Information and Knowledge Management
ISSN 2224-5758 (Paper) ISSN 2224-896X (Online)
Vol.5, No.7, 2015

# A GIS Performance Analysis of a 3G wireless Cellular Network

Etebong B. Isong[1] Uduak A. Umoh[2]

1. Department of Computer Science, Akwa Ibom State University, Ikot Akpaden, Mkpat Enin, .M.B 1167, Uyo- Nigeria.
2. Department of Computer Science, University of Uyo-Nigeria.

## Abstract

In this paper, GIS performance Analysis of a 3G wireless cellular network is presented. The research is motivated by the need for network operators and mobile users to have on the spot assessment of the network performance. This was achieved by studying the effect of population, road structure and visibility on the Erlang traffic of an existing 3G Network. The result expectedly revealed that densely populated areas are likely to experience high traffic and poor signal reception. Road structure analysis shows poor service quality along major roads due to high traffic within the study area while the visibility analysis revealed that the terrain structure of the study area does not support good visibility.

**Keywords:** GIS, 3G wireless cellular Networks, Erlang Traffic, Base Transceiver station.

## 1.1 Introduction

The Geographical Information System (GIS) is known for its ability to accept dataset from various sources provided they are in an acceptable format, processed and displayed in a variety of ways. Proper integration of different data layers using appropriate algorithms guarantee a high quality result or output that can aid informed decision. A number of researchers have utilized several GIS functionalities to map communication factors such as signal strength input data into the GIS environment for further analysis and display. This is evidenced in the work of [Radis et al. 1997], who used professional GIS tools and customized application Radio Telecommunication Modelling (RTM), for geographic data management and GSM network planning operations. They used sites database developed by network planners and implemented on Microsoft (MS) Access, cartographic GIS database re-organized and updated using ArcView/Spatial Analysis /RTM to comply with network planner's requirements.

In various fields there is need to manage geometric, geographic, or spatial data, which means data related to the air interface. The air interface may be the two dimensional abstraction of (parts of the earth's surface or a 3D-space representing a Digital Terrain Model. Since the advent of relational databases, there have been several attempts to manage such data in database systems. One of the benefits offered by emerging GIS technologies is the capability to deal with large collections of relatively simple geometric objects, for instance, a set of 100,100 polygons. Several terms have been used for database systems offering such support like pictorial, image, geometric, geographic, or spatial database system arise from the fact that the data to be managed are often initially captured in the form of digital raster images (e.g., remote sensing by satellites, or computer tomography in medical applications. The term 'spatial database system' has become popular during the last few years, and is associated with a view of a database as containing sets of objects in space rather than images or pictures of a space. Indeed, the requirements and techniques for dealing with objects in space that have been identified and well-defined extents, locations, and relations are rather different from those for dealing with raster images. A spatial database therefore has the following characteristics: (i) A spatial database system is a database system. (ii) It offers Spatial Data Types (SDTs) in its model and query language. (iii) It supports Spatial Data Types in its implementation, providing at least indexing and efficient algorithms for spatial join.

Many factors influence a successful GIS implementation. None however are more fundamental than having the right management strategy and software to implement these. The spatial database is the foundation by which all data is uniformly created and transformed. But maintaining the integrity and currency of the data is of fundamental importance. A classic error made by most organisations in the thinking that a generic spatial database is sufficient for their needs. The spatial database is the end product of a series of process that determine the specific functional requirements for the user and the key applications. Interoperability of data is also of a critical concern in the development of spatial data information systems. As technology drifts from newly created data to assimilation of all existing data, a properly designed spatial database is insurance for end user success.

Topology is one of the most useful relationships maintained in many spatial databases. It is defined as the Mathematics of connectivity or adjacency of points or lines that determines spatial relationships in a GIS. The topological data structure logically determines exactly how and where points and lines connect on the map by means of nodes (topological junctions). The order of connectivity defines the shape of an arc or polygon. The computer stores this information in various tables of the database structure. By storing information in a logical and ordered relationship, missing information, e.g. a line segment of a polygon is apparent. A GIS manipulates, analyses, and uses topological data in determining data relationship.

Network analysis uses topological modelling to determine shortest paths and alternate routes. For instance, a GIS for emergency service dispatch may use topological models to quickly ascertain optional routes for emergency vehicles. Automobile commuters perform a similar mental task by altering their routes to avoid accidents and traffic congestions. Likewise an electrical utility GIS could rapidly determine different circuit paths to route electricity when service is interrupted by equipment damage. Similarly, political re-districting planners could use certain algorithms to determine logical relationships between population groups and areas for district boundaries. Telecommunication networks are inherently spatial systems [Hepworth 2007][Baskis 2001]. Telecommunication infrastructure development is a process of spatial interaction and mutual growth between and demands. Geographical Information Systems [Chrisman 1997][Laurni and Thompson 1992] with their powerful data handling and spatial analysis capabilities, are ideal for meeting the information needs of telecommunications infrastructure development.

In Akwa Ibom State, Nigeria (the case study for the GIS mapping), the concept of topology representation is vital. With the application of this concept, 3G (Third Generation) cellular wireless networks stands to benefit from this research as they will obtain instant data on locations of Base station as well as signal and traffic quality reports, when all the nodes and locations at every point, line and regions under study are properly represented in a relational spatial database format. The topology data will also allow for the proper network planning and development of new sites. A detailed network analysis of QoS (Quality of Service) is necessary in study area. This would be obtained easily from the spatial database. Hence, availability of resources such as network channels to service traffic requests can be centrally managed at the various Base Transceiver Station(BTS) control sites, to ensure that areas with poor topologies are given due attention. Monitoring and tracking of certain events is also possible when the locations of each BTS can be accessed. The database could also hold handover data as users are transiting from one cell to another.

## 2.1 Related Works

In [Ajala 2005] GIS application was incorporated into a standard network monitoring tool to produce different types of dynamic maps as output to show different aspect of the network. He used a predicted coverage array which is a collection of geo-referenced polygons in space that represent the radial distance of the signal strength away from each cell based on the signal's interaction with environmental factors, as one of the input layer. A counter-based network statistics captured based on network-defined temporal frequency and stored in Oracle database server section formed another input data set. This created a GIS of a sort in which geo-referenced arrays served as spatial data while the dynamic statistics served as the attributes. Once this join has been accomplished, various dynamic thematic maps were created as output that gave insight into the geographic spread of a particular network phenomenon, e.g.; traffic, drop call, etc. [Guoray 2002] Proposes a GIS approach for analyzing the adequacy of a regional broadband infrastructure by spatially relating infrastructure facility with demand.

In this paper, to enhance the proper monitoring of Network Providers, we have offered a GIS solution with a Graphical User Interface (GUI) that can be integrated into mobile phones for users to qualitatively monitor the *Carried traffic* of the 3G cellular wireless network with respect to population (number of users, mobility and visibility. The advantage of the GIS solution is to provide network operators and mobile users with on the spot assessment of the network (in real time). If Network carriers are aware of locations where network degradation is high, then solutions could be proffered before the situation degenerate further.

## 3.1 Methodology

The transformation of information about the geographic environment to geospatial data, and in turn to maps can be achieved through information modelling. In this thesis, data about CDMA traffic of 3G cellular wireless network was first transformed into geospatial data to qualitatively view the performance of the system. The geospatial data were then transformed into cartographic maps with well-defined rules for cartographic abstraction, symbology and labelling, graphic refinement and map compilation.

### 3.1.1 Acquisition of Primary and Secondary Data

This research required a survey of a telecommunication operator's cell sites or base stations in Akwa Ibom State, Nigeria. During data gathering, we obtained data concerning the network's coverage areas. These data were collected with permission from the planning and optimization department of the network operator. The data collected includes operational sites and cells (base stations), their respective geo-reference locations (longitude and latitude) and addresses .To provide a qualitative view of the existing system's performance, we concentrate on Akwa Ibom State zone, and export the locations which represent the cell (mast) points, to the base map of the State. A spatial data analysis was performed on the Base maps to study the effect of (Population Density, Intervisibility and Mobility/Road structure) on the QoS.

The Base maps were scanned using a scanning machine and imported to the Geographical Information System (GIS) environment. The scanned maps were geo-referenced to assign geographical locations to each of the traffic dataset. This was achieved by using a latitude and longitude geographic referencing system based on the World Geodatic System 1984 ellipsoid. The ArcMap 9.2 software was used to carry out the geo-referencing and final digitization of the maps. The digital elevation model (DEM) of the study area which is a three-dimensional model depicting a part of the earth surface in digital format adopted the United States Geological Survey (USGS). The Digital Elevation Model (DEM) was used to generate the contour maps that will assist us perform the analysis of the operator's network.

We emphasize that the interface between GIS components layers must be standardized to provide syntactic interoperability. GIS efficiency and effectiveness of integration largely depends on whether the GIS components share a common data model, otherwise, mismatch of the data model will arise. A solution to this problem is the development of read-only spatial databases to avert unnecessary data modifications. Therefore, data must be appropriately verified before building the spatial database.

### 3.1.2 Description of Study Area

Akwa Ibom State is located between Latitudes $4^{0}30^{t}$ and $5^{0}30^{t}$ North and Longitudes $7^{0}30^{t}$ and $8^{0}20^{t}$ East. It occupies an area of 8412 Square Kilometres. The state is surrounded by the Qua Iboe River Basin, the western part of the lower Cross River Basin and the eastern half of the Imo River estuary. The location of Akwa Ibom State lies on the north of the Equator and within the humid tropics. Its proximity to the sea makes the state generally humid. Map of the study area is shown in Figure 3.1.

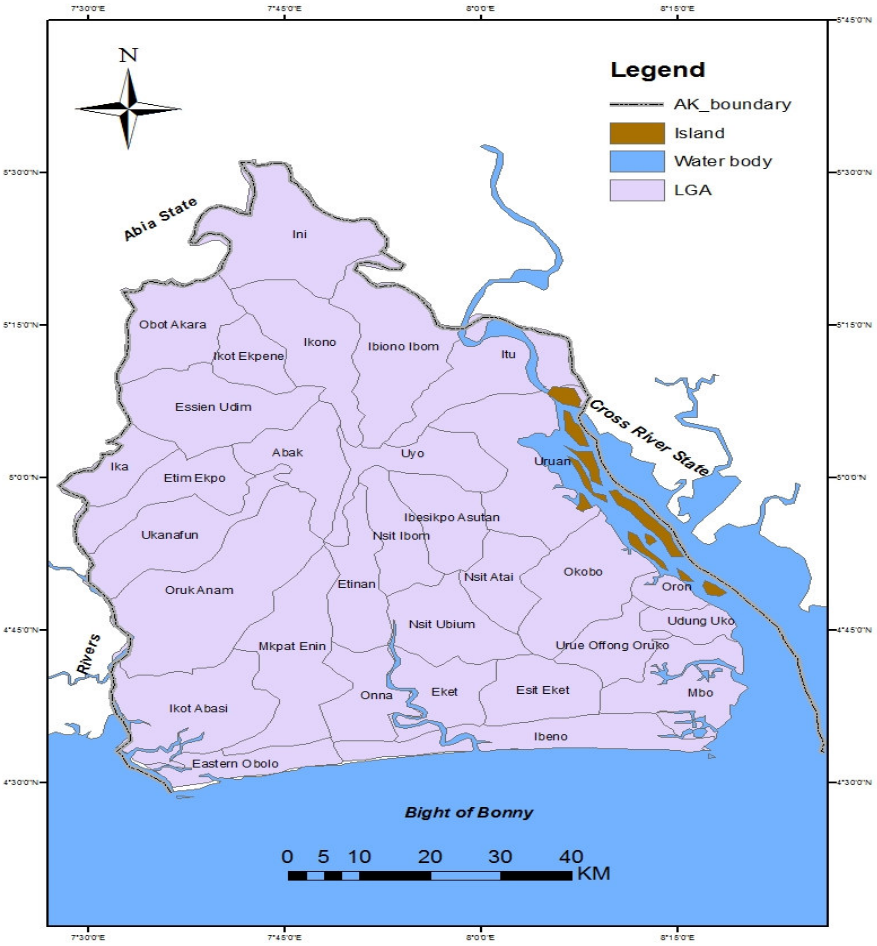

Figure 3.1. Map of Study Area

### 3.1.3 Population

Akwa Ibom State was created on the 23rd of September, 1987 from the former Cross River State of Nigeria. It has thirty one (31) Local Government Areas.The state is listed as the fourth most densely populated in

Nigeria with 541 persons/Km$^2$. The 2006 census revealed that some Local Government Areas such as Oron, Uyo and Ikot Ekpene have human density of more than 1000 persons/Km$^2$ . The most densely populated LGAs in Akwa Ibom State are Oron 2128, Uyo 1986, Ikot Ekpene 1116, Eket 983, Nsit Ibom 993 and Etinan 928 persons/Km$^2$ respectively. The least densely populated LGAs are Uruan and Okobo with 280 persons/Km$^2$ and 289 persons/Km$^2$ respectively; the rest have densities higher than 300 persons/Km$^2$ [Inyang 2010]. The map showing the population density distribution of Akwa Ibom State can be seen in Figure 4.1**.**

### 3.1.4 Procedure for Data Collection and Analysis

The researchers obtained data concerning the coverage area of the Service provider from the planning and optimisation department of the Company. The data collected included the operational sites and cell (Base Transceiver Stations), their respective geo-reference locations in the State and addresses. The BTS points were exported to the map and used for relevant spatial analysis operations. The Digital Elevation Model of the study area which is a three-dimensional model depicting a part of the earth surface in digital format was obtained from United States Geological Survey (USGS). The DEM was used to generate the respective contour maps and also perform the intervisibility analysis on the service provider's network facilities.

## 4.1 Discussion of Results

### 4.1.1 Population Analysis

It is expected that densely populated areas are likely to experience high traffic and poor signal reception which could result in congestions, blocking, outages, network failures, etc. This defect is as a result of the non-line-of-sight (NLOS) nature of the environment. Densely populated areas are mostly full of high rise buildings and other obstacles that impair signals. Also more people are joining the network, which in turn results in increased subscriber's base, resulting in call blocking, cell congestion, echoing, etc. This scenario is typical of Figure 4.1. As observed, the Akwa Ibom state population spread for instance, is not directly proportional to the population density per square meter. This implies that for the population density of a typical Local Government Area, the number of persons available may not be evenly distributed to ensure a smooth transmission. This is expected, as we experience frequent exodus of persons from rural to urban areas.

In some areas such as commercial nerve centres, the population seems to outweigh the number of servicing equipment, thus resulting in signal degradation due to ever increasing subscribers. Furthermore, some cities were not well planned, which greatly impair signals. Even in non-densely populated areas, the proliferation of mobile phones exceeds the coverage strength thus causing severe congestion and poor quality of service delivery.

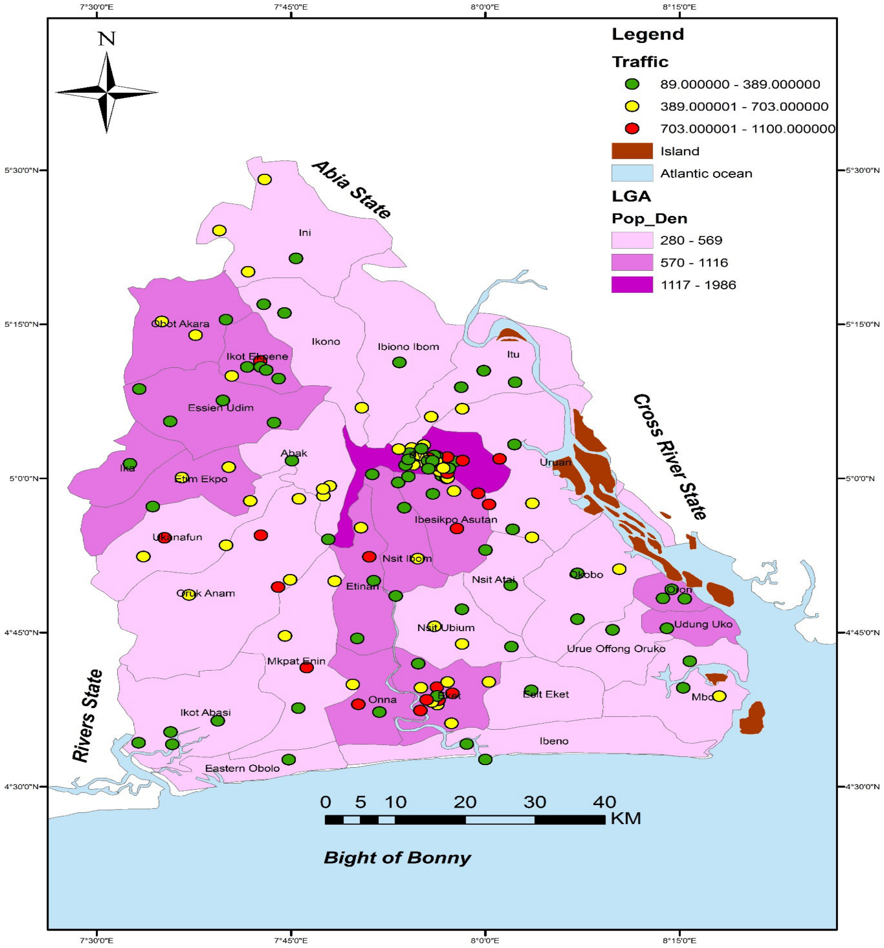

Figure 4.1. Population map showing Carried Traffic in the Study Area

### 4.1.2 Road Structure Analysis

To service travellers or users on the move; telecommunication operators plant handover base stations to ensure that call requests do not 'die off' or fade as a mobile user transits from one base station to another. These base stations are not for coverage and as such will not cover long distances. The base station controller (a central computer which specializes in making phone connections) and the intelligence of the cell phone keep track of and allow the phone to switch from one base station to another during conversation. As the user migrates towards a base station, it picks the strongest signal and releases the station from which the signal has become weaker.[Isong 2015] Figure 4.2 reveals a case where poor service quality is observed along major roads due to high traffic (within the study area). As expected, telecommunications companies would not want to waste revenue on boosting signal strength along these roads. One way of minimizing this effect is to apply effective power control mechanisms and condition base stations such that users do not experience the 'near-far' effect, i.e., strong signals swamping weaker signals, thus permitting only those closer to the base station to enjoy optimal services.

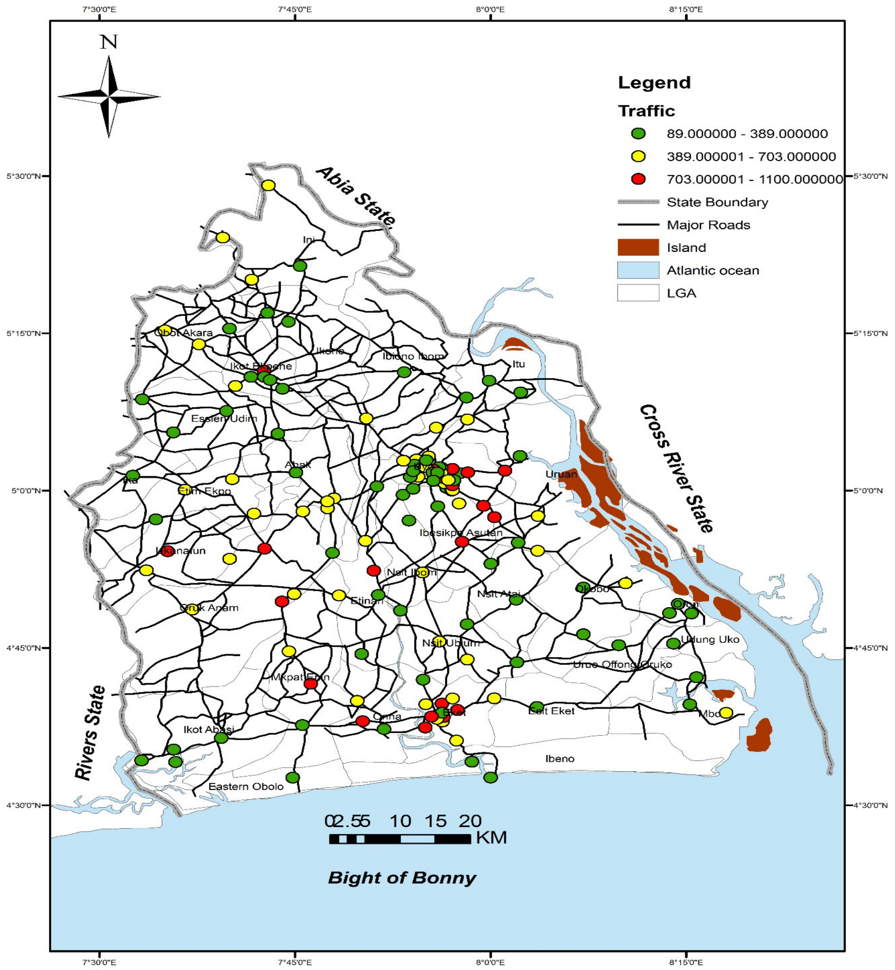

Figure 4.2: Road Map showing Carried Traffic in the Study Area

### 4.1.3 Visibility Analysis

Visibility is described by the signal attenuation between a transmitter and receiver (as a function of the propagation distance and other parameters which relates the terrain profile and its surface feature). Most of the problems of radio propagation are similar to the problems of inter-visibility analysis, i.e., the choice of data model (grids vs. triangular irregular networks, digital terrain model scale or resolution, profile retrieval algorithm; incorporation of ground cover data) and verification of the predicted results. Some users of GIS applications simplify inter-visibility problem by ignoring the clutter – an inefficient option for accurate radio communications planning. Clutter may include buildings – roof structures, building resources and high vegetation and shrubbery – trees, 2-D surface features that possess distinctive propagation properties.

As observed in Figure 4.3, poor visibility resulting from hazy weather conditions contributes to poor connection and adversely affects the network performance. This explains the reason for delays in network connectivity and incessant break-ups in communication. Poor visibility may also be as a result of signal absorption due to the following: (i) highly noisy environment in certain localities that were not pre-planned or well-planned, (ii) reflection and diffraction of the signals, most especially where there is monopoly/competition in the telecommunication market [Isong et al. 2015]. As shown in the Figure 4.3, traffic is also affected because there are numerous obstacles and poorly planned infrastructures which contribute to traffic jams. Also the terrain structure of the study area does not support good visibility.

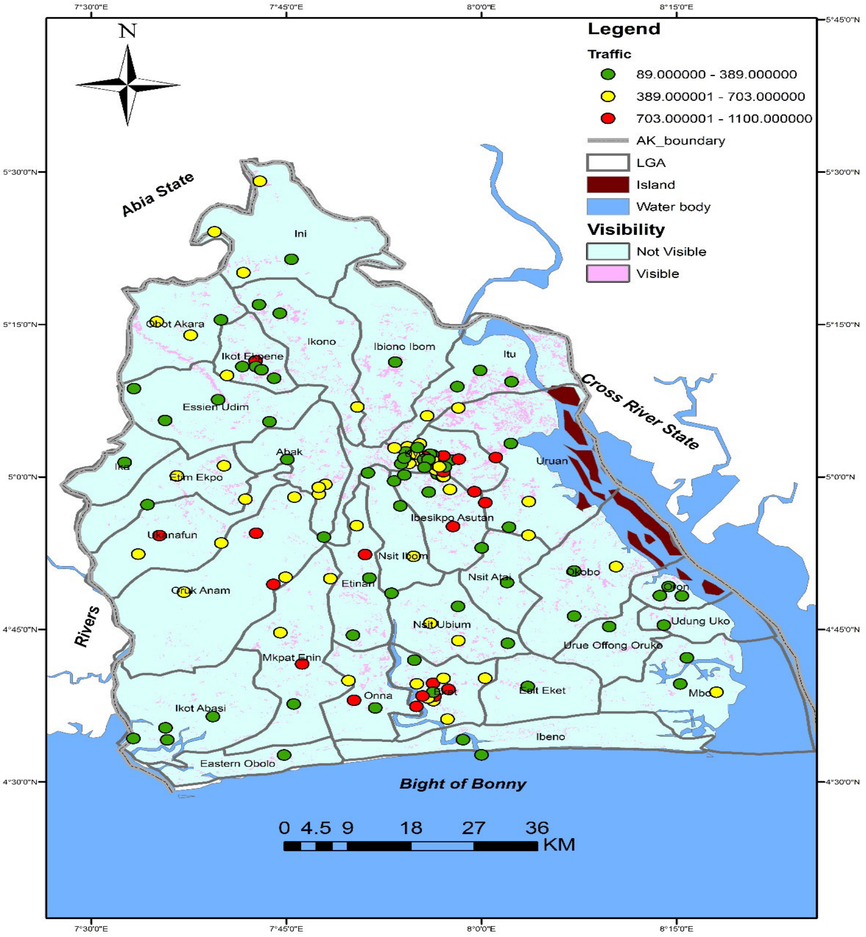

Figure 4.3. Visibility Map showing Carried Traffic in Study Area

## Conclusion

We have presented a GIS performance analysis of an existing 3G wireless Cellular Network in a bid to proffer optimised solutions to the existing traffic problems of network operators through proper monitoring of telecommunication traffic. With the GIS solution, a graphic user interface (GUI) can be integrated into mobile phones for users to monitor the Erlang traffic or Carried traffic with respect to number of users, mobility and visibility. The GIS has the advantage of providing network operators and mobile users with the on the spot assessment of the network ( in real-time).

## References

Ajala, I.(2005) *GIS and GSM Network Quality Monitoring:* A Nigerian Case Study. http://www.directionsmag.com/articles/gis-and-gsm-network-quality-monitoring-a-nigerian-case-study/123278. Accessed on 29 December, 2010.

Bakis, H. (2001). *Elements for Geography of Telecommunication*. Geographical Research Forum 4, 31–45.

Chrisman, N. (1999). *A Transformational approach to GIS operations.* International Journal of Geographical Information Science 13(7) 607-637.

Guoray C.A.(2002). *A GIS Approach to the Spatial Assessment of Telecommunications Infrastructure* Networks and Spatial Economics, 2: (2002) 35–63

Hepworth, M.E. (2007). *Information Technology as Spatial Systems.* Progress in Human Geography 11(2 ), 157–180

Isong E.B. (2015). *Modelling and Optimisation of Data/Voice Traffic in an established 3G Cellular Wireless Network.* Ph.D thesis in Information Management Technology submitted to Federal University of Technology, Owerri-Nigeria.

Inyang, I. B. (2010). *Akwa Ibom State. A Geographical Perspective.* Enugu: Immaculate Publication Limited.

Laurini, R. and D. Thompson. (1992). *Fundamentals of Spatial Information Systems*. London: Academic Press.

Radis, D., Bulavas, V. & Pleskis, K. (1997). *GSM Network Planning Tools on a base of ArcView GIS. Retrieved from* http://proceedings.esri.com/library/userconf/europroc97/10amfm/AM2/am2.htm.