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# Locating Global System for Mobile Communication (GSM) Base Stations Using Geographic Information System (GIS)

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## ABSTRACT

The global system for mobile communication (GSM) is planned to meet the needs of the whole subscribers. The number of subscribers increased as the population increased due to the acceptance of GSM services by the subscribers. Thus, there should be a way to monitor base stations that will meet the increasing demand of subscribers in any area as a population surge will lead to more subscriptions. This will allow GSM network operators to serve their subscribers better and ease network congestion. This work presents a review of mobile evolution from the first generation to the fifth generation. A review of global positioning system (GPS) technology and its applications to geographic information systems (GIS) was done. The coordinates of these base stations were taken using a GPS device. These base station coordinates were then exported to QGIS for the design of the map. Thereafter, the output map was then integrated into the website. The discussions on the results followed and some useful suggestions given will go a long way to help the operators of GSM in Nigeria and in general. If the propositions given are adhered to, it will go a long way to help the operators reduce congestion on their network and thereby increase the satisfaction of the subscribers.

***Keywords:*** Global system for mobile communication (GSM); Global positioning system (GPS); Geographic information system (GIS); Subscriber; MAP; Images

## 1. Introduction

Global system for mobile communication (GSM) wants to achieve communication anywhere, at any time, thus the increase in popularity and acceptance. As a result, different advancements in GSM are now available for a variety of applications. A base station acts as a gateway for, a wireless network in

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wireless communications, signals from a single or multiple mobile cellphones of a region. The base station routes the call to a close by, mobile terminals telecommunications connection in a wireless mobile system. The global system for mobile communication (GSM) was created with the intention of enabling communication everywhere and at any time, which allows calls between and within networks [1].

A cellular network, sometimes called a mobile network, is a type of communication network with a wireless link between end nodes [2]. Each cell in the network has at least one fixed-position transceiver, and the network is divided into three or more cell sites. These base stations offer network coverage to the cells thus allowing the content types of voice, data, and others to be transmitted. To avoid interference so as to provide quality guaranteed cell service, it employs a separate range of frequencies from its neighbours.

Meanwhile, a geographic information system (GIS) creates, maintains, examines, and maps many types of data. A geographic information system (GIS) and spatial data are effective means for preserving and visualizing georeferenced data, that is related to a specific location. Due to this reason, GISs have become indispensable in a wide range of sectors, such as mapping applications for land management, planning for urban development, facility construction and maintenance, as well as, operations optimization [3]. Thus, establishes the foundation for mapping and analysis, which are used in science and almost every industry. As a result, Spatial analysis and visualization-based location-based services are centred on location intelligence applications and geographic information systems (GIS). This study will allow the integration of MTN base stations to the GIS map in other to let the subscribers easily locate their cell sites and observe the activities going around them.

The specific objective of this work is to create a geographic information system (GIS) map for locating MTN base stations using Akure North and South Local Government areas of Nigeria as a case study. This study would enable a location-based service that would aid in the location of MTN base stations in the Akure Metropolitan Area so as to determine areas that are covered, or not thereby, giving operations a known area to work on and explaining their cell sites to unsatisfied subscribers. This work includes a Google Earth interface that allows service providers to track population and land use growth. In order to improve the effectiveness of this work, a database was built and linked to the GIS, thus aiding the operators in stormy capturing the GPS positions of the base stations. This will help the operators know when to expand the network's coverage area.

Section two of this work discusses the global system for mobile telecommunication (GSM), the geographic information system (GIS) and the global positioning system (GPS). Section three discusses the related literature; while a detailed architecture of the work is presented in section four. Sections five and six showed the implementation of the web-based used for the GIS map and the conclusion of the research.

## 2. Global system for mobile communication

Global system for mobile communications (GSM) is a mobile communication that is mobile stations transmitted using radio waves for calls wirelessly over a large area, to fixed landlines, or via the internet [4]. The cell phone is recognized as a mobile system with hardware, software, and a SIM card that actually allows the mobile phone number in this networked system. The cellular phone has undergone various developmental stages and advanced since it was first introduced as a mobile communication concept using two-way radio technology. Cellular phones were incredibly heavy, much like heavy when it was first introduced and this characterizes the first generation of GSM. Mobile communication has developed from a voice-only called first generation to one that can support other services, such as short messaging services and internet access.

The communications in the first generation (1G) were voice-only on mobile telephony and used analogue technology for its operation. In the second generation (2G), analogue technology was replaced by digital communication, which marginally enhanced wireless communication technologies. The basic demand for voice was met in the first generation, while the second generation brought high capacity and a wide coverage area. Data communication systems, that is, accessibility to the Internet on the phone, were the primary emphasis of the third-generation (3G) technology. The fourth generation (4G) gave access to a variety of communication technologies. 4G provides an answer to the quest for a combination of both voice and data on Internet Protocol (IP). 4G is IP-based communication that gives a true mobile broadband. The fifth generation (5G) technology has incredible data possibilities within the present mobile operating system, including the ability to connect unlimited call volumes and infinite data broadcasts [5]. The fifth generation of communication systems has low latency and fast speed when compared to the former generation [6].

## 2.1 Global positioning system (GPS)

The global positioning system is a satellite-based navigation system made up of a network of 24 satellites in six different orbital trajectories that are orbiting at a distance of 11,000 nautical miles in space [7]. The space segment, the control segment, and the user segment make up the three main segments of the global positioning system. The constellation of satellites that are currently in orbit, including working, backup, and inoperable units, makes up the space segment.

The users who have bought any of the several commercially available receivers are the only ones who make up the user segment. The control segment, the upkeep and proper operation of the satellites fall under the purview of (CS). Station keeping, or keeping satellites in their intended orbits, as well as keeping an eye on the health of their individual subsystems are included. The constellation of satellites in the space section is where users take their range readings. The user segment is made up of the user receiving equipment. A GPS receiver is a piece of hardware that receives L-band signals from satellites and processes them to calculate the user's position, velocity, and time (PVT).

The United States government has extended the capabilities of GPS to provide more benefits to the general public as a result of the widespread applications of GPS technology over the past decade. Three new signals have been added to the GPS: (i) a new L5 frequency in the ARNS band with a signal structure intended to improve aviation applications; (ii) Coarse Acquisition (C/A) code to L2C carrier (L2 civil signal); and (iii) a new military (M) code on L1 and L2 frequency for the DoD. Even in challenging circumstances, where C/A code tracking on L1 would be impossible, the enhanced GPS has the capacity to trace the signal.

## 2.2 Geographic information system (GIS)

A geographic information system (GIS) is a computer program that gathers, stores, validates, integrates, manipulates, analyzes, and presents information about locations on the surface of the Earth [8]. A geographical information system is used to manage many types of maps. These could be viewed as a number of distinct layers handling various types of maps. These may be seen as a number of levels, each layer containing information on a specific class of features. Each feature has a connection to both a record in an attribute database and a place on the map's graphical representation. Some of the software used for GIS are ArcGIS, QGIS, ArcMap among others. The software might vary quite a bit from one another for the reason of how each piece of software represents and manipulates geographic data, as well as the relational importance that each action is known [8].

## 2.3 GPS and GIS integration

Obtaining, storing, manipulating, analyzing, and displaying geographically referenced data are all possible with the use of a geographic information system (GIS) tool [1]. Data that are recognized by their geographic location are referred to as spatially referenced data like streets, light posts, and fire hydrants through geographic or spatial data can be acquired GPS, satellite imagery, and already-made maps are just a few examples of the sources. A GIS stores the information as a set of layers in the GIS database once it has been gathered. The information can then be analyzed using the GIS to help in decision-making [1].

The GIS field data is correctly and efficiently collected using GPS. GPS collects this information digitally, either in real-time or non-real-time. There are now several GPS/GIS systems in the market that offer centimeter-to-meter precision [9]. For each feature, most of these systems allow users to input user-defined attributes. There is also a built-in navigation feature for moving field assets. Some manufacturers of GPS receivers employ pen computer-based systems that enable data to be modified and displayed as it is gathered. Integrated GPS/GIS systems have applications in many fields, such as fleet management, forestry, agriculture, and utilities management [9].

## 3. Review of related literature

Kuboye et al. [1] presented the GSM base station monitoring using a geographic information system. They provided a location-based service that will help in the location of MTN base stations in the area so as to know which areas are still lacking. They designed a web-based geographic information system for locating MTN base stations in an area. Zu et al. [10] presented the development of a monitoring and management system for non-heritage tourist attractions based on mobile GIS and multisensory technology. They discussed the need to create a system for monitoring and managing tourist attractions that is rational and based on science. On the basis of mobile GIS and multisensory technologies, they explicitly discussed the creation of a monitoring and management system for scenic areas of intangible cultural assets.

Kim et al. [11] studied malaria vulnerability map mobile system development using GIS-based decision-making techniques. Making improvements to the usage of GIS data and multiplatform compatibility would help overcome the limitations of the earlier malaria risk analysis tools. Using GIS data, they created a mobile web-based malaria vulnerability map system. Baral [12] presented applications of GIS in community-based forest management in Australia (and Nepal). The paper explored the potential and constraints for the application of GIS technology in community-based forest management in Australia and Nepal. In the meantime, he studied GIS applications in forestry and community-based forestry across the globe. The paper found out what the stakeholders think about the need for GIS in CBFM in the Wombat State Forest (WSF), then prepared and showed a variety of GIS-related practical applications requested by community organizations in the WSF, and assessed reactions and issues. It also displays the GIS applications' advantages and disadvantages for community forestry as well as compares and contrasts Australian GIS application findings with Nepal's community forestry (CF).

Zhang [13] presented a classroom teaching evaluation and instruction system based on a GIS mobile terminal. The author desires to raise the standard of instruction in the elementary, secondary, and tertiary institutions as well as the universities throughout the nation. The work recognizes the importance of proper teaching evaluation and guidance given the current levels of education and instruction. Using GIS mobile terminals, its teaching assessment system was created that may enhance teacher-student contact and teaching diagnosis and aid further improve teaching. Chen et al. [14] provided a GIS-based method for predicting the field strength of mobile communication networks. They intend to assist network operators in making the greatest investments possible to increase the network's capacity and quality. The goal is to use a GIS to analyze the field strength coverage, visualize the projected signal strength, and predict the coverage of the city's cellular network. Maciej et al. [15] presented a research work on mobile GIS applications for environmental field surveys. They contributed to raising awareness of such mobile device options. Such software could improve data quality, accuracy, and workflow, which can aid in achieving study outcomes. They showed the usefulness and accessibility of mobile apps as a tool for doing field research.

Hariani and Astor [16] presented a research topic depending on distance, duration, congestion, and land usage, in determining the fastest route for fire engines in Cirebon City. They want to help identify several alternative routes that can be determined for the fire station trucks to the location of the fire and calculate the travel time on each alternative routine in Cirebon City. Then determined the best alternative routes for the fire trucks from the fire station to the fire in Cirebon City. Das et al. [17] presented a research project on the road network analysis of Guwahati city using GIS. In order to prevent problems like traffic congestion delays, increased vehicle operating costs, and road accidents in Guwahati City, they emphasized the necessity for and limitations on traffic movement. They analyzed a digitalized road network of the concerned city and found the shortest route between two places. Yang et al. [18] presented a research evaluation of hotel locations being done using a combination of web GIS and machine learning techniques. They were aware of the requirements for an accurate, unbiased, and objective evaluation of hotel locations. By developing an automated web GIS tool, they offer a novel method for assessing possible hotel property sites.

Ahmed et al. [19] engaged in GIS-Network Analysis for the Greater Cairo Area's Road Networks. They discovered that it is challenging to locate a specified destination, particularly using forest fire experts, opinions and GIS remote sensory in emergency circumstances in Cairo. Amiri et al. [20] worked in order to effectively suppress and control fires, prompt fire detection and early notification to fire stations are essential. The goal of the project was to create a method using a geographical information system (GIS) to decide where to place fire lookout towers based on the recommendations of forest fire specialists. Aouadj et al. [21] presented a contribution of GIS and remote sensing for the risk mapping of soil water erosion at Saida province (Western Algeria) in order to establish a strategy for employing remote sensing, the digital terrain model (DTM), and geographic information systems to map regions at risk of water erosion, they are worked on the contribution of GIS and remote sensing for risk mapping of soil water erosion at Saida Province (West of Algeria).

## 4. Model architecture

The architecture to build a geographic information system (GIS) based system for locating GSM base stations is seen in **Figure 1**. It has several phases namely the data acquisition, data preparation, data conversion, digitalization, and website interface (result).

### 4.1 Data collection

Data collection for this work was done primarily by using GPS. It was collected through the sighting of base stations of MTN Nigeria in the North and South local governments of Akure, Ondo state, with the use of a global positioning system (GPS). Akure is the state capital city of Ondo state in the Southwest geopolitical zone of Nigeria. MTN Nigeria is

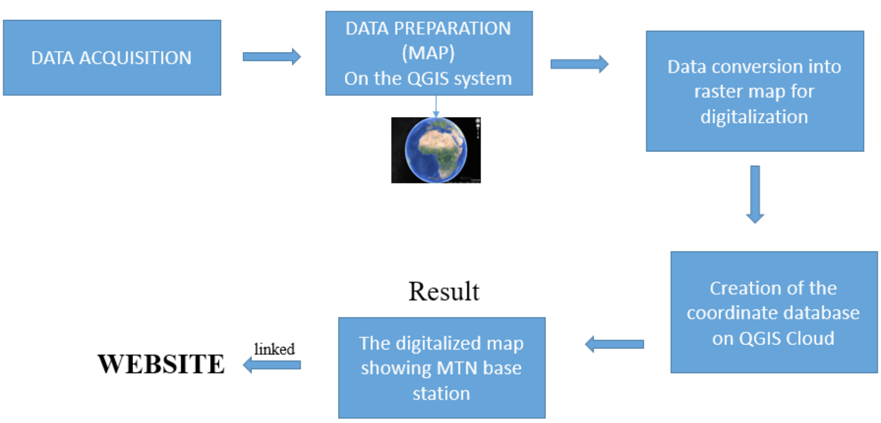


**Figure 1**. System architecture.

one of the GSM operators in Nigeria that has wide coverage over nearly all the geo-political zones in Nigeria. The data to the base station were recorded showing the location of each base station with their longitude and latitude using the global positioning system (GPS) device.

### 4.2 Data preparation

In the data preparation stage, the data which includes the site name of each base station location with the longitude and latitude were saved and converted to a CSV. file on an Excel spreadsheet. The file was saved and uploaded to Google Earth. It is a virtual globe, map, and geographic information system that depicts the earth by superimposing pictures from satellite imagery, aerial photographs, and a 3D GIS globe. As shown in **Figure 2**, users can view things like cities and homes by gazing perpendicularly down at the screen or at an oblique angle thanks to Google Earth's presentation of satellite photos of different resolutions of the Earth's surface.

### 4.3 Georeferencing images

Georeferencing refers to defining something's presence in space [22]. That is, identifying its position using coordinate systems or map projections. It is employed to describe the relationship between coordinate systems and raster or vector images. Four specific control points on the image with a red, orange, purple and yellow dot can be seen. Each of the site locations is in yellow arrow point as shown in **Figure 4**. The coordinates (longitude and latitude) of the MTN base stations were recorded at each location. Then, QGIS 3.10 is used for georeferencing. The coordinates are then inputted so that the images can be georeferenced. Geospatial data are viewed, edited, printed, and analyzed using QGIS, QGIS is a cross-platform desktop geographic information system (GIS) tool that is free and open-source. Users can generate, edit, and export graphical maps as well as analyse and alter geographical data using geographic information system (GIS) software like QGIS. QGIS supports raster, vector, and mesh layers. Vector data characteristics come in point, line,


**Figure 2**. The site locations are shown on the Google Earth.

and polygonal varieties. The application supports a range of raster image formats, the manipulation of geospatial data to acquire high-quality insight, and the ability to geo-reference images [23]. The location of the cell sites is indicated as shown using the location of the base station on the georeferencing points in **Figure 3**. It is clearly seen that some occupied areas have not been adequately covered by GSM operators. The places are shown as very distant base stations from one another. Some areas do not yet have base stations therefore to cell site covered the place.

In such places, the subscribers will be experiencing an ephaptic signal connection. Thus, the importance of this type of work is to let the operators know where to erect their base station so as to subscribers which will lead to optimum gain for their operators.

## 4.4 Creating a digitized map

Upon the capturing and georeferencing of the images, with the aid of an analysis tool in QGIS 3.10 the images will be connected. Images are preserved during the capture process in a manner that causes them to overlap. This overlap facilitates the seamless integration of all accessible photos into a single, complete image. Thereafter the border between Akure North and South local government was cut out and then converted to shape files as shown in **Figure 4**.

The coordinates of the base stations were collected, saved and inputted on an Excel spreadsheet. They were saved as CSV files and then they were exported to QGIS so they can be inputted in the attribute table. The event theme was then added using these coordinates. When this is done and the coordinates are activated, they immediately take their location on the map as shown in **Figure 5**.

As observed in **Figure 5**, the location of the already existing base station is clearly seen and the unoccupied area is also shown. As a result, the operators can now explore the yet to occupied areas for the possible erection of base stations so as to let

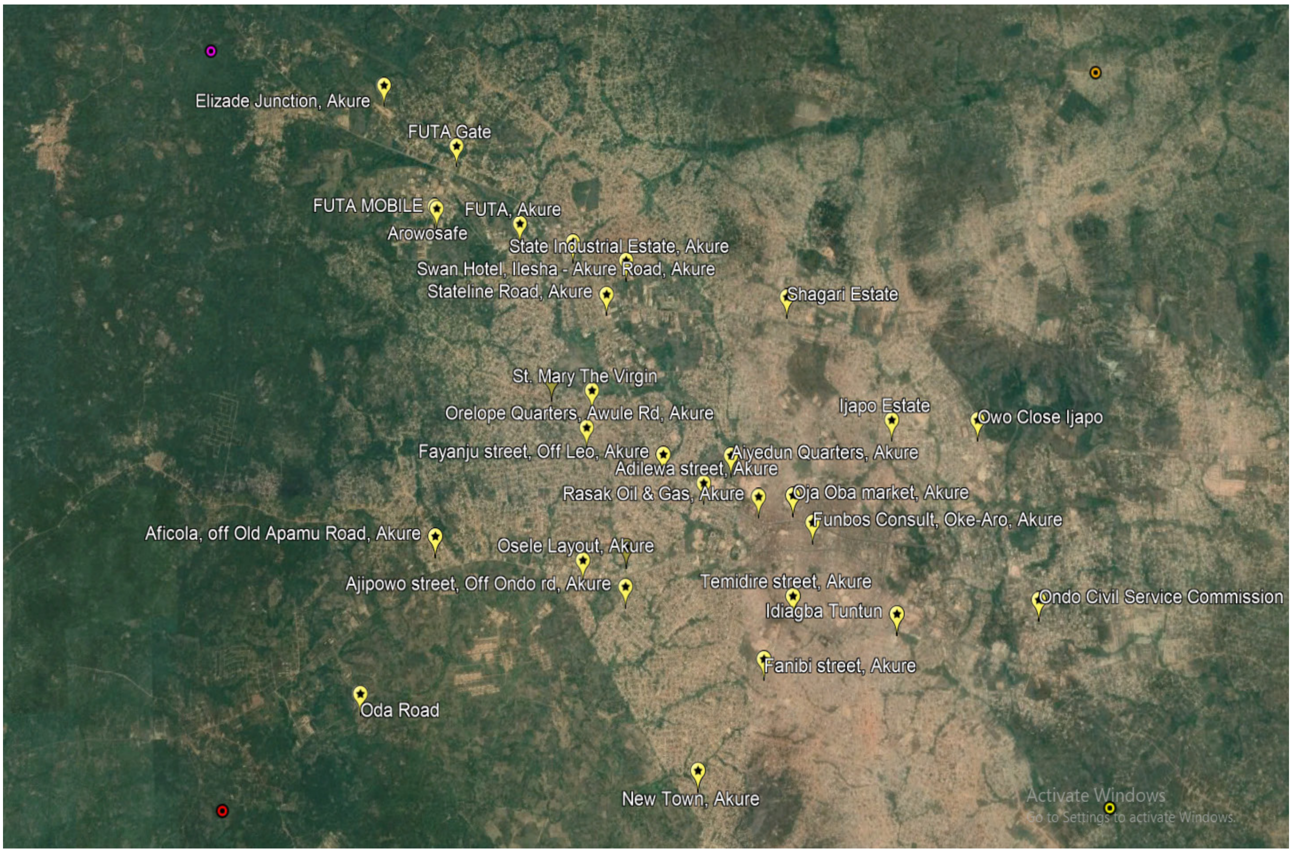


**Figure 3**. Geo-reference points and the site locations are shown on QGIS display.

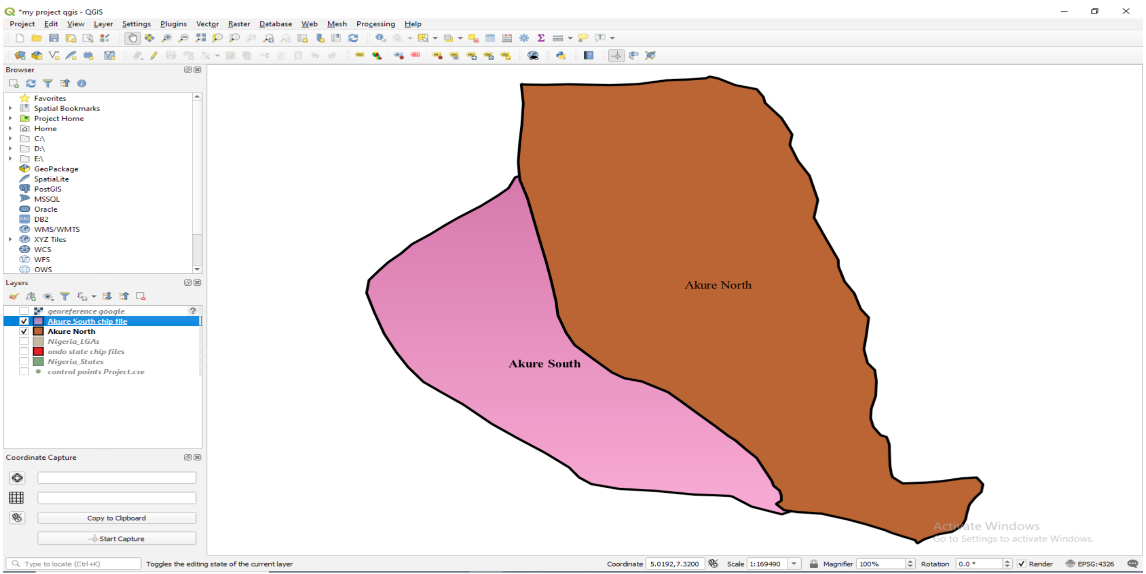


**Figure 4**. A digitalized map of Akure South & Akure North.

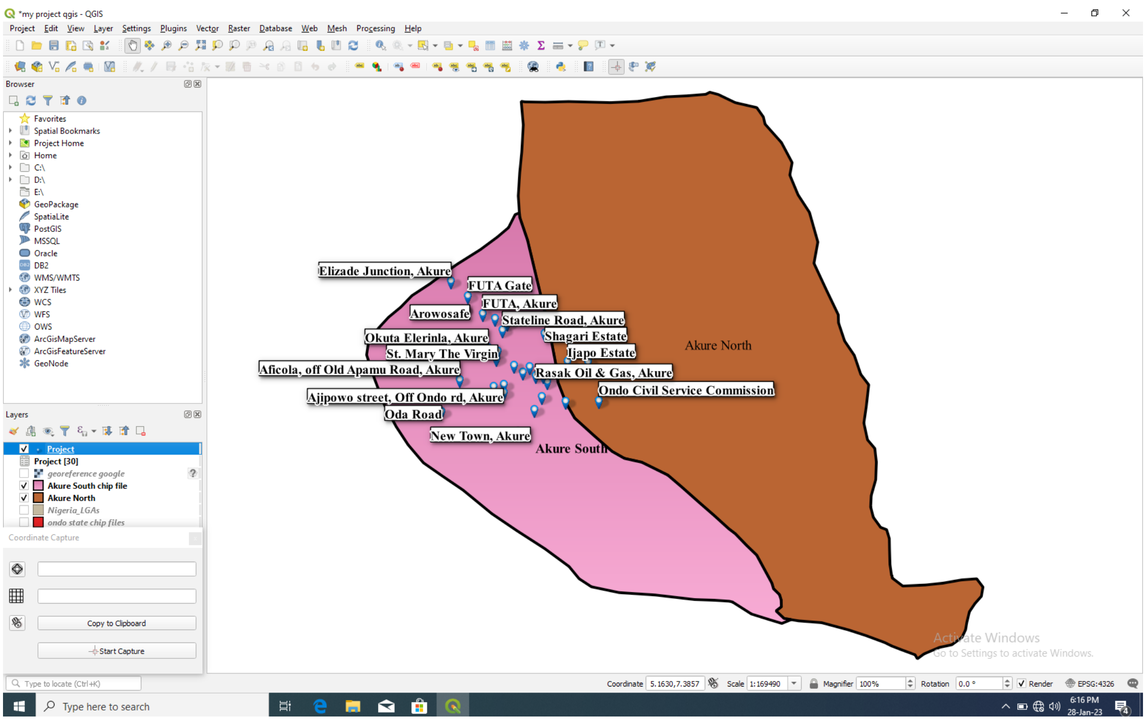


**Figure 5**. A digitalized map of Akure showing the base stations.

their signals cover the affected areas, thereby giving a level of satisfaction to subscribers who might have been experiencing epileptic communication signals of their GSM mobile stations. Thus, it will directly attract more subscribers and lead to increasing revenue for operators and satisfaction of the subscribers.

## 5. Web implementation

The digitalized map of Akure North and South local government that depicts the locations of the base stations was then integrated into a website so that it could be accessed online. The GIS Map page shows the digital maps of Akure North and South local governments indicating where the MTN base stations are located. On clicking the page, it displays the base station location; by clicking on a location it displays the site name, latitude and longitude respectively as shown in **Figure 6**.

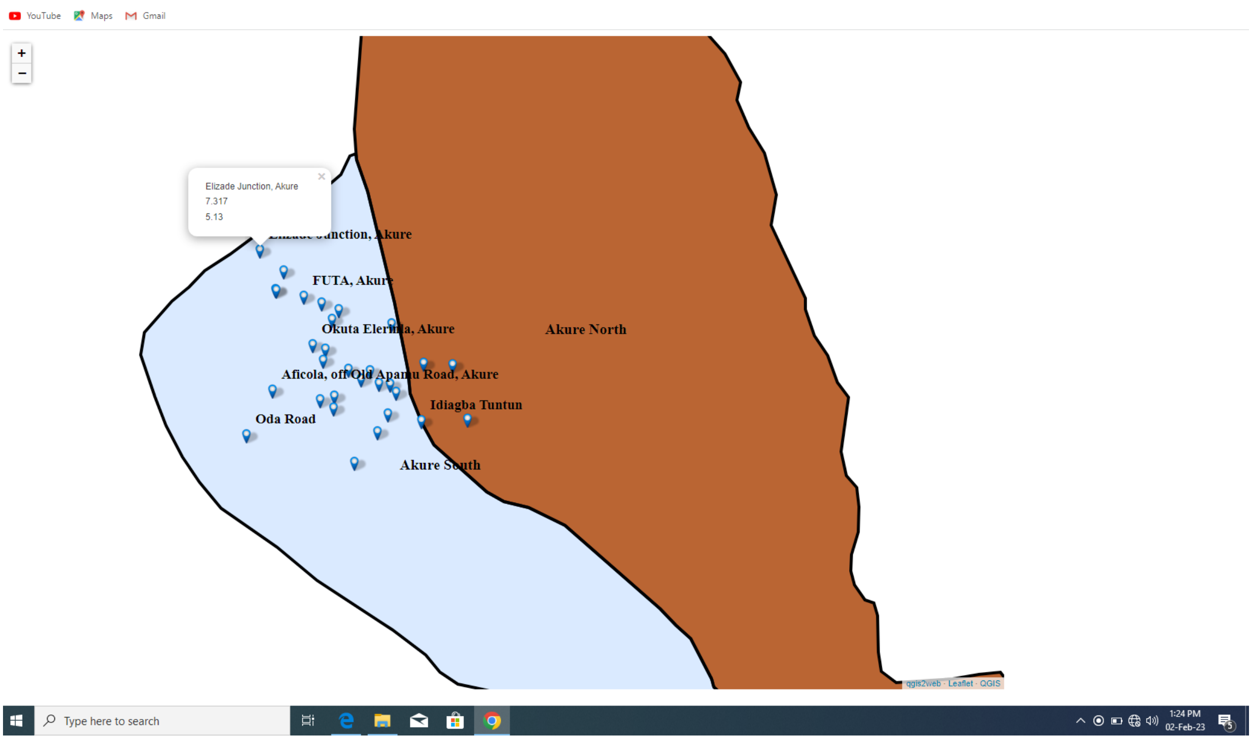


**Figure 6**. Web-based GIS map showing the base stations.

## 6. Conclusions

The work shows where the base station is needed to bring optimum satisfaction to the subscribers which will directly impact positively on the optimum profits returns of the operators. If these identified areas do not have enough or adequate base stations, the subscribers experience low or no signals. Thus, operators will be assisted in improving their services if implementation of this work is done. Operators should offer a map that shows the number and locations of their base stations in order to monitor the population growth so as to know when to install new base stations to better serve their users and prevent signal failure and other issues. This work has demonstrated the ability of GSM operators to locate and keep an eye on their base stations.

## Author Contributions

Bamidele Moses Kuboye was the one who generated the concept note, supervised the design and implementation and the preparation of the publication.

Victor Gbenga Abiodun was involved in the design, and implementation of the work.

## Conflict of Interest

There is no conflict of interest.

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