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Artificial Intelligence based technique for BTS placement

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Abstract. The increase of the base transceiver station (BTS) in most urban areas can be traced to the drive by network providers to meet demand for coverage and capacity. In traditional network planning, the final decision of BTS placement is taken by a team of radio planners, this decision is not fool proof against regulatory requirements. In this paper, an intelligent based algorithm for optimal BTS site placement has been proposed. The proposed technique takes into consideration neighbour and regulation considerations objectively while determining cell site. The application will lead to a quantitatively unbiased evaluated decision making process in BTS placement. An experimental data of a 2km by 3km territory was simulated for testing the new algorithm, results obtained show a 100% performance of the neighbour constrained algorithm in BTS placement optimization. Results on the application of GA with neighbourhood constraint indicate that the choices of location can be unbiased and optimization of facility placement for network design can be carried out.

1. Introduction

The deployment of Global System for Mobile (GSM) service in developing countries has been massive with an unprecedented market growth[9], this phenomenon is expected after long years of experiencing poor communication services. The fast growth rate of the GSM customer base has brought about a deployment of base transceiver stations (BTS) to meet coverage and capacity demands[2]. The dramatic increase on the number of BTS is attributed to the increase of subscribers, and advancement in technology (3G, UMTS) which opens room for advanced services and use of multimedia facilities in hand held phones. The telecommunication industry in Nigeria requires the construction of more mast and towers to improve teledensity which is presently only 50%[2].

The Base Station System (BSS) of the GSM network is the equipment located at a cell site. The BTS is responsible for maintaining connections to the mobile station (MS) within its cell. The BTS for a given geographical area have to be well positioned for maximum coverage and minimal interference which are the indexes for measuring the quality of any mobile service [5]. Unlike the mobile station that is handheld, the BTS is a conspicuous structure that has been the cause of much agitation from several quarters on the need for RF safety in base stations. The BTS contains several transceivers (TRXs) for transmitting and receiving information, the antennas for receiving

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information to/from one or more transceiver are also connected to the BTS. These antennas have to be mounted high to avoid interference and maximum coverage, necessitating the need for mast and towers and even the use of roof tops of high buildings, figure1 shows the picture of a BTS.

Figure1: Picture of a BTS

The presence of a BTS is always felt by the surrounding structures, human and material, irrespective of the fact that the BTS may be stand alone on a space with the minimum space as specified by regulations, the facility may be said to be optimally placed if the neighbours are not complaining. The process of cell planning is conducted in an ad-hoc fashion after manually inspecting maps depicting the propagation properties of the service area. There is a need therefore for a more efficient and automated cell planning model that taking compliance to regulation into consideration.

In this work an intelligent based technique for optimal site selection for facility placement, here referred to as the neighbourhood constraint based genetic algorithm. Genetic algorithm is an optimization tool capable of giving optimum results in situation where there are many conflicting options an requiring optimal balance. It has also proved to be a viable tool for search problems that are presented as N-P hard. This is so as Genetic algorithm have the capability to search large spaces efficiently without the need for derivative information. The concept of neighbourhood constraints is born out of a need to quantitatively evaluate the process of decision making for the best placement of facilities in a wireless telecommunication network, this case the Base transceiver station (BTS). Its implementation will lead to a situation where placement choice would be made based on realistic, unbiased evaluation with all variables and options taken into consideration and adherence to regulating bodies. The use of the neighbor constraint tool will lead to a saving of time that will be spent on manual site verification; it will also result in a reduction of cost that will hitherto be spent on site verification and subsequently automation of planning process leading to improved efficiency.

The remaining part of this paper is divided into three sections; section two is on literature review, a review of traditional network planning process and optimizing cell planning process are presented. Section three discusses the new methodology and implementation while results conclusion and references are presented in section four.

2. **Literature review**

In this section, detail review of the processes involve in telecommunication network facility placement is discussed. The issues discussed are basically traditional planning process, optimization algorithm for cell planning and use of genetic algorithm in facility placement. Detail discussions are subsequently presented.

2.1 *Traditional network planning:*

In cellular telecommunication provision, cell planning is done to ensure coverage and avoid interference in a network [1]. Deciding where to place the base station of a cellular network is a very important issue that is usually decided during the process of cell planning. One of the essential tools used in cell planning is the MapInfo which is a windows based software used for site location analysis. The selection process is typically based on location demographics, nearby facilities depicted in a geography map. Their limitation is that physical inspection and final decision of proposed sites will have to be taken by a team of radio planners. Manual investigations and tests are usually carried out to ascertain if the potential sites meet legal, civil and environmental requirements. This manual exercise is rigorous, inefficient and could be prone to errors as they are based on personnel experience[10]. Figure 2. is a chart showing a typical cell planning process[3].

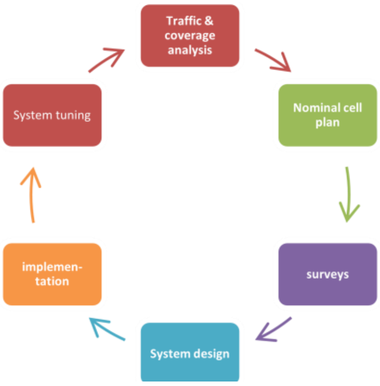

Figure 2: Traditional cell planning Process

2.2 Optimizing Cell Planning Algorithms.

Research have been ongoing on the optimization of cell planning process, the design issues in wireless network are very complex, involving resource allocation, interference cancellation and signal detection[7]. Most of these problems have large search space which makes them non-deterministic polynomial (NP)-hard hence solutions using analytical approaches have proved to be intractable and tedious [8]. These reasons have made many researchers to propose various techniques of heuristics methods for solving these problems. Finding the most optimal locations to place a base station which encompasses the antenna and other transmission facilities poses one of the most challenging design problems in the planning and deployment of a communications network [11]. The use of artificial intelligence have been undergoing much research and genetic algorithm has been found to be useful for solving this type of NP-hard problem [7,8,11,12].

3. Methodology

In this section, detailed explanation of Genetic algorithm and the neighbourhood constraint concept, and its implementation on a generated territory is presented.

The choice of locations for placement will be determined using an optimization tool referred to as Genetic algorithm GA. GA is a form of evolutionary algorithm (EA), which are algorithms that obtain their solutions based on the principle of natural evolution, such as adaptation and survival of the fittest. It is capable of giving optimum results in situation where there are many conflicting options and has proved to be a viable tool for search problems and also in problems that are presented as N-P hard.

GA utilizes a clearly defined procedure for solving problems with a finite time for termination. The major issues addressed in the implementation of GA's include, parameters coding, fitness function development and strategy for chromosome selection.

Basic steps taken in the implementation of Genetic algorithm begins with defining the optimization variables, its constitution and cost. It ends by testing for convergence.

3.1 Defining the neighbour constraint:

The neighbourhood constraint process intends to place values (weights) on the neighbours surrounding a choice position, these are them evaluated and the position with the least weight or optimal value is chosen, it is a minimization algorithm. Figure 3 is a typical neighbourhood map depicting the various neighbours of the BTS as $L_1 - L_8$, the summation of the various weight ($\sum L$) gives the optimization equation. An open space as neighbour is assigned the value zero. In applying GA to optimization placement selection, the neighbour evaluation and criteria will be used selecting the optimal site.

L1	L2	L3
L4	BTS	L5
L6	L7	L8

Figure 3: A 3 X 3 neighbor map

$$F(L) = \sum L_i$$
$$= L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7 + L \quad (1)$$

3.2 Assigning weights to neighbour:

The International Telecommunication Union (ITU) and bodies' in-charge of telecommunications regulations in various countries have guidelines bordering on the building of towers and mast. In these guidelines minimum setbacks of towers from existing structures are specified in meters. In computing weights for the BTS neighbours a bar chart is generated depicting the minimum distances and the corresponding weights. Table 1 below shows the allocation of weights which is proportional to the specified standard clearance required by law.

Table 1: Minimum setbacks for towers and mast/neighbor weights

S/N	Constraint list	Min. Distance (m)	weight (L)	Legend
1	Residential	20 x 20	2	
2	Commercial	12 x 12	1.2	
3	Industrial	12 x 12	1.2	
4	Civic/cultural	20 x 20	2	
5	Educational	150	15	
6	Health /clinics	150	15	
7	Highways	50m	5	
8	Open space		0	

3.3 Problem Representation
A decision on mode and form of representing the system information is taken prior to starting optimization, for this work the relevant parameters will be encoded using binary numbers, for ease of implementation and best performance. The BTS are encoded using two coordinates X-Y of the territory which form the chromosomes. The number of bits to be used for representation was determined using equation (2) [6].

$$2^{mj-1} < (bj - aj)X10^{p} \leq 2^{mj} - 1 \qquad (2)$$

Where;

m is the required binary bits
a is the lower limit of the decimal range
b is the upper limit
p is the required precision in decimal points.

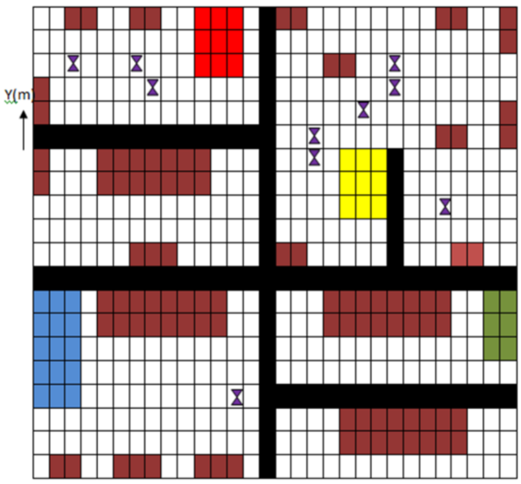

Fig. 4 Experimental territory of 2Km by 3km

4. Results
The experimental data is a 2km by 3km territory developed to test the new algorithm. The experimental data is a typical suburban area with existing infrastructures as represented in figure 4. A data base of the territory was generated and fed into the algorithm. The programme for the genetic algorithm was written in matlab 7.5

The following parameters setting were used for optimization: Initial Population =50; Generations=30; Probability of crossover =0.25; Mutation Rate=0.01 ; Precision=1

Ten rounds of iteration were run and the results obtained are shown in table 2. The algorithm in each round selects the optimal location for the BTS based on optimization criteria. The coordinates of the optimal position selected by the algorithm is given (row and column). The 'Type' column depicts the existing structure on selected site. The neighbor weighting is also shown. Selected optimal sites are plotted on the territory map as purple colored asterisk (♦).

Table2: Results of GA optimization

RUNS	LIKELY LOCATIONS			Neighbour weight
	Row	*Column*	*Type*	(∑ L)
1	14	18	Open space	0
2	16	21	"	0
3	18	7	"	0
4	17	23	"	0
5	17	8	"	0
6	18	23	'	0
7	12	26	"	0
8	15	18	"	0
9	18	3	"	0
10	4	13	"	0

4.1 Discussion of results:

Ten rounds of iteration were carried out; in each round the algorithm selected the optimal location. For this experiment, the sites selected by the algorithm from the experimental data were all open spaces with minimal neighbor weighting of zero. This showed a 100% performance of the neighbor constrained algorithm in placement. Selection of sites is in adherence to regulation and consideration of neighbor which is unbiased and efficient.

The results reveal a concentration of the selected location on the upper half of the territory which is sparsely populated with less buildings. 90 % of sites selected are located in the upper half of the territory with only 10% in the lower half of the territory. Each round of iteration took a few second approximately 30 seconds, which is clear indication of the time saving to be derived from its use. The algorithm through the several iterations there was a clear avoidance of BTS placement on roads, and algorithm to seek out optimally regions with less neighbor.

4.2 Conclusion

In this paper, the application of GA with neighbourhood constraint has been presented. Results indicate that the choices of location are unbiased and optimization of facility placement for network design can be carried out. Further work will involve the implementation of this new algorithm in a real territory and combining with other objectives of coverage optimization and interference minimization. The application will lead to a quantitatively evaluated decision making process that is unbiased, fast and automated for the placement of Base transceiver station (BTS).

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