THE USE OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM (GIS) IN EXECUTING TERRAIN ANALYSIS FOR SITING GLOBAL SYSTEM FOR MOBILE COMMUNICATION (GSM) TRANSMITTING MASTS

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Abstract
This paper used the GIS to create a virtual reality of what exists on the ground at present, with the hope that it will aid in explaining why GSM reception is poor at the Federal University of Technology, Yola (FUTY). Secondly, 'what-if' scenarios were created in order to locate transmitting sites that will ensure maximum coverage at the FUTY. A descending arm of the Bagale hills was identified as the obstruction causing partial blockage, hence partial reception at the University. Viewshed analysis revealed that moving one of the transmitting masts westwards, would eliminate the poor reception at FUTY. The paper revealed the necessity for proper GIS terrain analysis prior to siting GSM masts.

INTRODUCTION

Ever since the introduction of the Global System for Mobile communications (GSM) in Nigeria, telecommunication has gradually become very accessible to ordinary citizens. As competition became fiercer among telecommunication companies, so the cost of owning a handset continues to drop. Affordability of telecommunication systems is however not the only advantage the GSM brought to Nigeria. It has also reduced the rate at which people travel, since it is now easier to make the call rather than make the trip. The effect of distance in commercial, governmental, communal and even family activities was suddenly reduced to the barest minimum. This is, however, not saying that problems don't exist with the use of the GSM.

One of the most persistent problems faced by GSM subscribers is poor network coverage. This is the situation being experienced by Mobile Telecommunication Network (MTN) subscribers living at the outskirts of Jimeta-Yola metropolis. The experience of subscribers living at the Federal University of Technology, Yola is a typical example; and will be used as a case study in this paper.

At FUTY there are three categories of GSM reception. The first category is areas which have full reception most of the time. The second category is areas experiencing fluctuations in reception. Fluctuations were usually of two types – rapid fluctuations (where changes in reception occur within seconds); and diurnal fluctuations (where reception exists in the night, but vanishes completely during the day). Finally, the last category is those areas where reception is always absent. It is very unlikely that MTN designed the situation to be so. This is because the University has the highest cluster of MTN subscribers in the entire city. What then has MTN done wrong? How can the wrong be rectified? These are some of the questions this paper wants to address.

The incidence of poor network coverage is closely linked with base station (BS) planning. The GSM uses series of radio transmitters known as base stations (BS) to connect the cell phone to the GSM network. Each BS is also termed a cell, so named because it covers a certain range within a discrete area. Base stations are all

interconnected, which is why one can move from one cell to another without loosing connection.

The limiting factor in the range of a base station is the receiving range rather than the transmitting range. The receiving range is determined largely by site noise and interference factors (Kinley, 2004). It was very difficult getting information about the receiving range of the MTN base station. This is because MTN engineers are located outside the state. The receiving range used in this study was estimated at 12km. This figure was determined by a simple logical deduction. The distance from the closest base station to the FUTY campus is 12km (measured on the satellite image). If some parts of the campus receive full reception, throughout the day, then the receiving range cannot be less than 12km.

Many terrain-related problems have been solved successfully using the geo-spatial analysis capabilities of the GIS. Goran & Finney (1991) reported how the US military constructed an 87ft radar tower at Fort Lewis, Washington for the purpose of communicating with aircrafts during aviation training. About 500ft radius of trees had to be cleared around the tower to afford space for radar transmission. However, it was later discovered that obstruction from trees still posed a problem, and an additional 1000ft radius (making a total of 1,500ft radius still needed to be cleared. Using the GIS line-of-sight ability, maps showing the areas visible from an observer's location were produced. Results showed that trees and hills just east and south west of radar tower could easily interfere with radar transmission, even after the 1,500ft radius clearance. The analysis also showed that adding 50ft to the tower's height would allow the needed clearance, without any need to clear 1000ft radius of trees.

Likewise, Kevin *et al* (1994) reported how an integration of the GIS and Computer Aided Design (CAD) can be used to visualize landscape changes. The main goal of the project was to develop a modeling process whereby features and their attributes in a GIS database are used to construct 3-Dimensions (3D) objects in a CAD system, which when assembled together constitute simulated views of the visual landscape under consideration. Results showed that the application is most appropriate for visualizing regional landscape change, rather than specific land parcels. When compared to photographs, vegetation data were found to contain the most inaccuracies.

Other applications includes range land planning and management – where the slopes of training sites were identified before military training (Dilks & Finney, 1994); Landslide prediction – where watershed analysis was conducted on the digital terrain
model of study area in order to predict landslides (Merry & Wu, 1994); and flood risk mapping – where a digital terrain model, a soil strength map and a land use map were generated, and overlaid digitally to produce the flood risk map (Balogun & Okoduwa, 2000).

STUDY AREA

Jimeta-Yola, the capital of Adamawa State is located in the North East of Nigeria. With a population of about 290,114 (1996 census), the city is actually two settlements joined by an expressway. The ancient town of Yola, sit of the Lamido, is located at the south while Jimeta, the commercial nerve centre of the state, and also home to the non-indigenes is located in the north. Moving further north, about 10km away from Jimeta, at the other side of the River Benue is the Federal University of Technology, Yola. A very conspicuous topographic feature in this area is the Bagale hills, which rises to a height of about 2000m.

Between November and February, Jimeta-Yola is under the influence of dry continental and relatively stable air masses from the northeast (the harmattan). Rainfall increases steadily from April to June in the area. Temperature in this climatic region is high throughout the year because of high radiation income, which is relatively evenly distributed throughout the year (Adebayo, 1999).

There are three MTN transmitting masts in the city. The first located at a private residence in Jimeta (Alhaji Bornoma's residence) has Universal Transverse Mercator (UTM) coordinates of 220984N, 1025697E; is 41m high. The second mast located behind the Guaranty Trust Bank, Jimeta has a UTM coordinate of 218732N, 1025511E. This mast is the shortest with a height of 24.7m. This is probably because it is very close to the airport. The last mast was sited at Yola-town post office. It has a UTM coordinate of 223464mN, and 1017963mE and a height of 36.7m

METHODOLOGY

Overview:

Using the ILWIS GIS package a digital elevation model (DEM) of the study area was first created. A satellite image of the area was next draped on the DEM, to give a 3D view of the study area. The DEM was exported to IDRISI for Windows where the viewshed analysis was executed. Viewshed analysis was first run based on the location of the existing viewports (i.e. the transmitting masts). One of the viewports was then moved to another part of the study area (what-if scenario), and another viewshed analysis was conducted.

Data:
The data used consisted of:
- 4 topo sheets (Girei N/W, Girei S/W, Numan N/E and Numan S/E) - 1974
- 2 scenes of SPOT XS images (i.e. Scene K84, J331 & K84, J332) - 1995

Hardware:
- Garmin 12 GPS
- Dell latitude laptop computer
- T45xi Hewlett Packard printer, scanner & photocopier

Software:
- D-View (Software package designed for opening SPOTXS images)
- Integrated Land & Water Information System (ILWIS) 3.0 Academic (A raster based GIS package)
- IDRISI32 for Windows (A raster-based GIS package)
- CorelDraw Version 10 (Package dedicated to manipulating graphics)

Creating the DEM:
The digital elevation model was created in 3 stages:
- Creating background image
- Digitizing contour lines
- Interpolation of contour values

Creating Background Image:

Relevant portions of the 4 topographic sheets were scanned into the computer. The topographic sheets were scanned into CorelDraw package. Concatenation was done carefully in CorelDraw, making sure that contour lines of a specific value in one sheet aligns precisely with contour lines of the same value in the

other sheet. This way, the four topo sheets were joined together into one whole piece. After concatenation, the four objects were grouped into a single computer object and subsequently exported to ILWIS GIS package.

In ILWIS, the topo sheet was geo-referenced by tie-points using GPS coordinates derived from strategic parts of the city. The 'File/Create/Geo-Reference' module was used to create the geo-reference. Since only DEMs having a 'GeoRef Corner' geo-reference system can be viewed in 3D, it became necessary to resample the topo sheets, from 'Tie-points' geo-reference system to 'GeoRef Corners' geo-reference system. This was done with the 'Operations/Image Processing/Resample' module. It was only when the toposheet was in 'GeoRef Corners' georeference system that on-screen digitizing of the contours began.

Digitizing Contour Lines:

The topo-sheet became the background upon which contour lines were digitized. While the topo-sheet was displayed on the screen, the 'File/Create/Segment Map' module was activated and used to create a vector file, upon which the contour lines were digitized. By giving the vector segment map a value domain, it was possible to allocate each contour line a specific value. By so doing each contour line was painstakingly digitized into the vector file.

Interpolation of Contour Lines:

Interpolation of contour lines was done through the 'Operation/Interpolate/Contour Interpolation' module. The 'nearest neighbor' interpolation technique was chosen for this work. The outcome of the interpolation process was the digital elevation model (Fig 4). By applying the 'Operations/Visualisation/Display3D' module, the DEM could be viewed in 3D (Fig 1).
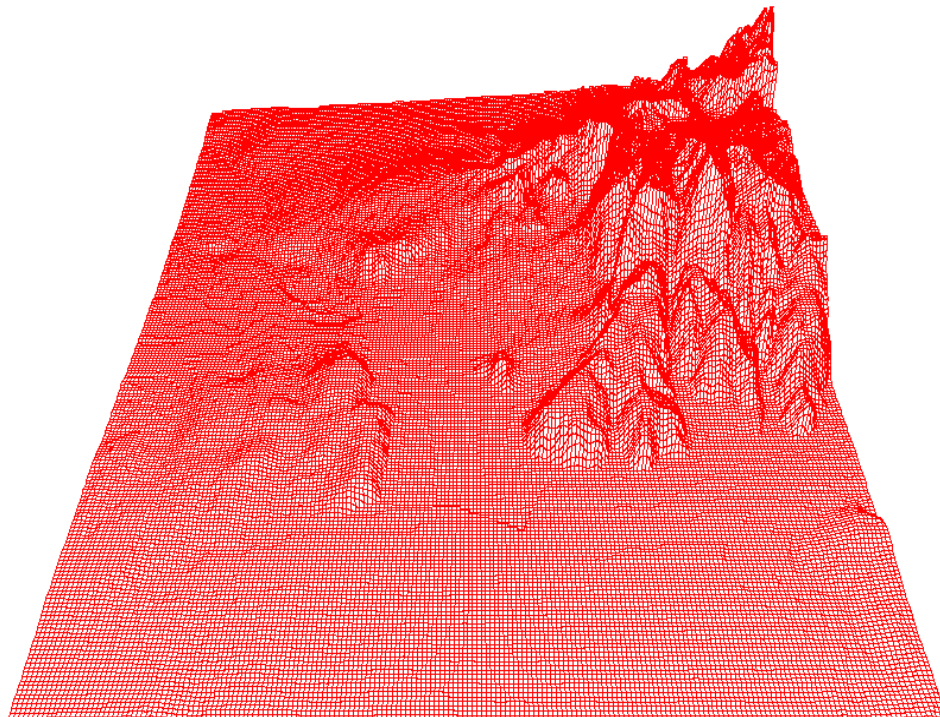

Fig 1: 3D view of Digital Elevation Model (DEM) of study area.

CREATING 3D VIEW OF SATELLITE IMAGE

In order to have a clearer understanding of the nature of the topography of Jimeta-Yola, the satellite image of Jimeta/Yola needed to be viewed in 3D. This was done by first processing the images appropriately and later draping the image on the DEM.

Processing the Image:

The study area was covered by 2 scenes of SPOT XS images – ie scene K84, J331 & scene K84, J332. The D-View package was used to open the 2 scenes. A color composite of each scene was created with contrast stretch before saving the images in tagged image file format (TIFF). Saving geo-referenced images in TIFF format removes all inherent geo-references. Thus the satellite derived coordinates in the satellite image was immediately lost.

Once the image was in tiff format, it became easy for the two scenes to be imported into CorelDraw. Using the shape tool in CorelDraw, a large chunk of areas outside the study area was removed, thus making each image much smaller than it was previously. The now reduced images were then concatenated after visual inspection. Once concatenation was complete the two images were grouped together making them one computer object before finally exporting it to ILWIS.

In ILWIS, further processing was required. The image was first geo-referenced using 'tie-points'. This allowed the coordinates of the various parts of the image to be compatible with that of the DEM. However, before it can be draped on the DEM, it must have the same pixel size and have equal row and columns with the DEM. This was again achieved by re-sampling the image from its present geo-reference to the geo-reference of the DEM. The final satellite image used, after all the necessary image processing, is as shown in Fig 2.

Draping:

The 'Operations/Visualisation/Display3D' module was opened. In this module, the 3D ''GeoRef 3D' was specified and the image to be draped was also specified. The outcome of the drape is the creation of a 3D view of the satellite image (Fig 3)

VIEWSHED ANALYSIS

Viewshed Analysis (also known as line-of-sight analysis) is the type of analysis that allows an analyst to know areas that are in view from one or more viewports. Applications of viewshed analysis are numerous. Military applications could include the location of sites best for military outposts. In law keeping, the police could use it for locating areas suitable for monitoring crime, or monitoring traffic flows. Television stations could use it to detect suitable areas for locating transmitting masts etc.

Three view ports were used in this study. Since each view port represents a GSM transmitting mast, this implies that the result of the analysis indicates areas that receive signals (in view) and those that do not receive signals (not in view) from the transmitting masts. The analysis was done twice. Firstly, the analysis was done to identify areas in view based on the present locations of the three transmitting masts; and secondly another one was done, after digitally shifting one of the transmitting masts to a presumed better location.
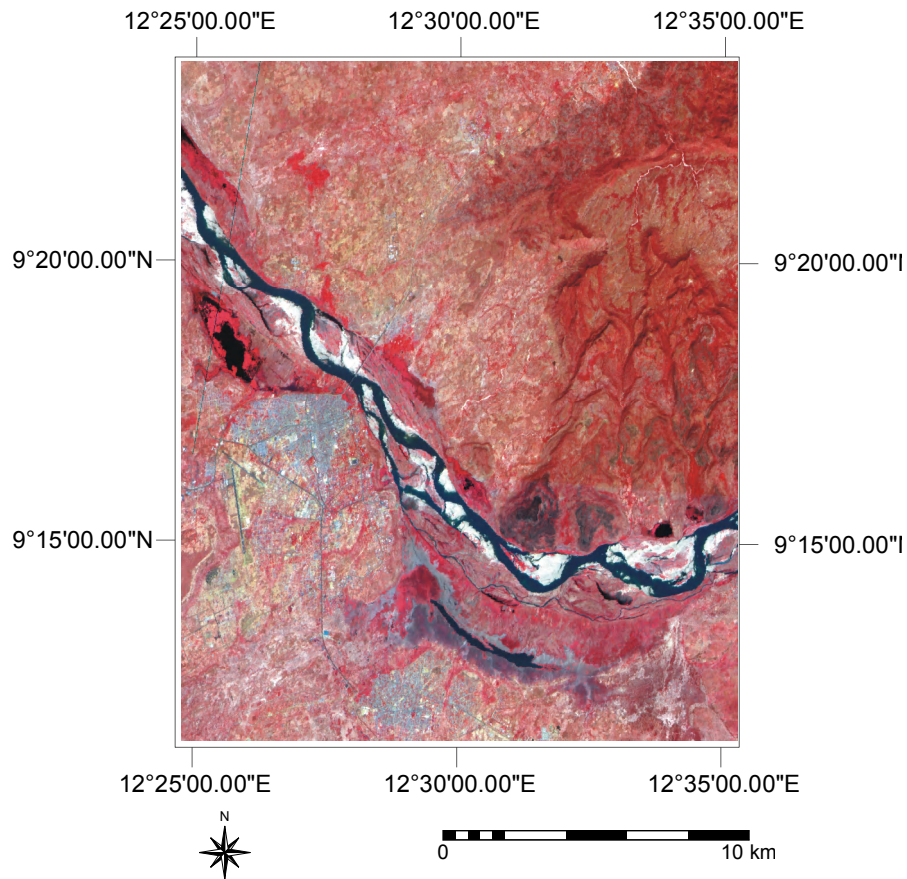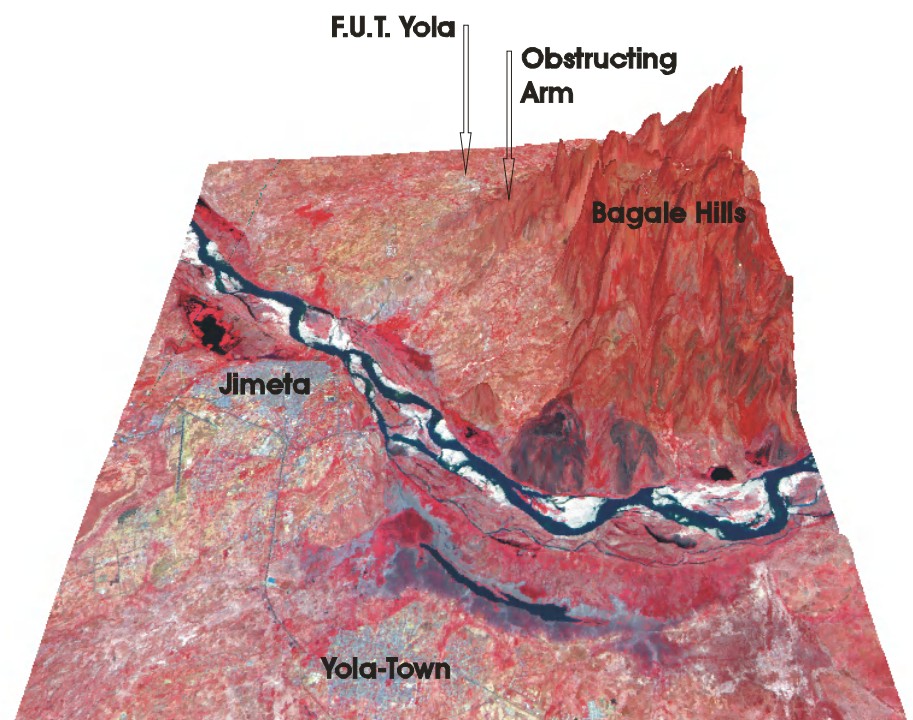
Fig 2: Satellite Image of study area in 2D

Fig 3: Satellite Image of study area shown in 3D.

RESULTS & DISCUSSION:

Figures 5 and 6 reveal the results of the viewshed analysis. In Fig 5, it is evident that a large part of the University cannot receive signals from the MTN transmitting masts. The 3D view of the satellite image of study area (Fig 3) gives a clue to why this is so. While the Bagale Hills is clearly out of the line of sight of the transmitting signals, there is an arm of the hill, which descends gently across the line of sight. This obstructing arm (Fig 3) is responsible for the poor network coverage experienced at the University. Any solution to the problem must therefore put this obstructing arm into consideration. It was in view of this that the viewport representing the transmitting mast behind Guaranty Trust bank was shifted westward in such a way as to avoid the obstructing arm of the Bagale hills.

The outcome of that shift was quite rewarding since the area occupied by the university is now in view (Fig 6). It can therefore be safely asserted that a shift of the transmitting mast behind the Guaranty Trust bank (0218732mN, 1025511mE) towards the North West to a point with coordinates 0216411mN, 1032637mE will guarantee the FUTY campus (case study for this paper) uninterrupted GSM reception, without reducing the existing area covered by the network.

However, the recommended location for the new transmitting mast is a very remote and uninhabited part of the study area. Also, due to the absence of roads leading to the point in question, the only means of accessing the point is probably by canoe through the River Benue. This, no doubt, introduces new logistics and security concerns. Since the bottom line of the GSM business is profit, a realistic assessment of the cost benefit of various alternatives will determine how best to move forward. The importance of the GIS can therefore be viewed from the fact that, it can be used to produce such alternatives.
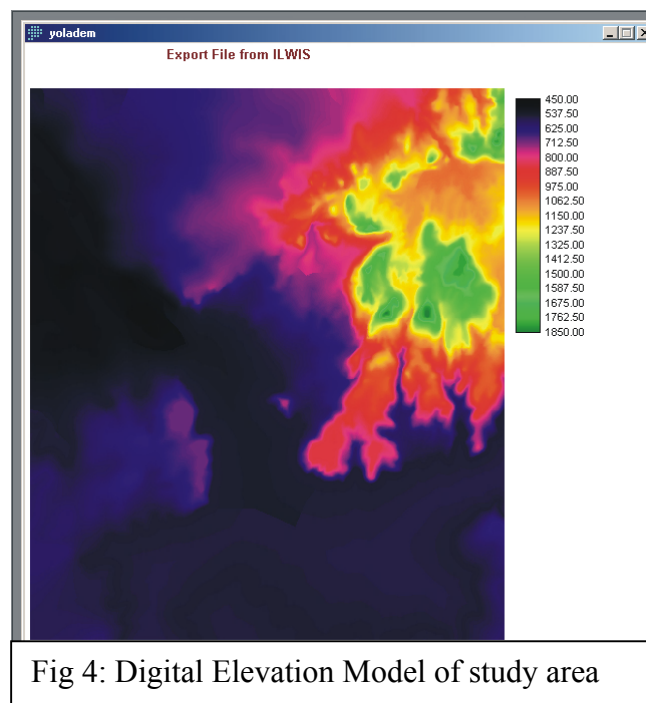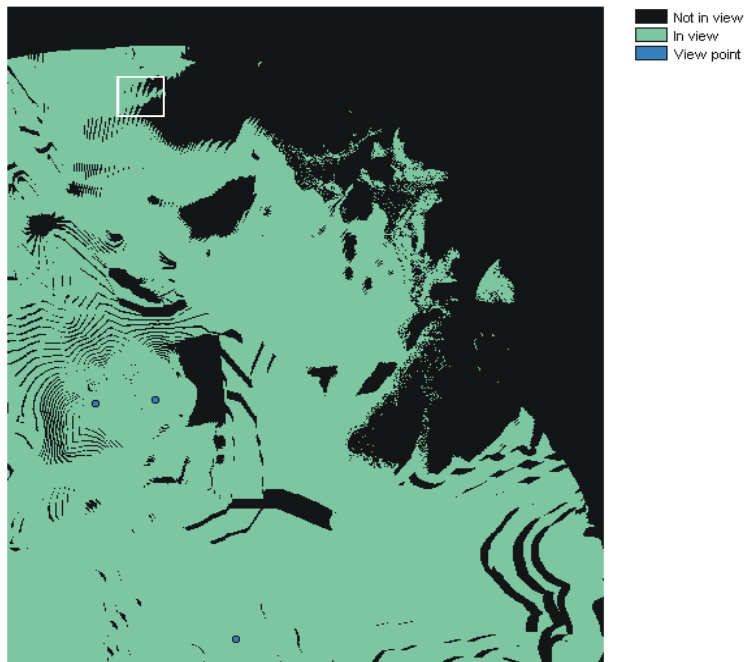

Fig 4: Digital Elevation Model of study area

Fig 5: Outcome of Viewshed analysis based on existing locations of GSM masts. Location of FUTY is shown in white box.
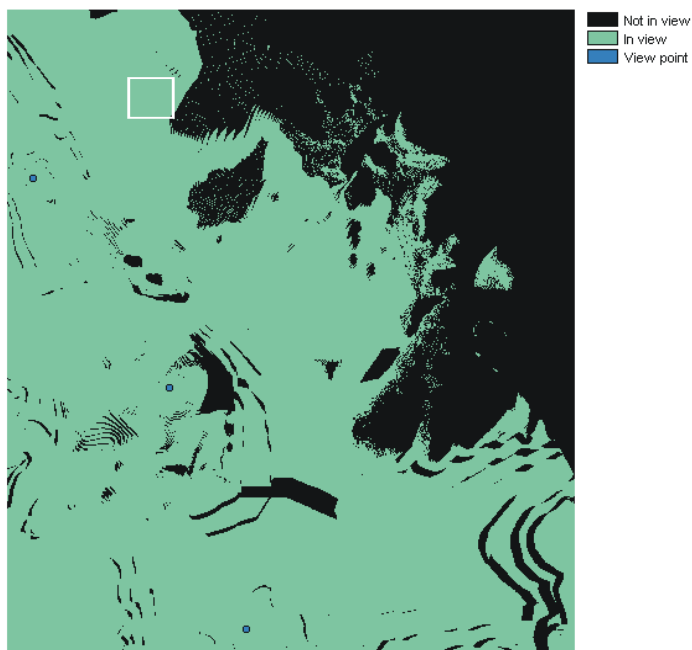

Fig 6: Outcome of Viewshed analysis, after shifting one of the Viewports to a new location. Location of FUTY is shown in white box.

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