THE BASE TRANSCEIVER STATION (BTS) PLACEMENT: - ISSUES AND OPTIMALITY

Alenoghena C. O[1], and Emagbetere J. O[2]
[1]Dept. of Telecommunications Engineering, Federal University of Technology Minna,
Email: carol@futminna.edu.ng; alenca2@yahoo.com
[2]Dept. of Electrical/Electronic Engineering University of Benin, Nigeria,
Email: joyokumo@yahoo.com

Abstract:

The tremendous growth in terms of users in the mobile communication sector has resulted in the need for the provision of network facilities to meet with coverage and capacity demands. The BTS is that part of the mobile unit responsible for managing the radio network, its main function is to provide control and radio coverage functions for one or more cells and their associated mobile subscribers (MS). The crux of many agitations today is tied to the presence of base station's towers and mast in our neighborhoods. The end process of BTS placement involving inspection and final decision of proposed sites is usually taken by a team of radio planners. This manual exercise is rigorous, inefficient and could be prone to errors and bias as they are based on personnel experience and judgment. This paper explores the place of the BTS in a wireless network, its composition, viability, and placement challenge. A review of placement , and proposes the use of an artificial intelligence planning tool for the optimal placement of base stations.

Key words: BTS, Network planning, Neighbor constraint, Genetic algorithm, Placement.

1.0 Introduction:

The birth of wireless communication has brought about an unprecedented increase in access to communication systems, leading to the availability of communication means to regions hitherto deprived. The GSM in particular has gone a long way to bridge the digital divide in the developing countries; one cannot but applaud the benefits of the GSM revolution. The position of the largest and fastest growing telecom market in Africa has been given to Nigeria; she is also ranked among the ten fastest growing in the world [1]. The position however is not without its attendant consequences. With an average penetration rate of 50%, there is an anticipation of growth to meet the international average of 76% [1]. Such growth comes with its own environmental cost. While there is shortfall of BTS to meet the telecommunication need of Nigeria, we experience the shutting down of BTS sites. This occurrence leads to revenue loss for the provider and has its attendant impact on network quality of service. Some concerned agencies has therefore made submission to government on the need to harmonize telecommunication regulations in the country.

Research findings indicate that the quality of service of the GSM system in the country is unreliable, with its accessibility and retainability unsatisfactory. Operators are yet to meet customer's satisfaction as subscribers still have to own several phones/network at the same time in case of network failure and emergency [2]. The presence and multiplication of the base station in places hiertherto not expected, have brought to fore issues like environmental safety, and aesthetic beauty of our towns [3].

Section two of this paper discuss in detail the BTS and network planning, in section three the use of genetic algorithm is reviewed and conclusion is presented in section four.

2.0 The Base Transceiver Station:

The base transceiver station (BTS) (also referred to as base station) is the equipment provided at a cell site by which means network coverage is provided over a given region. It consists of receivers, transmitters, and most importantly the antenna. These antennas have to be mounted at a minimum height to obtain required coverage for an area. The need of mounting the antennas high necessitates the construction of mast and towers cable of handling the sectors antennas and also those for radio link. At the bottom of each tower, there is a housing for the transmission equipment and other additional equipment used for the proper operation of the base station. The BTS for a given geographical area has to be well positioned for maximum coverage and minimal interference. These parameters are the indexes for measuring the quality of any mobile service [4].

A typical Base Station consists of the following equipment and facilities

i. *The radio frequency equipment*; This establishes the microwave link between the site to the closet base station controller, with its microwave antenna. Alternatively this link can be established for remote locations by use of fiber cables or satellite links.

ii. *Digital equipment*: This is in a cabinet made up of several transceivers (TRXs) each assigned one pair of frequency for transmitting and receiving information.

iii. *The antennas:* These are used for receiving information from/to one or more transceiver. The antennas are usually omnidirectional sectored antennas.

iv. *Towers and Mast:* Used for holding the antennas usually built to a maximum allowable height.

v. *Integrated power unit:* This consists of a site transformer for the public utility service, an automatic mains failure panel (AMF), a battery bank, generator unit with a a 200-400litre diesel holding tank and in a few cases, a solar panel.

The land space requirement for a standard out-door base station is a minimum of 10 square meters and slightly bigger for an in-door BTS. Presently the regulation allows for tower heights of 30 -35 meters and maximum transmit power of 20MW. The energy requirement of the base station is 60A, 53V for the digital and radio equipment. More will be required for air-conditioning for the indoor unit

2.1 Network Cell Planning in Nigeria

In cellular telecommunication system, deciding where to place the base station of a cellular network is a very important issue that is usually done during the process of cell planning [5].The BTS for a given geographical area has to be well positioned for maximum coverage and minimal interference, these are the indexes used to measure the quality of any mobile service [3]. In Nigeria, 98% of GSM base stations (cell sites) are sited within 20 meters from residences, offices, schools, business buildings, petrol stations and public arenas [6].

The traditional process of cell planning is conducted in an ad-hoc fashion, after manually inspecting maps depicting the propagation properties of the service area. In Nigeria the map information (mapinfo) is one of the essential tools used in cell planning. The mapinfo 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 taken by a team of radio planners. This manual exercise is rigorous, inefficient and could be prone to errors and bias as they are based on personnel experience and judgment [7].

2.2 Research on base station placement.

The design issues in wireless network are very complex, involving resource allocation, interference cancellation and signal detection. Wireless network problems bothering on facility placements have been found to have large search space, This makes them non-deterministic polynomial (NP)-hard problems. The use of analytical approaches have been found to be tedious and intractable [7]. These reasons have made many researchers to propose various techniques of heuristics methods for solving these problems. A heuristic is a part of an optimization algorithm that uses the information currently gathered by the algorithm to help to decide which solution candidate should be tested next or how the next individual can be produced. Numerous heuristic methods are in existence. These include: Tabu Search method (TS), Simulated Annealing (SA), Gradient Descent Search (GDS), Genetic Algorithms (GA) and Ant Colony Optimization (ACO) [8]. 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 [9]. 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.[7,9,10,11]

3.0 *Genetic Algorithm in facility placement*

Genetic algorithm (GA) is an optimization tool that is based on the principles of genetics and natural selection. It is an evolutionary computational (EC) technique which abstract natural principles of evolution like selection, mutation, adaptation and survival of the fittest into algorithms that are then used to search for optimal solutions to a problem [12]. GA has proved to be an efficient searching tool as it found application in complicated problems in physics, engineering, biology and economics. Genetic algorithm is an optimization tool capable of giving optimum results in situation where there are many conflicting options as is the case with placement of BTS. The use of GA to making the final decision on BTS site proves to be unbiased, efficient and automated.

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.

Process diagram fig 1, gives the basic steps in the implementation if GA in a facility placement problem.

1. *Randomly create a* ***population*** *of candidate solutions.*

2. *Until the algorithm termination conditions are met, do the following;*
(each iteration is called a generation):
  (a) Evaluate absolute measure of each individual in new pop.
  (b) measure fitness:
    i. ***Select*** *two* ***individuals*** *at random from pop so that individuals who are more fit are more likely to be selected.*
    ii. ***Cross-over*** *the two individuals to produce two new individuals.*
  (c) Let each individual in new-pop have a random chance to ***mutate****.*
  (d) Replace pop with new-pop.

3. *Select the individual from pop with the highest* ***fitness*** *as the*

Fig1: implementation of GA

There have been research works justifying the use of genetic algorithm in the optimal placement of network facilities. Genetic algorithm was used to determine the best placement for base station antennas in a 3G network, with key emphasis on coverage maximization with interference and cost minimizations, results showed a 98% coverage in the network [7]. The use of GA and tabu search for the optimal placement of base station in a radio network with coverage optimization as common objective was explored with simulation results showing GA performing better than Tabu search for increased randomness of mutation operators [9]. Traditional and random weighted forms of GA were used for the optimal placement of base station while taking coverage and health effect as objective functions, its implementation showed less base station and higher coverage obtained for Cairo city as compared with an existing network [13]. A multi objective GA for the placement of base station using real number representation was done in and implemented on a flat terrain without considering constraints, resulting in a 99.78 % coverage as optimal with traffic, map and terrain taken into consideration.

3.1. *Introducing the Neighbour-constrained BTS placement algorithm:*

In view of the foregoing, there is a need for a cell planning model for Nigeria, which will take into cognizance the peculiar nature of our urban places that are characterized by town poor planning, few high rise buildings and a poorly enlightened public. The outcome of radio planning is to achieve the locations of the BTS in a manner such that radio coverage is maximized while equipment and maintenance cost are minimized. The challenges faced in obtaining the optimal position for the placement of base station affect both the operators and the customers.

The neighbor constraint process intends to place values (weights) on the neighbors surrounding a choice position, these are them evaluated and the position with the least weight or optimal value is chosen. The optimization will be carried out using Genetic algorithm. The following are the expected benefits of using the neighbor constraint;

- Decisions on BTS placement will be based on realistic, unbiased evaluation, with all variables and options taken into consideration.
- It will result in the saving of time that will be spent on manual site verification.
- Reduce cost that will hitherto be spent on site verification
- Automation of planning process leading to improved efficiency

3.2 *Proposed Neighbor Map*

The proposed neighbor map is shown in fig 2. Choice of placement will be based on the immediate neighbors. The neighbors are labled L_1 to L_8. The consideration of neighbors in deciding the placement of BTS is drawn from the need to operate within the ambit of the law and minimize the severity of effects on humans and property located near a BTS. These include protection from mishap due to collapse of the mast, noise from generators and even fire outbreak due the presence of fuel within the premises of the BTS.

L_1	L_2	L_3
L_4	BTS	L_5
L_6	L_7	L_8

Fig.2: 3 X 3 neighbor map

3.3 *Weights on neighbor*

The various neighbor weightings are drawn based on regulations governing the minimum setbacks from the BTS towers and mast to existing structures in meters. The weights for the ‘neighbours’ (L_i) are drawn from a corresponding bar chart generated with their distances. Table 1 below shows the minimum distance from structures as recommended by the government of Ghana [.

Table 1: Minimum setbacks for Towers and Mast

S/N	Constraint list	Min. Distance (m)	weight (L)
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	Mixed	20 x 20	2
6	Educational	150	15
7	Health /clinics	150	15
8	Highways	50	5
9	Open space		0

The total weight of the position will be given as;

$F(L) = \sum L_i = L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7 + L_8$ …………. (1)

In the final implementation of the base station placement algorithm, a multi-objective genetic algorithm (MOGA) function will be used. The objective functions will be, coverage optimization (F_C), interference minimization (F_I) and neighborhood minimization (F_L). The final objective function will be given by equation (2); where w_1,w_2,and w_3 represents the weights that corresponds to the priority placed on each objective function

$F(X) = w_1F_C + w_2F_I + w_3F_L$ ………… (2)

$w_1 + w_2 + w_3 = 1$ ………… (3)

4.0 Conclusion:

The provision of good wireless network coverage with good QOS is hinged on an optimal placement of the BTS, as the country advances towards having a right of way for communication facilities. The application of genetic algorithm in base station placement has been shown to be efficient and promises a more efficient planning process. Introduction of the neighborhood constraint will lead to a more realistic placement of BTS that is regulations complaint. There is need therefore to support research on acquiring an intelligent base tool for the optimal placement of base stations.

4.1 References

1. Dr. Eugene Juwah, (2011) "Telecommunications Business n Nigeria: How Far?" International Communications Lecture Organized By The Nigeria-Swedish Chamber Of Commerce On Friday, April 8, 2011, Hecommerce House, Victoria Island, Lagos.
2. J. J. Popoola, I. O. Megbowon, V. S. A. Adeloye (2009) "Performance evaluation and improvement on quality of service of global system for mobile communications in Nigeria" Journal of Information Technology Impact Vol. 9, No. 2, pp. 91-106, 2009.
3. J. J. Biebuma, E. Esekhaigbe "Assessment of radiation hazards from mobile phones and gsm base stations" Journal of Innovative Research in Engineering and Science 2(1), March, 2011. ISSN : 2141-8225
4. Hanif D. S, Chandra M. P, and Theodore S. R. "Optimal Location of Transmitters for Micro-Cellular Radio Communication System design ieee Journal on selected areas in communications, vol. 14, no 4, May 1996 pp 662-673
5. Ajay Mishra "Fundamentals of Cellular Network Planning and Optimisation" John Wiley & Sons Ltd, England (2004) pgs 21-31
6. Okonigene, R.E.; "Siting of GSM Base Station Antenna and Its Health Consequences" Information Technology: New Generations (ITNG), 2010 ieee Seventh International Conference on pgs 613 -618
7. Job Munyaneza, Anish Kurien, Ben Van Wyk, (2008) "Optimization of Antenna Placement in 3G Networks using Genetic Algorithms" *Proc IEEE Third International Conference on Broadband communication, Information Technology and Biomedical Applications pg. 30 – 37*
8. Thomas Weise (2009) " Global Optimization Algorithms- Theory and Application" second edition www.it-weise.de assessed August 2010
9. Rodney S. Rambally, Avinash Maharajh "Cell Planning Using Genetic Algorithm and Tabu

Search" 978-1-4244-4457-1/09/$25.00 ©2009 IEEE pgs 640-645

10. Jorg Zimmermann, Robin Hons, Heinz Mu¨hlenbein (2003) "ENCON: an evolutionary algorithm for the antenna placement problem" Elsevier Science Ltd, Computers & Industrial Engineering pg. 209-226.
11. Yong Seouk Chio, Kyung Soo Kim, Nam Kim (2008) "The Displacement of Base Station in Mobile Communication with Genetic Approach" EURASIP Journal on Wireless Communications and Networking, Article ID 580761
12. S.N.Sivanandam · S.N.Deepa "Introduction to Genetic Algorithms" ISBN 978-3-540-73189-4 Springer Berlin Heidelberg New York (2008) pgs 15-37.
13. S. M. Gaber, M. E. El-Sharkawi, and M. Nour El-deen traditional genetic algorithm and randoM-weighted genetic algorithm with gis to Plan radio network" URISA Journal Vol. 22, No. 1 • 2010
14. Government of Ghana, guidelines for the deployment of communications towers http://www.nca.org.gh/128/120/Guidelines.html assessed on August 13th 2012 pg. 41-42