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Geospatial Mapping of Signal Strength of Telecommunication (Mast) in Some part of Minna Metropolis Chanchaga Local Government, Minna Niger State.

Abdulmalik M. Olaniyi[a], *Muhammed O. Jamiu*[a], *Mahmud Baba*[b], *Zitta Nanpon*[c]

Department of Surveying and Geoinformatics, Federal University of Technology, Minna Niger State
[a]m.olaniyi@futminna.edu.ng
[a]horlarleycon3@gmail.com
[b]mahmud.baba@futminna.edu.ng
[c]zitta.nanpon@futminna.edu.ng

Abstract

Geospatial mapping of telecommunication signal strength (SS)is a critical technique used to visualize and analyze the distribution and quality of wireless communication coverage across various terrains and environments. This approach integrates Geographic Information Systems (GIS) with signal propagation models to assess how factors such as terrain elevation, infrastructure, and land use influence signal strength. By providing adetailed spatial understanding of coverage areasnetwork (MTN, GLO, AIRTEL AND ETISALAT), geospatial mapping aids in optimizing the placement of telecommunication infrastructure, identifying and addressing coverage gaps, and improving overall network performance. The technique is invaluable for network planning, particularly in the expansion of services to rural and underserved areas, as well as in urban environments where signal interference and obstruction are common. Furthermore, it supports regulatory compliance, ensures equitable access to communication services, and contributes to environmental sustainability by guiding the strategic placement of infrastructure. As telecommunication networks continue to evolve with advancements like 5G, geospatial mapping remains an indispensable tool for ensuring efficient, reliable, and high-quality communication services.

Keywords: 5G, AIRTEL, GIS, GLO, MTN, ETISALAT

1. Introduction

The influence of telecommunication on the socio-economic development of global cities is substantial. This technology facilitates the rapid and efficient transfer of various media forms across extended distances through diverse systems, including wires, radio, optical, and electromagnetic channels. The advent of the Global System for Mobile Communication (GSM) in Nigeria in 2001 marked a period of exciting possibilities, attracting numerous Nigerians to exploit the burgeoning sector. By mid-2002, the subscriber count in Nigeria reached approximately 2.27 million, skyrocketing to over 143.05 million by 2015 (National Bureau of Statistics, 2015). Nigeria's four major GSM service providers, namely MTN, GLO, Airtel, and 9mobile (formerly Etisalat), exhibit varying subscriber percentages, with MTN leading at 61.21 million subscribers (42.8%), followed by GLO at 21.0%, and Airtel and 9mobile at 20.5% and 22.3 million subscribers (15.7%), respectively (NBS, 2015).

The surge in GSM users underscores the imperative for telecommunication network providers to address the communication needs of this rapidly expanding user base (Olukolajo *et al.,* 2013). To ensure comprehensive network coverage, many telecommunication stations strategically position themselves in close proximity to their target users. These stations, along with cellular telecommunication masts, constitute crucial components of the infrastructure essential for an effective communication system. According to (Hart *et al.,* 2012), telecommunication masts are towering structures designed to support antennas for telecommunications and broadcasting, ranking among the tallest man-made structures. A typical telecommunication mast tower comprises a steel beam frame with a height ranging from 25 to 55 meters and a concrete base of approximately 144m^2 (12x12m). The structure houses antennae, transmitters, and receivers, capturing high-frequency radio waves from cell phones. Antenna ranges vary from 1.5 to 2.4km to as long as 48 to 56km. Enclosed by either block walls or steel poles and wire, the mast structures include a power source and various accessories, catering to the diverse needs of service providers (Hart *et al.,* 2012).

2. Study Area

Minna Metropolis including (Albishiri, Gurara, Gbeganu, Fadukpe, Kure Market, Kpakungu) in Niger State which is situated between latitude 8°00' to 11°30' North and longitude 03°30' to 07°40' East. It shares borders with Zamfara State to the North, Kebbi State to the West, Kogi State to the South, Kwara State to the South West, Kaduna State to the North-East, and the Federal Capital Territory (FCT) to the South East.

Figure 1: Satellite view of the study area (Source: SAS Planet)

3. Methodology

This section addresses the overall structure of the project research. It details the general procedures and methodologies employed, including the types of data collected and their sources, the instruments and materials used for the project's successful implementation, as well as the methods of data processing and presentation. The framework of the methods used are presented in Figure 2.

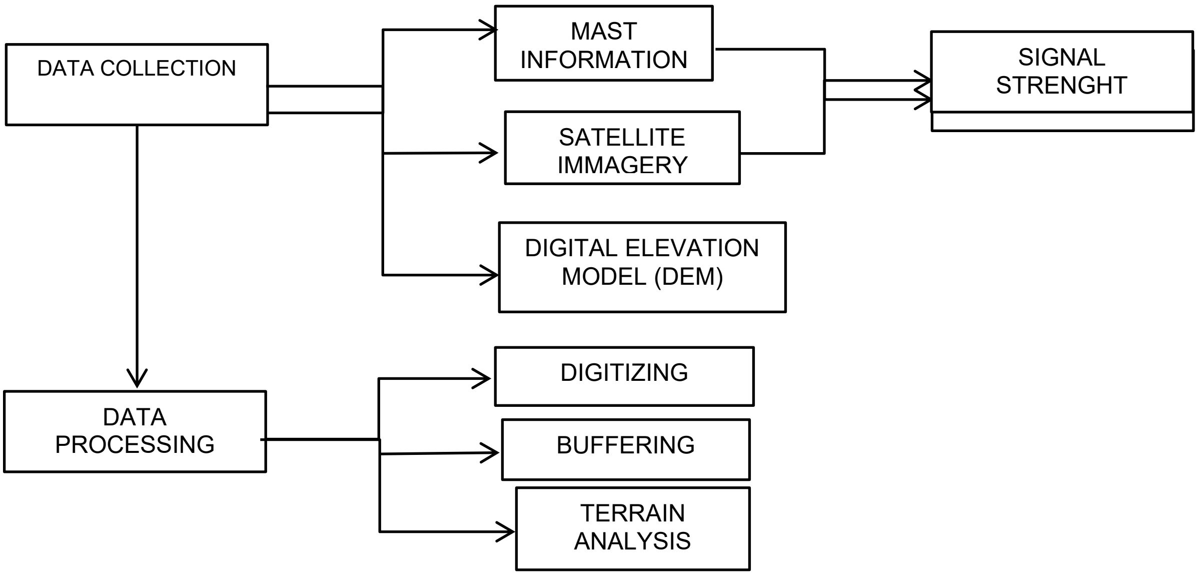

Figure 2: Conceptual framework

3.1 Data collection

The Primary Data acquisition was carried out on the site. These data include mast ID based on the cell type as presented in Table 1, the coordinates of the mast obtained using Hand held GPS and the signal strength of the mast (morning observation) using cell phone (Tecno Pova LD7) and extent of coverage of the mast as shown on Table 2. The secondary data was downloaded which are satellite imagery of some part of minna metropolis, which include: Albishiri, Askia Madinat, Fadukpe, Gbeganu, Gurara, Kasan Gwari, Kure Market, and Kpakungu. The satellite imagery was downloaded from SAS Planet. SAS Planet is a program designed for viewing and downloading high resolution satellite Imagery and conventional maps which are already been Geo-referenced. Digital Elevation Model (DEM) i.e., the 3D representation of s terrain's surface was created from terrain data. A DEM resolution of 30metres was obtained from USGS (United State Geological Survey). This DEM was processed to derived slope, aspect and contour which is correlated with signal strength data to assess the impact of terrain on signal propagation.

Table 1: The Breakdown of Service Providers in Some Part of Minna Metropolis

S/N	Cell type	No. Of Cell
1.	Mtn Nigeria	08
2.	Globacom	05
3.	Airtel	06
4.	Etisalat	02

Table 2: The Breakdown of Service Providers in Some Part of Minna Metropolis

S/N	Name Of Location Of The Mast	Name of service Provider	Mast's Co-Ordinate Easting(m)	Mast's Co-ordinate Northing(m)	Signal Strength (dbm)
1.	Albishiri	MTN/AIRTEL	226890.150	1060941.334	73/75 dbm
2.	Askia Madinat	MTN/AIRTEL	228811.541	1063430.773	68/70dbm
3.	Fadukpe	GLO	227799.131	1063483.812	74 dbm
4.	Fadukpe	AIRTEL/ETISALAT	227776.513	1063879.395	71/72 dbm
5.	Fadukpe	MTN	227934.993	1064087.900	68dbm
6.	Fadukpe Bosso R.	AIRTEL	228626.945	1064496.162	71dbm
7.	Gbeganu	MTN/GLO	227725.073	1062388.025	75/78dbm
8.	Gurara	GLO	227292.799	1061227.296	71dbm
9.	Kasan Gwari	MTN/AIRTEL	228190.949	1065092.111	71/74dbm
10.	Kasan Gwari Estate	MTN	228329.844	1065174.693	70dbm
11.	Kure Market	MTN/GLO	228885.760	1063914.110	72/74dbm
12.	Kpakungu	MTN/AIRTEL	229070.073	1061824.377	71/69dbm
13.	Kpakungu	GLO/ETISALAT	229100.976	1061743.488	69/73dbm

3.2 Data processing

The data processing includes adding attribute data of the masts to ESRI ArcGIS environment and all other data including the satellite imagery which are already been geo-reference, data base creation and digitization of the satellite imagery to obtain a vector-based data in relation to primary data observed. The Satellite imagery of the study area was later taken into ArcCatalog environment where it was spatially referenced to WGS 1984 Zone and digitized after creating shape files that holds the attributes of spatial features on being depicted.

3.2.1 Digitizing

After the satellite imagery was added in the ArcGIS environment, creation of shape file are made for each features like Buildings Masts, Roads, Rivers. Then the Editing was started by click on the Editor toolbar and select "Start Editing", The editing layer was chosen by select the feature Template of Each features. In the "Creature Features" window (usually on the right side), each feature template was selected that corresponds to the type of feature that was digitized (point, line and polygon). When the digitizing was finished then "Stop Editing" was clicked. And the editing was saved.

3.2.2 Buffering analysis

Service areas where each of the mast signal strength reached was depicted by buffering. It involves creating a zone around a spatial feature, typically to a specific distance of radius (300m, 700m and 1000m) to assess the impact of the signal on the zones or areas covered on the Digitized map.

3.2.3 Terrain analysis

The process of DEM was done to derive slope, aspect, contour, and viewshed maps, which were then correlated with signal strength data to assess the impact of terrain on signal propagation. To process slope, aspect, contour and viewshed the downloaded DEM from USGS was add to GIS environment through the clicking of add data tools, by clicked on Arc tools box. The arc tools box shows spatial analysis tools which also shows a lot of analysis tools when clicked, among them is surface analysis tools. Surface analysis tools were clicked and shows slope, aspect, contour, viewshed, and the likes, then the slope, aspect, contour, and viewshed was derived respectively.

4. Result and discussion

4.1 Mapping location of telecommunication mast

In converting the satellite imagery of some part of Minna metropolis Chanchaga Local government into vector format, a procedure called digitization was carried out. After creating the shape file, the masts positions were located and all other features like (roads, buildings, rivers) on the scene of the imagery was converted in points, lines and polygons based on their spatial feature and also shows the location of each mast in the study areas. Which the mast was represented with the symbol shows red and green colour as shown in Figure 3.

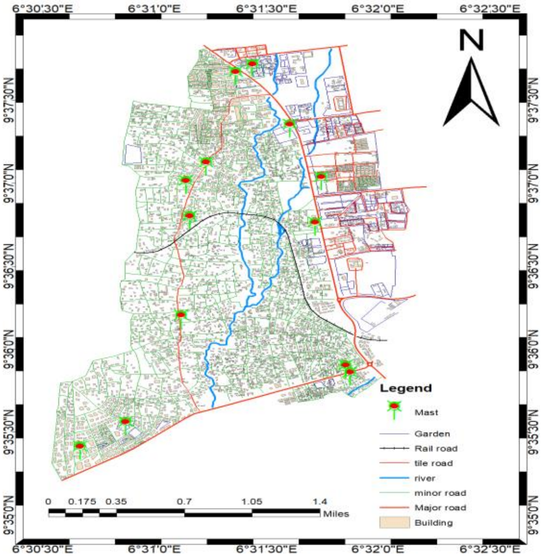

Figure 3: Map showing location of telecommunication mast

4.2 Buffering analysis

This shows the buffering analysis of each mast's radius (300m, 700m, 1000m) of the study areas respectively, that shows the area of strong and weak signal strength. In this analysis the masts radius 300m, 700m, 1000m coverage. It shows the map when the signal was strong, weak and very weak respectively. In telecommunication, buffer zones are typically defined around signal sources like Mast. These zones represent areas at varying distances from the source and were used to estimate signal strength. For instance, buffer zones were created at intervals of 300 meters, 700metres and 1kilometer to represent when the signal is strong, weak and very weak. In radius 300metres coverage, people living within the radius coverage will enjoy the network signal i.e., they will easily access to strong network. In radius 700metres coverage, users around the area experienced weak signal strength i.e., they will not easily access to the network unlike the people living around the radius 300metres. In radius 1000metres coverage people living around the radius will be experienced very weak signal i.e., very poor network.

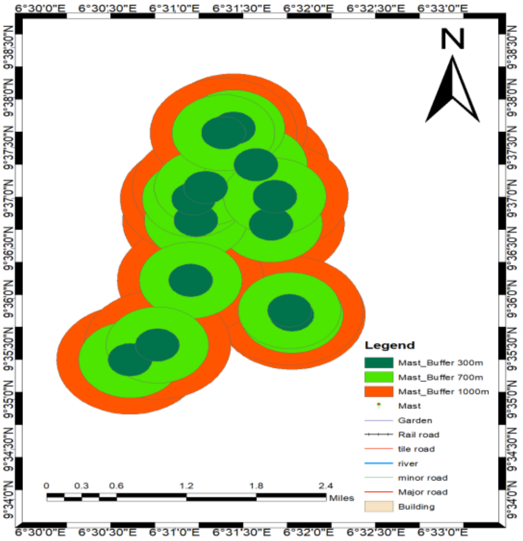

Figure 4: Map showing buffering analysis of masts radius 300m, 700m, 1000m coverage

4.3 Terrain analysis of the study area

Terrain plays a crucial role in the propagation of telecommunication signals. Factors such as slope, aspect, contour and viewshed all influence how signals travel through space. Higher elevations typically provide better signal coverage due to reduced obstructions, while lower areas, particularly those surrounded by hills or mountains, may experience weaker signals due to shadowing effects. The slope of the terrain can lead to signal scattering, reducing the strength in areas with steep inclines. Aspect, or the direction a slope faces, also affects signal reception; slopes facing away from a tower may receive weaker signals due to lack of direct line-of-sight. Slope is the steepness or incline of the terrain. The slope is a critical factor in signal propagation as shown in Figure 6. Slope has a significant impact on the geospatial mapping of telecommunication signal strength. In the context of radio frequency (RF) propagation, slope affects how signals travel over terrain and interact with obstacles. The aspect map for the study area was developed as represented in Figure 7. The Aspect shows the direction that a slope faces, which can affect how a telecommunication signal is received. This is the compass direction that a slope faces. The impact of aspect on signal propagation is closely related to how signals interact with the terrain and environmental factors.

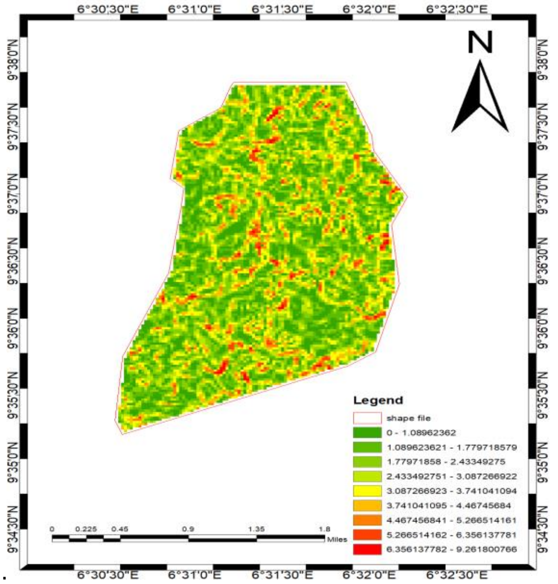

Figure 6: Map showing slope of the study area

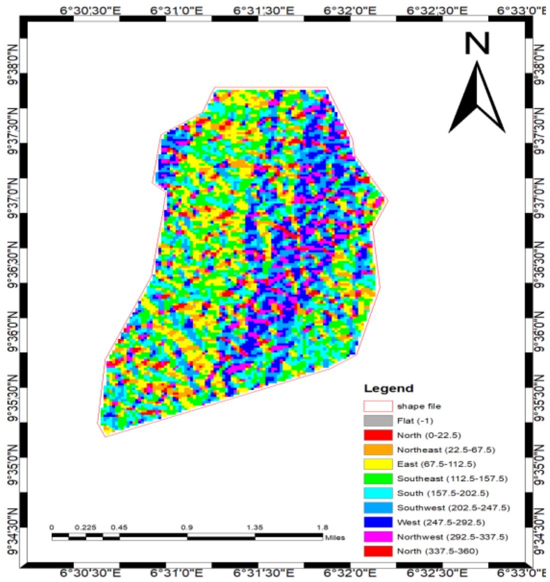

Figure 7: Map showing Aspect of the study area

4.4 Contour and viewshed of the study area:

Contour analysis helps in understanding the terrains impact on signal strength. Contour lines represent the elevation and shape of terrain on maps. It directly affects how signals travel over land by influencing elevation, slope and the shape of the terrain, they affect line of sight, Signal diffraction, reflection, and path loss. The contour for the study area is presented in Figure 8. A Viewshed represents the geographic area that is visible from a specific observation point, considering the terrain's elevation and observer's height. Viewshed Analysis is crucial tool in this study, it identifies the areas that are visible from the mast location based on terrain and elevation data. It determines whether there is a direct line of sight between a transmitter and a receiver, which is crucial for understanding where signals can propagate effectively. The Viewshed map of the study area is represented in Figure 9.

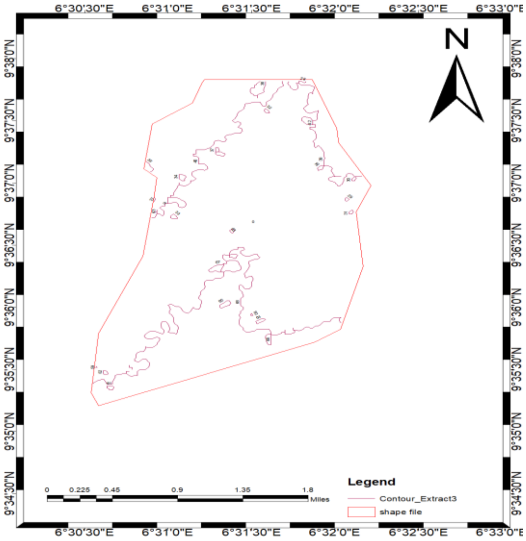

Figure 8: Map showing Contour of the study area

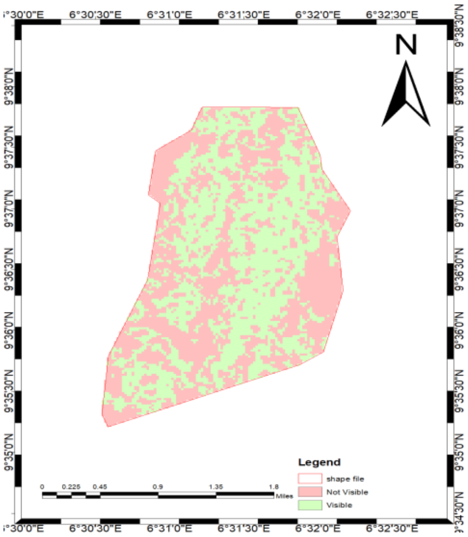

Figure 9: Map of Viewshed of the study area

5. Conclusion

Geospatial mapping of telecommunication signal strength is essential in the planning, optimization, and maintenance of wireless communication networks. By integrating Geographic Information Systems (GIS) with signal propagation models, this approach allows network operators to visualize and analyze how various factors such as terrain, infrastructure, and environmental conditions affect signal coverage and quality. Geospatial mapping is very important in ensuring telecommunication networks are efficiently designed to provide robust and reliable coverage, thereby enhancing user experience and ensuring access to communication services across diverse geographic areas. It also supports regulatory compliance, economic efficiency, and the sustainable expansion of telecommunication infrastructure.

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