A_d = \frac{G_d \lambda^2}{4\Pi\eta}$$

with G_d = receiving antenna gain

λ = wavelength of the signal

$$\gamma = P_s G_t G_d \left(\frac{\lambda}{4\Pi d}\right)^2 \quad (7)$$

which is the same in logarithm form as

$$\gamma(dB) = P_s + G_d + G_t - 20\log\left(\frac{4\Pi d}{\lambda}\right) dB \quad (8a)$$

Therefore, the propagation free space pathloss $P_L = 20\log\left(\frac{4\Pi d}{\lambda}\right) dB$ (8b)

The average received signal decreases with the distance between the transmitter and receiver, d, in a logarithm manner. The generalized form of the propagation path model is obtained by modifying the log-distance path loss model with the path loss exponent '*n*' that varies with the environments. This log-distance path loss model P_L is given by Yong *et al.*, (2010) as;

$$P_L \alpha \left(\frac{d}{d_o}\right)^n \quad (9)$$

which can equally be written as:

$$P_L(dB) = P_L(d_o) + 10n\log\left(\frac{d}{d_o}\right) \quad (10)$$

where n = path loss exponent which depends on the environment

d = the distance between the transmitter and receiver

d_o = reference distance at which the path loss inherits the characteristic of free-space loss, when comparing (10) and (8a), n = 2 for free space environment

2.1 Okumura-Hata Model

This is one of the commonly used path loss models for predicting the attenuation of signal in urban area. It is used in mobile wireless communication systems which operate at frequency range of 500 – 1500MHz and has the maximum coverage of 100km.

According to Yong *et al.*, (2010), the path loss or signal attenuation P_L is given as

$$P_L(dB) = P_{LF} + A(f,d) - G_d - G_t + G_e \quad (11)$$

where: P_{LF} = free space path loss

$A(f,d)$ = attenuation factor at frequency ‘ f ’ and distance ‘ d ’

G_d = gain of the receiving antenna

G_t = gain of the transmitting antenna

G_e = gain of the environment

The Okumura model has been extended to suburban and open area by Hata model (Yong *et al.,* 2010). The Okumura-Hata model is the most commonly used path loss model in cluster environment. According to Yong *et al.*, (2010), the Okumura-Hata path loss P_{LOH} at the distance ‘ d ’ is

$$P_{LOH}(dB) = 69.55 + 26.16\log f_c - 13.82\log h_t - C_r + (44.9 - 6.55\log h_r)\log d \qquad (12)$$

where:

f_c = carrier frequency

h_t = transmitting antenna height

h_r = receiving antenna height

C_r = correlation coefficient of the receiving antenna depending on the size of coverage.

with $C_r = 0.8 + (1.1\log f_c - 0.7)h_r - 1.56\log f_c$ for medium sized coverage

also $C_r = 3.2 + (\log(11.72h_r))^2 - 4.97,\ if\ \ 200MHz\ \ f_c \le 1500MHz$ for large sized coverage.

Therefore, for the suburban area, the path loss $'P_L'$ is given by Yong *et al.,* (2010) as

$$P_L = P_{LOH} - 2\left(\log\frac{f_c}{28}\right)^2 - 5.4 \qquad (13)$$

2.2 Long Term Evolution Network

According to Noman *et al.,* (2011), Long Term Evolution (LTE) started in 2004 by the Third (3rd) Generation Partnership Project (3GPP). It evolved from Universal Mobile Telecommunication System (UMTS) and has two categories namely evolved UTMS terrestrial radio access (E-UTRA) and evolved UMTS terrestrial radio access network (E-UTRAN). LTE is a new development towards the 4th Generation (4G). This was embarked on due to the emergence of mobile TV, streaming content, multimedia, online gaming, and other new services. The LTE system provides the followings: higher data rate for services such as Voice over Internet Protocol (VoIP), streaming multimedia, video conferencing, secondly it has low latency which is the time required to connect to the network. Thirdly, Frequency Division Duplex (FDD) and Time Division Duplex (TDD) schemes can be used on the same platform. It also supports multiple output schemes and standardization of Quality of Service (QS) on all interfaces (Aderemi *et al.,* 2011; Cox 2012; Kale and Jadhar, 2013).

LTE system consists of User Equipment (UE), Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and Evolved Packet Cone (EPC). The UE comprises the Mobile Terminal (MT), the Terminal Equipment (TE) and the Universal Integrated Circuit Card (UICC) which is also Universal Subscriber Identity Module (USIM). The USIM saves information, that is, keeps information about the user’s activities and network activities. The E-UTRAN processes the information from the EU and sends it to the EPC. The E-UTRAN consists of evolved base stations known as eNodeB abbreviated as eNB. eNB is a base station that controls the mobile units by receiving and sending signals using the processing functions of LTE air interface (Cox 2012, Noman, *et al.,* 2011; Aderemi *et al.,* 2011; Nkordey *et al.,* 2014).

2.3 Genetic Algorithm

Genetic Algorithm (GA) is defined as a heuristic method on survival of the fittest. It was discovered as a useful tool for search and optimization problems. It looks for the best solution among all the possible solutions represented by one point in the search space, that is, search the search space for the best solution. GA is a stochastic algorithm because the selection and reproduction need random procedures. It also considers a population of solutions and keeping in mind many solutions at each iteration. The algorithm recombines different solutions to get better ones. It is robust in dealing with sorting due to its ability to perform very well on a range of problems. It can be applied to resolve any problem.

GA is a series of steps for solving a problem, that is, a problem solving technique that makes use of genetics as its model of problem solving. GA is a search method to find appropriate solutions to optimization. In optimization technique, the problem comprises finding the solution of best fit, that is, the one with pay off from all the possible solutions. When the search space becomes large, enumeration is soon no longer feasible due to too much time. GA works on a population of possible solutions with each representing a chromosome. The first thing is the coding of all the solutions into a chromosome. After the chromosome, a set of reproduction operators has to be obtained, the reproduction operators are applied to the chromosomes for performing mutations and recombination. Selection compares individual in the population by using the fitness function. GA deals with the problems that maximize the fitness function. After which initial population of chromosomes is generated randomly.

The GA loops over an iteration process that consists of the following steps namely; selection of individuals for reproduction, the second step is the reproduction or crossover to form offspring due to recombination and mutation, the evaluation of the fitness of the new chromosome, lastly replacement of the old population by the new ones. The algorithm stops when the population converges toward the optimal solution. In short, the basic GA consists of the following: generating genetic random population of a chromosome, evaluating the fitness $f(x)$ of each chromosome x in the population and creation of new population by using the following: selecting two parent chromosomes based on their fitness, forming new offspring due to crossover of parents, acceptance of new offspring in the population, replacement of new generated population for sum of algorithm, stop when best solution is returned (Sivanandam and Deeper, 2008; Colin and Jonathan, 2002; Wolgang *et al.*, 1998).

3. Materials and Methods

LTE signal strengths are measured for four sites ID at different locations. The measurement of signal strength is obtained using the Drive Test (DT) equipment. The DT consists of user equipment (UE), Global Positioning System (GPS) module, LTE software and computer system. The computer system used for the research work is HP Laptop with 4G RAM, 2.3GHz processor speed. The LTE software is installed for recording UE values and post DT analysis. Genex probe is used for the DT activities. The UE used for the DT is Huawei E 57765-601 mobile wifi which is a high-speed packet access mobile hotspot because it supports 1800 MHz/2600MHz FDD and 2300MHz TDD. The GPS module is connected to the laptop to navigate as the drive test is carried out and determine the coordinates of the base station.

Four base stations used are swift Network 4G LTE base stations in Lagos, Nigeria. These four base stations are of different location, longitude, and latitude. The demography of the base stations is characterized by many buildings, objects and highly populated. Table 1 contains the longitude and latitude of the base stations considered for investigation. The pictorial view of the environment around the LTE Base Station is shown in Figure 1

Table 1: LTE base stations location

LTE Base Station	Longitude	Latitude
1	E 3.5850	N 6.46917
2	E 3.5396	N 6.44223
3	E 3.64952	N 6.47215
4	E 3.60859	N 6.44711

Figure 1: A panoramic view of sub-urban environment around the base station

3.1 Method of the Drive Tests

The equipment are setup to carry out the Drive Test (DT) in a Single Site Verification (SSV). In this case, there is no handover among the test sites which eliminates the handover.

As the DT vehicle drives away from the base station, the Reference Signal Received Power (RSRP) for each of the four LTE Base Station sectors is measured at every 100m away by UE and reduces gradually. The GPS navigates the DT and the mean of the RSRP determines the mean value for each of base stations is used to determine the path loss. The other parameters of the base stations are the height of the antenna, Azimuth angle, transmit power and gain of the antenna. Base station '1' has antenna height of 20 m, transmit power of 12.2 dB antenna gain of 18 dB and Azimuth angle of 110°, 200°, 220° for each of the sectors respectively while LTE base station '2' has the antenna height of 27 m, transmit power of 12.2 dB, gain of 18 dB and Azimuth angle of 60°, 170°, 290° for each of the sectors respectively. The base station '3' has the same gain as others but the heights of the antenna are 31 m, 27 m, and 25 m for each of the sectors and azimuth angle of 40°, 120° and 220° respectively. The fourth (4th) base station has transmitted power of 12.2 dB, height of 25 m with antenna gain of 18 dB. The path loss measured from the four base stations are contained in Table 2.

Table 2: Path loss measured from different base stations

Distance(m)	Path Loss (dB)			
	Site 1	Site 2	Site 3	Site 4
100	103.46	107.43	108.11	102.51
200	107.48	113.99	112.93	103.15
300	111.54	120.68	118.29	109.72
400	117.33	127.02	127.80	113.53
500	121.74	131.86	131.91	124.57
600	126.94	138.31	138.73	131.20

3.2 Optimization by Genetic Algorithm

This is achieved by MATLAB application package using the GA processes at 2.3GHz with base station parameters. This is carried out to obtain the values for the model parameters that are in agreement to the field measurement or better for future development. The Okumura-Hata has low path loss values. GA tunes the Okumura path loss for the determination of optimized path loss as it evaluates the genomes in its population for each path loss. The objective function is obtained, the number of optimization variables *npar* used is 6 with variable limits *var*, between 0 and 3. The GA parameters used are as follows: population size *popsize* of 12, mutation rate, *mutrate* of 2, selection of 0.5. Subsequently, population of members that survive, mutations and number of making are determined.

Initial population is created by initializing the counter, determining the population cost, minimizing the mean of population. The counter is incremented, the mating is performed using single point crossover after which mutation of the population is carried out. The new offspring and the mutated chromosome are evaluated, sort the cost and associated parameters. Then, the statistics for a single non averaging run is carried. Maximum number of iterations used is 100. The results are displayed at the output. Figure 2 is the flow chat of the process.

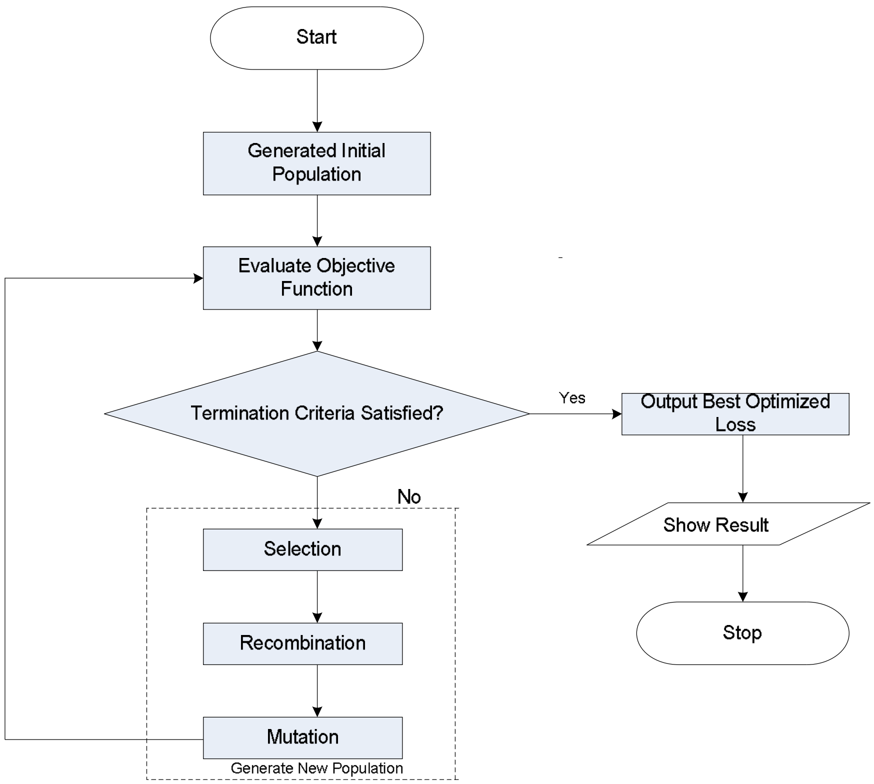

Figure 2: Flowchart of Genetic Algorithm

4. Results and Discussion

The results obtained through the measured values with DT, the Okumura-Hata path loss model and the optimized GA path loss for the four LTE base stations are presented in Figures 3 to 6. The path loss (dB) for each of the base stations is obtained every 100 m interval. Figure 3 shows the path loss (dB) against the distance in (km) for the LTE base station '1' which is in the longitude E 3.585 and latitude N 6.469167. At 600 m the path loss values obtained are 127 dB, 85 dB, 128 dB for the measured RSRP value, Okumura-Hata model, and optimized GA model respectively. Figure 4 presents the path loss values for the base station '2' located at latitude N 6.44223 and longitude E 3.53968. Also at 600 m away, the path loss for measured values, Okumura-Hata model and optimized model are 130 dB, 85 dB, 142 dB respectively, Similarly, in Figure 5, the path loss for measured values, Okumura-Hata model and optimized GA model are 84 dB, 139 dB, 143 dB respectively at 600 m from the base station '3' at longitude E 3.36492 and latitude N 6.47215. Figure 6 depicts the path loss of station '4' at longitude E 3.60859 and latitude N 6.44711, at 600m away, pathloss of 132 dB, 85 dB, 135 dB are the values obtained for measured with DT, Okumura-Hata model and optimized GA model respectively.

The results are justifiable in that the RSRP decreases as the distance from the base station increases resulting in higher path loss. The Okumura-Hata model underestimated the path loss for LTE system because the measured values are higher than the Okumura-Hata model; this makes it unsuitable for planning of the LTE system. The losses obtained are due to many buildings, many moving objects and a few vegetations in the base stations environment. The optimization of Okumura-Hata model by GA reduces the error. The optimized model is a little bit above the measured values to accommodate future development in the area. These results indicate that the optimized Okumura-Hata model is suitable for planning of the LTE system in this environment.

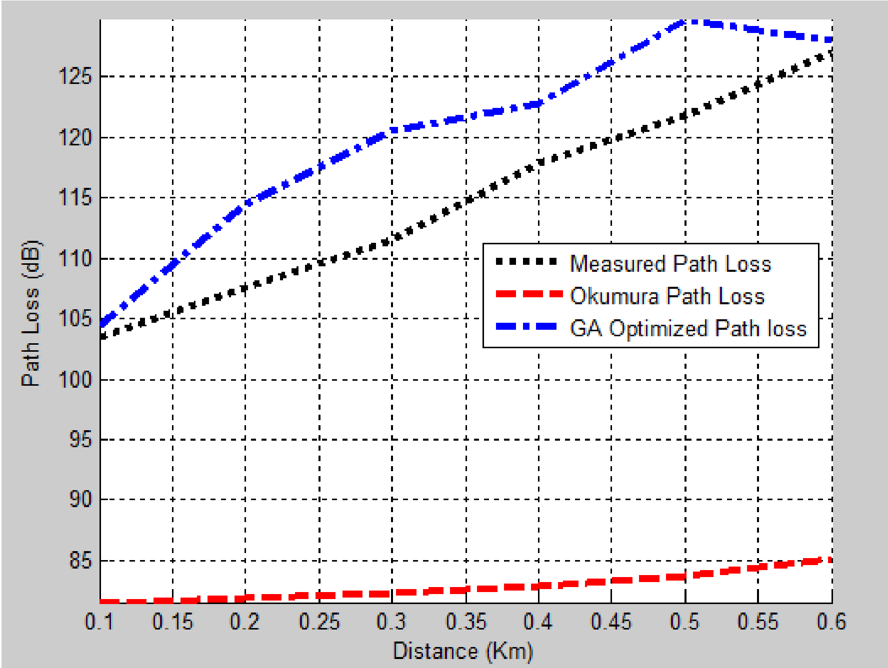

Figure 3: Pathloss of the measured, GA optimized, and Okumura-Hata model values versus distance for the LTE base station 1

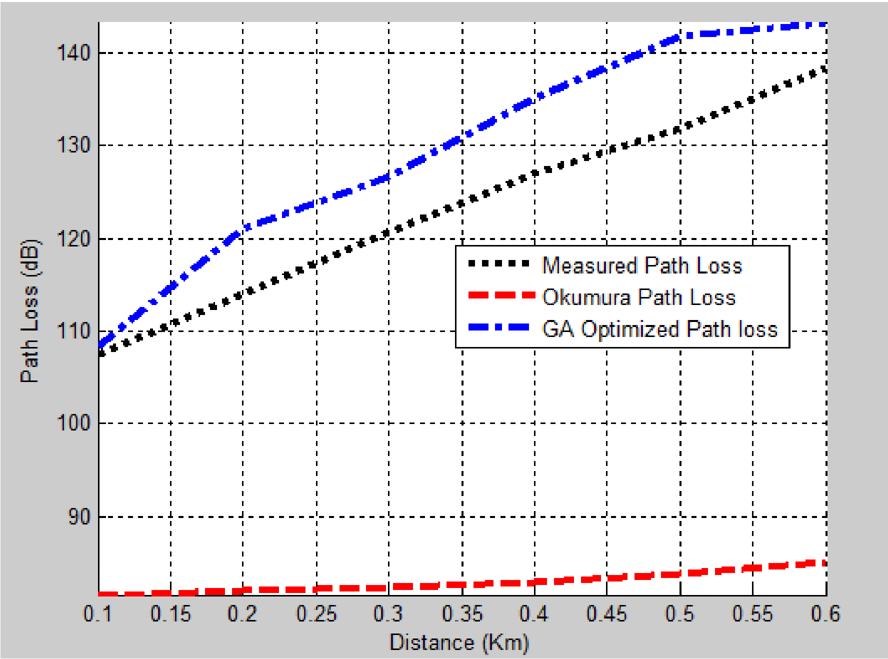

Figure 4: Pathloss of the measured, GA optimized, and Okumura-Hata model values versus distance for the LTE base station 2

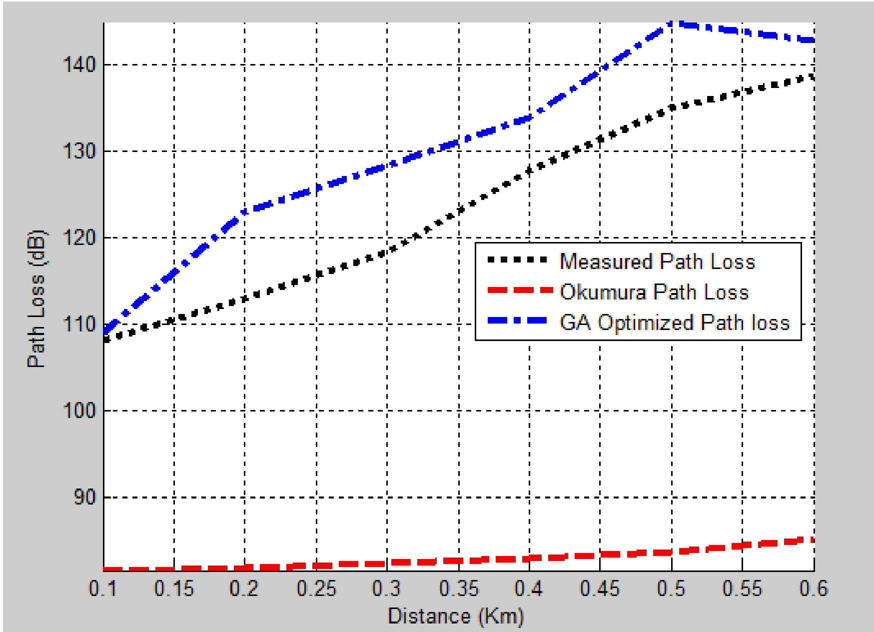

Figure 5: Pathloss of the measured, GA optimized, and Okumura-Hata model values versus distance for the LTE base station 3

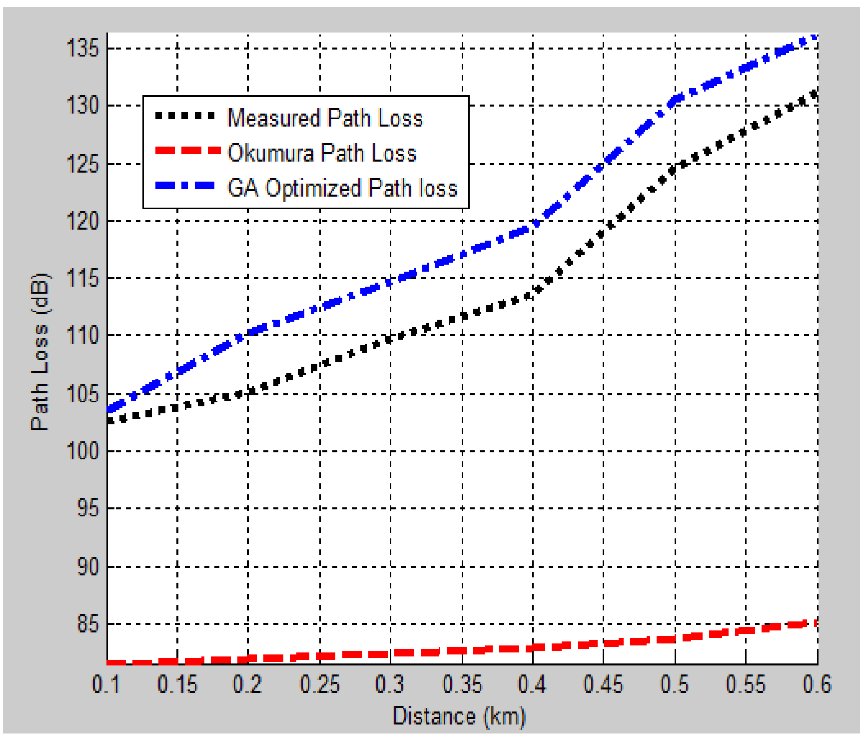

Figure 6: Pathloss of the measured, GA optimized, and Okumura-Hata model values versus distance for the LTE base station 4

5. Conclusion

In this paper, the signal strengths from the four LTE base stations at different distances up to 600m are measured through Drive Test to determine the path loss value. The Okumura-Hata model is also used to determine the path loss for its suitability in LTE station using base station parameters. The difference between the measured values and Okumura-Hata model values are optimized using Genetic Algorithm for its suitability. The results obtained show that the optimized model predicts the path loss better than the existing model for LTE system at 2.3 GHz. The results obtained can be used for further planning of the LTE system.

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