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Design and Implementation of Neighborhood Control Optimal GSM Base Transceiver Station Placement Using Genetic Algorithm

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ABSTRACT
This study looked at the problems of placement of Base Transceiver System (BTS) for Global System for mobile Communication (GSM) in Nigeria and the degree of compliance by the GSM operator to lay down rules and regulations. To achieve this, existing data from a GSM service provider operator on placement of BTS was used as input in this study, to compare with our optimal global system for mobile communication base transceiver station placement using genetic algorithm design writing in java programming language. The result shows that existing system have not totally complied with NCC and NESREA regulations but our implementation showed a greater improvement to the adherence to these regulations in terms of neighborhoods considerations.

Keywords: *Global System for Mobile communication (GSM), Base Transceiver Station (BTS),Neighborhood Consideration (NHC), Genetic Algorithm (GA), Nigerian Communications Commission (NCC) and the National Environmental Standard Regulatory Agency (NESREA)*

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1. INTRODUCTION

Given the mode of operation of GSM technology, Base Transceiver Stations (BTS) are required for the provision of GSM services. Consequently, network of base stations were established in areas that enjoyed the GSM services all over Nigeria. Mobile network are leading the evolution of the information and communications society towards the mobile information society [2]. However, studies have shown that exposure to GSM radiations are linked to health hazards such as fatigue, headache, decreased concentration, dizziness, local irritation, tumour induction, sperm motility, morphology and viability, cancer, especially brain tumour and leukaemia, viral and infectious diseases [1,6]. Given these potential health impacts of BTS on humans, the National Environmental Standards and Regulations Enforcement Agency (NESREA) established guidelines for National Environmental Standards for Telecommunications and Broadcasting Facilities. The guidelines provided for the establishment of BTS within a minimum setback of ten (10) meters from the perimeter wall (fence) of residential/business premises, schools and hospitals. Similarly, where there is no perimeter wall (fence), the BTS must be at a minimum of twelve (12) meters from the wall of residential, business premises schools and hospitals[4,12] .There is no doubt that the telecommunication system in Nigeria has undergone a revolution since the deregulation of the GSM market. Similarly, the Nigeria Communication Commission NCC, seeing the robust growth in the sector, encouraged the entry of more mobile operators into the GSM market in the year 2001 [8,18].

The mobile telecommunication industry in Nigeria is growing and is still undergoing extraordinary changes brought about by the introduction of new technology according to [3,14]. The changes have led to an increase of BTS in cities, towns and villages in Nigeria. This led to the concept of neighborhood control in this study, which is the inclusion of consideration of the structure in the immediate environment (neighbor) in the selection of a suitable site for the BTS. This involves the consideration of many issues amongst which are: the availability of land, safety and health considerations, accessibility for maintenance purposes, issues of radio frequency requirements, capacity issues, line of sight and height of the neighboring buildings. The key problem identified in the placement of base station in Nigeria is the manual inspection of proposed site by engineers. The engineers' then leaves the process of cell planning to a team of radio planners for the final decision of the Base Station Transceiver (BST) site, who take these decisions based on their experience. The final decision can be subjective, giving room for bias and not give opportunity for a wider consultation for other option. The importance of environmental consideration in BST placement has resulted in operator views by many with the notion of their placement requirement. The shutting down of a BST over regulatory breach has multiple effects as it results in loss of network coverage for the area and a big financial loss for the operator [1]. The neighborhood concept was born out of the need for more efficient and automated cell planning tool that takes compliance to regulation into consideration and gives the operator the opportunity to search for a larger space for a near optimal placement. In the presence of agitation and public concern for the installation of base station in residential area, in Nigeria however there is cooperation between the ministries of environment, health and the ministries involve with the telecommunication regulation in putting in place an acceptable legal and regulatory framework. In this study, we look at the existing BST architecture and designed a BTS architecture which includes Genetic Algorithm (GA) for optimizing the placement of the BTS and taking the neighborhood into consideration in determining its location by BTS, with maximum and minimum distance from populated environment in Nigeria.

The challenges facing the GSM and other industries in Nigeria is the lack of engineers and professional, and also inadequate power supply, theft, multiple taxation by the government, poor telecommunication infrastructure and inadequate skilled manpower and that these challenges could be combated through technological innovation coupled with extensive research and development [5]. These challenges was further buttress by [4] in a study that was conducted in Ile-Ife Oshun state Nigeria, that the location of GSM Communication Base Transceiver Station in Ile-Ife has been investigated in other to verify the compliance of BTS providers in accordance to NCC and NESREA guidelines on installation and placement of BTS. The results of the research show that 79 BTS were installed and 72.5 % are in operation. 45.6% of the BTS has setback to building structures at 5 m while 59.5 % executed setback of 10 m, in accordance to NESREA and NCC guidelines. Despite the challenges confronting the GSM service providers, deregulation of the sector has brought about positive socio-economic changes in the lives of the subscribers [15]. [6] in his study has claimed that the introduction of Global System for Mobile Communications (GSM) phone with the un-regulated sitting of communication towers have increased the exposure of great percentage of the population to electromagnetic radiation and the concomitants health hazard in Nigeria and concluded, that the community should always be involved in any decision to erect a base station in their neighborhoods. But [16] concluded that the conventional GSM architecture must be designed in order to allow BTS to be installed outside populated areas, while keeping a relative small MSC transmission power and with a suitable solution we could reduce human exposure to GSM radiation levels. While [13] tried the adjustment of parameters in antenna placement problem using GA and was evaluated by assuming a flat area but insisted that further work should be done on the algorithm so that it can consider the terrain features.

According to [9] in their work on characterization of the radiofrequency radiation potential of Alakahia and Choba communities in Port Harcourt, Rivers State, Nigeria, advised that residential and office buildings should be located hundreds of meters away from base stations. There should be prudent avoidance of exposure to RFR from base stations. Manufactures of base station antennas should consider the principle of reducing the output power intensity as low as reasonably achievable. This is to ensure that the proposed site will not create any adverse economic, safety and aesthetic impact on nearby properties and the overall community. The surrounding here referred to as 'neighbors' to a BST site. These are pertinent issues and great challenge to wireless communication providers and regulators. The fear of the impact of the facilities has added to the many agitation, conflict, legal issues and refusal for permission to be granted for site that would have given optimal coverage and better service delivery [19]. The international telecommunication union (ITU) in collaboration with other relevant bodies like world health organization (WHO), international commission on Non-ionizing radiation protection (ICNIRP), have come up with radio regulation bordering on safety to guide the operation of telecommunications regulation in various countries to developed their legal and policy framework to guide the operation of the telecommunication services [17]. The literature review so far agreed that a better understanding of the policy framework guiding the deployment of radio base station and the placement of base station is a must for GSM operators in Nigeria for the safety and health implications of the growing populations in the neighborhoods.

2. MATERIALS AND METHOD

The method applied in this study, is to use data from the existing placement of BTS from a GSM operator to compare with our neighborhood control optimal global system for mobile communication base transceiver station placement using genetic algorithm design. The Neighborhood Control (NHC) design is a novel method which is applied to the BTS. This method approached the BTS problem as a Wideband Code Division Multiple Access (WCDMA) placement problem which can be addressed through optimization, because it has several objectives to be optimized. As the number of objectives of the problem increases, the complexity of the problem becomes high as the objectives considered are contradictory to one another, since multiple solutions obtained as candidate solutions of the problem. Genetic Algorithm (GA) has the potential advantage as a multi-point search tool for optimization problems with multiple objectives. However, GA has been mainly applied to optimization problems with a single objective. This work considers the BTS placement process as a multi objective problem which considers the working area where the BST must be installed. Assuming the number of BTS that will be located in the neighborhood area being conceded is S such that S is assigned $\{1,2,...,n\}$. The possible locations have to be defined since BTS cannot be placed at arbitrary locations such as residential buildings, public roads and inside the stadiums. The design also considered looking at a set of test points (TP) within the neighborhood area, where a TP is assigned {1,2,...,m} and a test point is a location where a signal must be received above a minimum specified service threshold to ensure a required quality of service. A particular test point is said to be covered by a BTS (A) if $P - PL \geq Sq$, where Sq is the coverage threshold required by the receiving equipment, and P is the power transmitted by the BTS. In a WCDMA BTS placement problem, one wishes to select a subset of possible locations within the set S where to install BTS, and to assign Test Point (TP) to the available base stations taking into account the traffic demand, and the signal quality in terms of Signal to Interference Ratio (SIR) in the design. Figure 1 shows the neighborhood control design.

The Neighborhood Control (NHC) design is in charge of the geographic land mark futures, which helps the prospective network owners to place BTS within the control location. The NHC equations were derived from the formula, Population Density = Number of People/Land Area, was used to derive the NHC equations (1),(2),(5) and (9).
http://education.nationalgeographic.com/education/activity/calculating-population-density/?ar_a=1

Area type (AT) is the number of people living within a square meter of the neighborhood (cell area) and this includes the buildings in that cell area. This can be calculated as given by equation (1)

$$AT = \frac{\text{Number of people within a square mile}}{\text{Number of buildings within a square mile}} \quad (1)$$

Availability of land (AL) is the total area occupied by buildings in the neighborhood (cell area). It can be calculated as given by equation (2)

$$AL = \frac{\text{Total area}}{\text{Area occupied by buildings}} \quad (2)$$

Safety and health considerations (SHC), is the velocity of dispersed radiation by the mast in the neighborhood (cell area) as given by equation (3) and (4) which is derived from [11].

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$$SHC = \frac{Q.}{L*D*W} \quad (3)$$

$$D = \frac{V}{1 - \lambda d\eta / \eta d\lambda} \quad (4)$$

D = Dispersion
Q = Amount of Released
L = Distance of Residential Area from Mast
D = Dispersion
W = Wind Speed
V = Velocity
λ = Wavelength
η = Refractive index

Accessibility for maintenance purposes (AMP) of the base transceiver station, through flat land that is available in the area type is given by equation (5).

$$AMP = \frac{\text{Height difference from A to B}}{\text{Horizontal distance from A to B}} \quad (5)$$

Issues of radio frequency requirements (IRFR) is the amount of signal frequency wavelength dispersed and it is derived from the principle of electromagnetic waves propagate of Calculating wavelength with the energy equation which is given by equation (6) http://www.kentchemistry.com/links/AtomicStructure/waveequations.htm

$$IRFR = \frac{(4Лd)^2}{(\lambda)^2} \quad (6)$$

where:

d = distance from transmitter
Л = pie
λ = wavelength

Capacity issues (CI) is the capacity within cell area limited by available bandwidth and operational requirements. Each network operator has to size cells area to handle expected traffic demand. To calculate the total capacity available, the volume is adjusted according to the period being considered. The available capacity is difference between the required capacity and planned operating capacity [10]. This is given by equation (7).

$$CI = \frac{\text{Actual output}}{\text{Maximum possible output}} \quad (7)$$

Line of Sight is an imaginary line that exists between two objects. Radio transmissions require a clear path between antennas known as radio Line of Sight. Line of sight propagation is a characteristic of electromagnetic radiation or acoustic wave propagation which means waves travel in a direct path from the source to the receiver. Electromagnetic transmission includes light emissions traveling in a straight line. The rays or waves may be diffracted, refracted, reflected, or absorbed by the atmosphere and obstructions with material and generally cannot travel over the horizon or behind obstacles [7].

Line of sight (LS) is the ability of a mast to receive signals from another mast within the neighborhood where it is located is given by equation (8).

$$LS = \sqrt{2 * (\text{height of mast}1)} + \sqrt{2 * (\text{height of mast}2)} \quad (8)$$

Height of the neighboring building (HNB) is the height of the mast over the heights of the building is given by equation (9).

$$HNB = \frac{\text{Height of mast}}{\text{Height of building}} \quad (9)$$

Genetic Algorithm(GA) is based on the principle of evolution and natural genetics it has been successful in solving many optimization problems including the BTS placement problem. The design of a GA starts with solution encoding, creation of individuals that make a population, and evaluation of the individuals. During the evaluation each individual is assigned a fitness value according to a certain fitness function. Based on the fitness value, some of the better individuals are selected to seed the next generation by applying crossover and

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mutation to them. In GA, the variables can be represented in binary, integer, and real. This paper considers the value encoding scheme. To evaluate the performance of the proposed algorithm, the network data given in for 64kbps uplink and 144kbps downlink data service are used for the cell planning process which goes through the selection process to find out which individuals can be taken as parents for crossover. The individuals are selected based on their fitness values. An individual with higher fitness value is likely to be selected. The best six individuals are selected for crossover. The crossover produces new individuals in combining the information contained in the parents. Depending on the representation of the variables, different methods must be used. Basic crossover methods include one-point crossover, multi-point crossover, and uniform crossover. After the creation of all the children, the mutation operator possibly changes them. It scans each gene of all children and changes the value of a gene with the mutation probability. Different mutation probability values between 0 and 1 were evaluated and the optimum value of 0.6 was used. For binary operation, the mutation was implemented by changing 1s to 0s or 0s to 1s in a randomly selected point in chromosomes. After the mutation process was finished the children needed to be evaluated. The best chromosome is then found and the algorithm started with selection again. The stopping criterion is fulfilled if the number of generations is reached. Fitness is a function which takes a candidate solution to the problem as input and produces as output how "fit" or how "good" the solution is with respect to the problem in consideration. Calculation of fitness value is done repeatedly in a GA and therefore it should be sufficiently fast. A slow computation of the fitness value can adversely affect a GA and make it exceptionally slow. In most cases the fitness function and the objective function are the same as the objective is to either maximize or minimize the given objective function. However, for more complex problems with multiple objectives and constraints, an algorithm designer might choose to have a different fitness function, the objective function derived from equations 1 to 9 using algebraic method is given by equation (10).

$$\text{Objective function} = \frac{AT*AMP*AL*LS*CI*AMP}{HI*IRFR*HNB} \quad (10)$$

3. RESULTS AND DISCUSSIONS

After the system model was developed using Java, its performance was carefully assessed and evaluated. The system evaluation is based on criteria that are clearly relevant with defined standards of interpretation. The desired characteristics of the data are that they provide an accurate representation of the environment to be tested and that there are sufficient data to allow for robust inference.

Results from data set used in generating the important optimum values parameters, was generated following the Nigeria Environmental Standard and Regulation Enforcement Agency (NESREA) and Nigeria Communication Commission (NCC) rules and policies. The ten base transceiver stations are also assumed to be ten solutions and locations on the geographical area. The task of the algorithm is to find the most suitable set of solutions and locations among the ten predefined geographical area, taking into account the following objectives:

i. Maximizing the network coverage with the aim of covering all the locations.
ii. Minimizing the safety and health conditions.
iii. Minimization of the cost of the network by using fewer locations.

The Genetic Algorithm steps for the BTS system is outlined below:

Step 1: Input population initialization
Step 2: Evaluation of individual
Step 3: Optimization criteria met
Step 4: Selection
Step 5: Crossover
Step 6: Mutation
Step 7: New population
Step 7: Continue from step 2 until best individual is gotten with result.
Step 8: Stop.

The working area with possible BTS solutions and locations is illustrated in figure 1. Each solution and location represents the possible base station location while the symbol (+) represent High Rise Buildings with colour red , the symbol (*) represent Population with colour blue, the symbol (#) represent Flatland with colour green, and the symbol (%) represent Solution with colour black. The solutions and locations are randomly distributed in the entire working area.

During the initialization phase, 10 individuals are randomly generated with an initialization probability. Each individual is encoded as a value string. The length of each individual is 8 bits since the set of available genes are made of 8 elements. The initialization probability of 0.1 or 10% is found to be optimum after the evaluation of different values between 0 and 1. This means that 90% of the base stations are set to be active. These active genes are randomly distributed in the individual. Simulations were carried out on a natural environment as described previously. In order to get good results, the genetic algorithm parameters must be tuned before the algorithm is used. There are three parameters that must be tuned for the algorithm to converge optimally. These parameters include the initialization probability, the crossover probability, and the mutation probability.

Table 2: BTS map solution and locations

Solutions	Locations
7	456, 70
6	408, 282
4	133, 432

The chromosomes and gene value of the initialization dataset, before crossover and mutation as shown in table1 which shows the initial Genes which are Area Type (AT), Availability of Land (AL), Safety and Health Condition (SHC), Accessibility and Maintenance Purpose (AMP), Issues of radio Frequency Requirement (IRFR), Capacity Issue (CI), Line of Sight (LS) and Height of Neighboring Building (HNB), and the chromosomes from data1 to data10. It should be noted that there are changes in values of data 1, 2 and 3 while data 4, 5, 6, 7, 8, 9 and 10 remain constant, because crossover and mutation has not taken place it is still in the initialization state. When it was uploaded into the GA, it gave a maximum of three BTS map solutions and locations in the result, as shown in Figure 2.

Table 4:BTS map solution and locations

Solutions	Locations
6	264, 63
4	17, 261

Table 2 shows BTS map which represents the optimal solutions and location for generation 0, where the solutions and locations are geographical map areas of the longitude and latitude position of the BTS. These are solution 7 at location 456, 70; solution 6 at location 408, 282 and solution 4 at location 133, 432. Figure 3 shows a chart representation of table 1, it shows the chromosomes present in the population and their gene values.

Table 3 shows the changes in data 1, 2, 3, 4, 5, 6, and 10 while there are no changes in values of data 7, 8 and 9 which remain constant, because GA selects data for crossover and mutation. The crossover and mutation produces new individuals in combining the information contained in the parents. The uniform crossover is used in this study. After the creation of all the children, the mutation operator possibly changes them. It scans each gene of all children and changes the value of a gene with the mutation probability. Different mutation probability values between 0 and 1 were evaluated, the result from the fitness and probability score shows that only optimum value of 0.1 will be used. For value encoding, the mutation was implemented by random, only improving chromosomes are randomly chosen and exchanged only if they improve solution (increase fitness). After the mutation process was finished the children needed to be evaluated. The best chromosome was then found and the algorithm started with selection again. The stopping criterion was fulfilled if the number of generations was reached. The next generations (new offspring's) optimal solution results when compared with the initial generation optimal results, it can be seen that there are differences in the solutions and locations which will best suit the GSM operators to select from. Figure 4 shows the screen short for Generation 1 optimal solution.

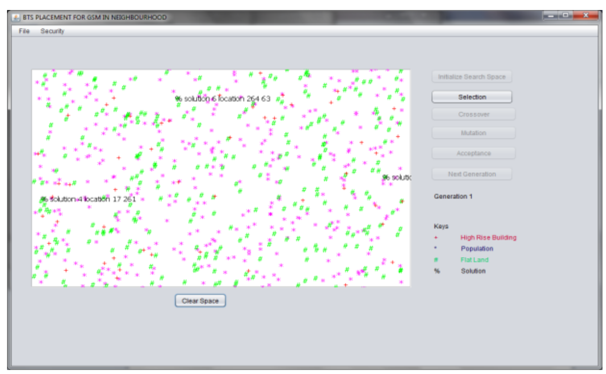

Figure 4: Screen short of the BTS optimal map solutions and locations for generation 1

Table 4 shows BTS map which represents the optimal solutions and location for generation 1, where the solutions and locations are geographical map areas of the longitude and latitude position of the BTS, with solution 6 at location 264, 63 and solution 4 at location 17, 261.

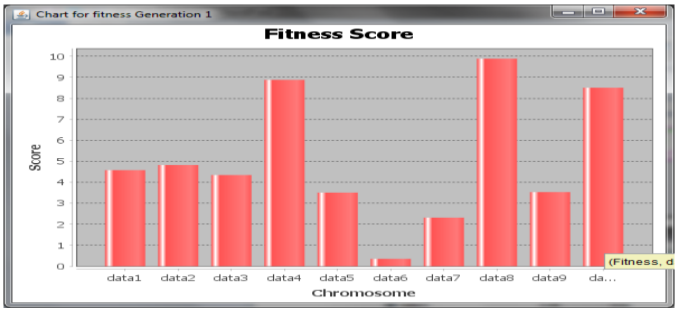

Figure 5: Screen short chart for the fitness score

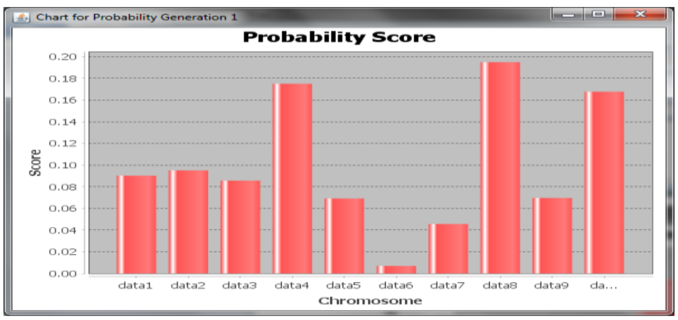

Figure 6: Screen short chart for the probability score

Table 5 shows the fitness and probability score, which shows that chromosomes 8, 4, 10, 2, 1, and 3 stand a chance of being selected for next crossover and mutation. And this is shown clearly in the chart for fitness score in figure 5, and the chart for probability of being selected in figure 6.

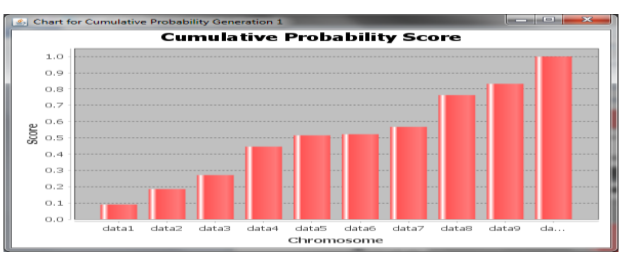

Figure 7: Screen short chart for the cumulative probability score

Table 6 shows the cumulative probability score of 1.0. The chart in figure 7 shows this clearly.

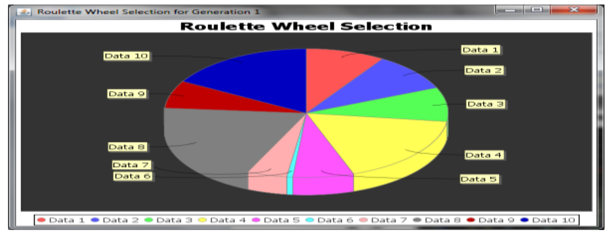

Figure 8: Screen shot of the roulette wheel selection

Table 7 and figure 8 shows the Roulette Wheel Selection for Generation 1 where it clearly showed that chromosomes 8, 4, 10, 2, 1, and 3 stand a chance of being selected for next crossover and mutated.

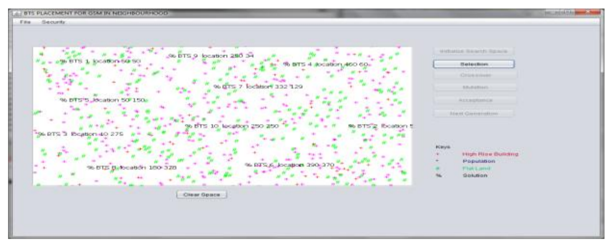

Figure 9: Screenshot of the Existing System BTS Placement Solution

Table 8 shows chromosomes of the existing system before crossover and mutation, this is reflected in figure 9. Table 9 shows the BTS geographic area solutions and location as showed in figure 8, these are solution 1 at location 50,50, solution 2 at location 5, solution 3 at location 10,275. Solution 4 at location 460,60, solution 5 at location 50,150, solution 6 at location 390, 370, solution 7 at location 332,129, solution 8 at location 180,378, solution 9 at location 250,34,and solution 10 at location 250,250.

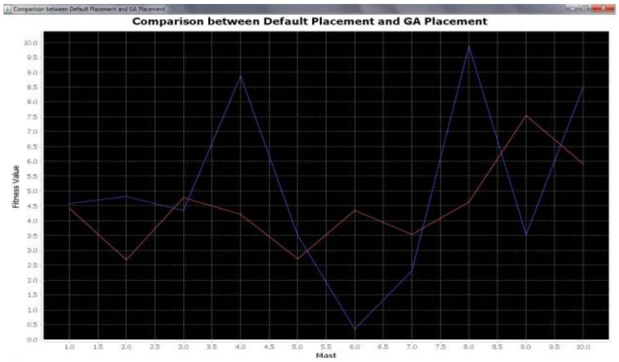

Figure 10: Screen shot of the BTS graphical comparison before and after crossover and mutation

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Comparing the existing system before and after crossover and mutation, this showed that the chromosome after crossover and mutation is by far better off as shown in table 10 and reflected in figure 10. Which shows the chromosomes of the existing system and the new optimal solutions, where it was shown that the results of chromosomes 8, 4, 10, 2, 1, and 5 in the optimal solution showed improvements when compared with the existing system. Figure 9 shows the comparison of the existing system BTS placement fitness values with the new optimal solution fitness value. The optimal solution from the new model we developed goes to show that a standard for placing BTS in Nigerians neighborhoods has been set, following the rules and policies of NESREA and NCC.

4. CONCLUSION

The placement of Base Transceiver Station (BTS) for GSM Communication providers in Nigerians neighborhoods has been investigated in other to verify the compliance of GSM providers in accordance to NCC and NESREA guidelines on location and placements of BTS. The results from this study show that the existing system did not completely complied with guidelines of NCC and NESREA, but when compared with the genetic algorithm optimal solution results it was clear that it complied with the guidelines. Conclusively, this research is a success; a developed system that can be used in the placement of base transceiver station in the neighborhoods of Nigeria Cities.

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APPENDIX

Snapshots/sample source codes of the implementation using Java.

```
/**
 *
 * @author Nwelih Emmanuel
 */
public class Simulation extends javax.swing.JFrame {
   int count=0;
   Graphics2D population;

        Graphics2D flat;
        Graphics2D highrise;
        Graphics2D solution;
int generationcount=0;
List <String> popx=new ArrayList<String>();
List <String> popy=new ArrayList<String>();

List <String> highx=new ArrayList<String>();
List <String> highy=new ArrayList<String>();

List <String> flatx=new ArrayList<String>();
List <String> flaty=new ArrayList<String>();

int mastx[]={0,0,0,0,0,0,0,0,0,0};
int masty[]={0,0,0,0,0,0,0,0,0,0};
int select[]={0,0,0,0,0,0,0,0,0,0};

double fitness[]={0,0,0,0,0,0,0,0,0,0};

double proba[]={0,0,0,0,0,0,0,0,0,0};

double cumproba[]={0,0,0,0,0,0,0,0,0,0};

double
at[]={4.50,3.01,5.45,8.10,3.20,0.32,2.11,9.02,3.22,7.76};
double
al[]={5.10,6.51,3.34,8.10,3.20,0.32,2.11,9.02,3.22,7.76};
double
shc[]={3.50,4.61,6.4,8.10,3.20,0.32,2.11,9.02,3.22,7.76};
double
amp[]={4.60,3.51,3.4,8.10,3.20,0.32,2.11,9.02,3.22,7.76}
;
```

```
double
irfr[]={7.50,3.01,2.4,8.10,3.20,0.32,2.11,9.02,3.22,7.76};
double
ci[]={3.20,3.51,0.5,8.10,3.20,0.32,2.11,9.02,3.22,7.76};
double
ls[]={1.50,6.01,4.6,8.10,3.20,0.32,2.11,9.02,3.22,7.76};
double
hnb[]={3.50,5.01,5.6,8.10,3.20,0.32,2.11,9.02,3.22,7.76};

double
at1[]={4.50,3.01,5.45,8.10,3.20,0.32,2.11,9.02,3.22,7.76}
;
double
al1[]={5.10,6.51,3.34,8.10,3.20,0.32,2.11,9.02,3.22,7.76}
;
double
shc1[]={3.50,4.61,6.4,8.10,3.20,0.32,2.11,9.02,3.22,7.76}
;
double
amp1[]={4.60,3.51,3.4,8.10,3.20,0.32,2.11,9.02,3.22,7.76
};
double
irfr1[]={7.50,3.01,2.4,8.10,3.20,0.32,2.11,9.02,3.22,7.76}
;
double
ci1[]={3.20,3.51,0.5,8.10,3.20,0.32,2.11,9.02,3.22,7.76};
double
ls1[]={1.50,6.01,4.6,8.10,3.20,0.32,2.11,9.02,3.22,7.76};
double
hnb1[]={3.50,5.01,5.6,8.10,3.20,0.32,2.11,9.02,3.22,7.76
};

/** Creates new form Simulation */
  public Simulation() {
    initComponents();
    jButton2.setEnabled(false);
    jButton3.setEnabled(false);
    jButton4.setEnabled(false);
    jButton5.setEnabled(false);
    jButton6.setEnabled(false);
  }

  /** This method is called from within the constructor to
   * initialize the form.
   * WARNING: Do NOT modify this code. The content
of this method is
   * always regenerated by the Form Editor.
   */
  @SuppressWarnings("unchecked")
  // <editor-fold defaultstate="collapsed"
desc="Generated Code">//GEN-BEGIN:initComponents
  private void initComponents() {

jFileChooser1 = new javax.swing.JFileChooser();
    jPanel5 = new javax.swing.JPanel();
    jTabbedPane1 = new javax.swing.JTabbedPane();
    jPanel1 = new javax.swing.JPanel();
    jPanel10 = new javax.swing.JPanel();
    jPanel11 = new javax.swing.JPanel();
    jPanel12 = new javax.swing.JPanel();
    jTextField1 = new javax.swing.JTextField();
    jButton8 = new javax.swing.JButton();
    jButton9 = new javax.swing.JButton();
    jPanel13 = new javax.swing.JPanel();
    jButton10 = new javax.swing.JButton();
    jPanel14 = new javax.swing.JPanel();
    jLabel7 = new javax.swing.JLabel();
    jLabel8 = new javax.swing.JLabel();
    jLabel9 = new javax.swing.JLabel();
    jLabel10 = new javax.swing.JLabel();
    jLabel11 = new javax.swing.JLabel();
    jLabel12 = new javax.swing.JLabel();
    jLabel13 = new javax.swing.JLabel();
    jLabel14 = new javax.swing.JLabel();
    jButton11 = new javax.swing.JButton();
    jComboBox1 = new javax.swing.JComboBox();
    jComboBox2 = new javax.swing.JComboBox();
    jComboBox3 = new javax.swing.JComboBox();
    jComboBox4 = new javax.swing.JComboBox();
    jComboBox5 = new javax.swing.JComboBox();
    jComboBox6 = new javax.swing.JComboBox();
    jComboBox7 = new javax.swing.JComboBox();
    jComboBox8 = new javax.swing.JComboBox();
    jButton12 = new javax.swing.JButton();
    jPanel2 = new javax.swing.JPanel();
    jLabel16 = new javax.swing.JLabel();
    jTextField2 = new javax.swing.JTextField();
    jButton13 = new javax.swing.JButton();
    jButton14 = new javax.swing.JButton();
    jSeparator1 = new javax.swing.JSeparator();
    jLabel17 = new javax.swing.JLabel();
    jButton15 = new javax.swing.JButton();
    jSeparator2 = new javax.swing.JSeparator();
    jLabel18 = new javax.swing.JLabel();
    jLabel19 = new javax.swing.JLabel();
    jSeparator3 = new javax.swing.JSeparator();
    jLabel20 = new javax.swing.JLabel();
    jLabel21 = new javax.swing.JLabel();
    jLabel22 = new javax.swing.JLabel();
```

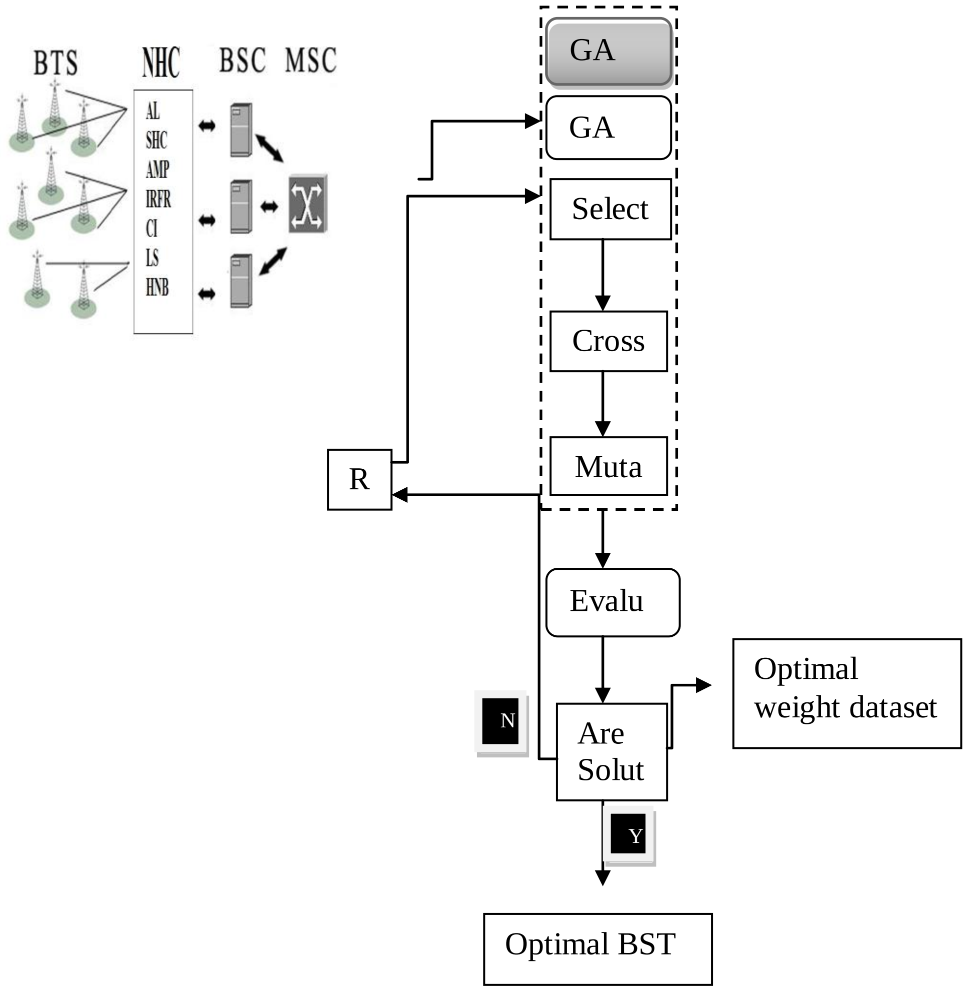

Figure 1: Neighborhood Control Design of the Proposed System

Vol. 11, No. 1, March 2018, pp. 12 - 27 *ISSN 2006-1781*
E. Nwelih, P. O. Asagba and C. Ugwu (2018), Design and Implementation of Neighborhood Control

Table 1: Chromosomes and gene value of the initialization before mutation and crossover

Chromosome	Gene Value							
	AT	AL	SHC	AMP	IRFR	CI	LS	HNB
Data 1	4.5	5.1	3.5	4.6	7.5	3.2	1.5	3.5
Data 2	3.01	6.51	4.61	3.51	3.01	3.51	6.01	5.01
Data 3	5.45	3.34	6.4	3.4	2.4	0.5	4.6	5.6
Data 4	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Data 5	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Data 6	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Data 7	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
Data 8	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02
Data 9	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22
Data 10	7.76	7.76	7.76	7.76	7.76	7.76	7.76	7.76

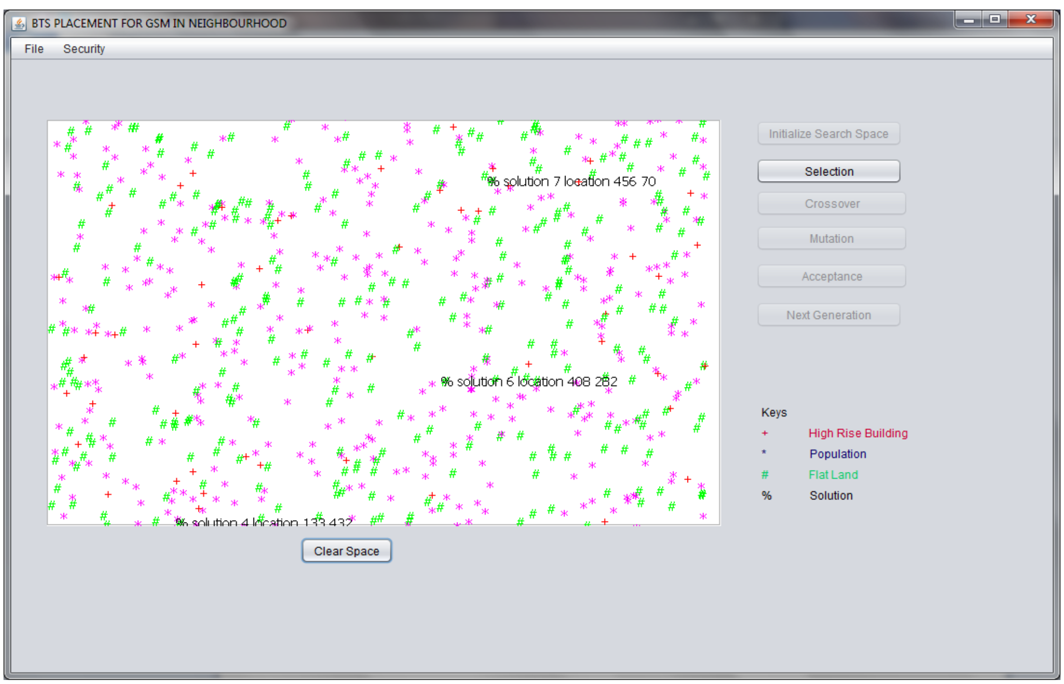

Figure 2: Screen short of the BTS optimal map solutions and locations for generation 0

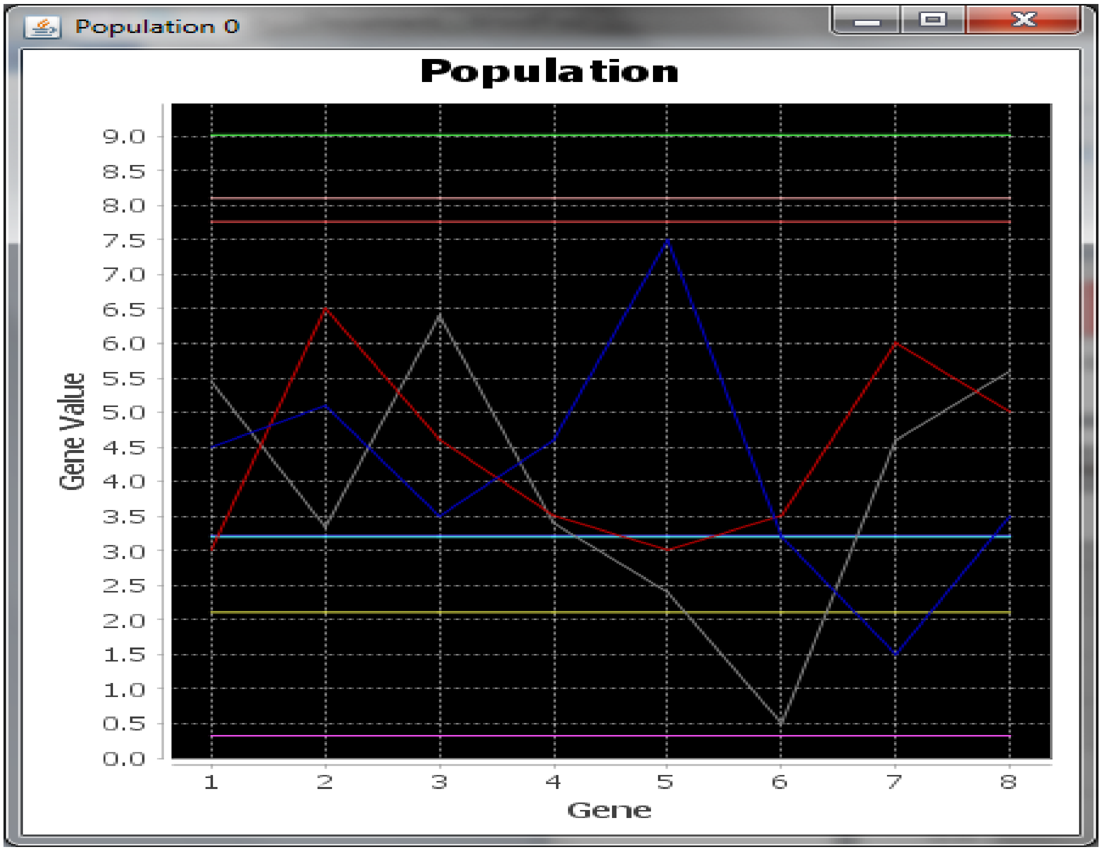

Figure 3: Screen short of the initial population

Table 3: Chromosomes and gene value after crossover / mutation

Chromosome	Gene Value							
	AT	AL	SHC	AMP	IRFR	C I	LS	HNB
Data 1	6.78	5.1	3.5	4.6	7.5	3.2	1.5	3.5
Data 2	2.11	6.51	4.61	3.51	3.01	3.51	6.01	5.01
Data 3	7.76	3.34	6.4	3.4	2.4	0.5	4.6	5.6
Data 4	3.22	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Data 5	2.11	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Data 6	7.76	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Data 7	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
Data 8	9.02	9.02	9.02	9.02	9.02	9.02	9.02	9.02
Data 9	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22
Data 10	6.78	7.76	7.76	7.76	7.76	7.76	7.76	7.76

Table 5: Fitness and probability score

Chromosome	**Chance of Being Selected**
Data 1	0.0902434411391208
Data 2	0.0950528221339601 6
Data 3	0.0856231931047526 4
Data 4	0.1750830834076356
Data 5	0.0691686255437572 6
Data 6	0.0069168625543757 27
Data 7	0.0456080624679149 5
Data 8	0.1949690632514657 6
Data 9	0.0696009294534057 5
Data 10	0.1677339169436113 4

Table 6: Cumulative probability score

Chromosome	**Chance of Being Selected**
Data 1	0.0902434411391208
Data 2	0.1852962632730809 6
Data 3	0.2709194563778336
Data 4	0.4460025397854692
Data 5	0.5151711653292265
Data 6	0.5220880278836022
Data 7	0.5676960903515171
Data 8	0.7626651536029829
Data 9	0.8322660830563887
Data 10	1.0

Table 7: Roulette wheel selection

Chromosome	Chance of Being Selected
Data 1	0.0902434411391208
Data 2	0.0950528221339601 6
Data 3	0.0856231931047526 4
Data 4	0.1750830834076356
Data 5	0.0691686255437572 6
Data 6	0.0069168625543757 27
Data 7	0.0456080624679149 5
Data 8	0.1949690632514657 6
Data 9	0.0696009294534057 5
Data 10	0.1677339169436113 4

Table 8: Chromosome of the existing system before crossover and mutation

Chromosome	Existing System
Data 1	4.42045
Data 2	2.682576
Data 3	4.779218
Data 4	4.215914
Data 5	2.717841
Data 6	4.34584
Data 7	3.537811
Data 8	4.631531
Data 9	7.541978
Data 10	5.919316

Table 9: solution and map locations of BTS

Solutions	Locations
Data 1	50,50
Data 2	5
Data 3	10,275
Data 4	460,60
Data 5	50,150
Data 6	390,370
Data 7	332,129
Data 8	180,378
Data 9	250,34
Data 10	250,250

Table 10: Comparison between existing system before/after crossover and mutation

Chromosome	Before crossover and mutation	After crossover and mutation
Data 1	4.42045	4.575342465753424
Data 2	2.682576	4.81917808219178
Data 3	4.779218	4.3410958904109584
Data 4	4.215914	8.876712328767123
Data 5	2.717841	3.506849315068493
Data 6	4.34584	0.3506849315068493
Data 7	3.537811	2.3123287671232875
Data 8	4.631531	9.884931506849313
Data 9	7.541978	3.528767123287671
Data 10	5.919316	8.504109589041095