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Spatial Variation of the Received Signal Strength of Mobile Telephone Network (MTN) over Dutsin-Ma Town, Katsina State, Nigeria

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ABSTRACT
The need for coverage areas assessment is important at ensuring quality of service. This study investigated the spatial variation of the Received Signal Strength (RSS) of MTN in Dutsin-Ma Town, Katsina State, Nigeria. The RSS was measured along four different routes from the main Transmitting Base Station (TBS) located at Unity Bank area using an Android Smartphone Samsung Galaxy Model A20. GPS receiver was used to monitor the elevation, geographic coordinates and Line-of-Sight of the various data points from the TBS up to about 2 km for each route using drive test protocol. Three sets of measurements were carried out covering morning, afternoon and evening. The obtained data were used to classify the coverage areas into Primary, Secondary, Tertiary and Fringe based on 3/4G-GSM standards. From the results, the mean values of the RSS for Routes A, B, C and D were -62, -91 and -75 dBm; -71, -90 and -85 dBm; -68, -99 and -83 dBm; -63, -93 and -83 dBm for morning, afternoon and evening respectively. These findings revealed that MTN RSS is more reliable in the morning and evening compared to the afternoon over Dutsin-Ma. This could be attributed to higher tower load which characterizes the afternoon times compared to morning and evening. Results also revealed that Route A, has the Best Area Network coverage, followed by routes D and B, while route C recorded the weakest. MTN Nigeria is advised to site more TBS in Dutsin-Ma to improve their quality of services in the community.

Keywords:
Received Signal Strength,
Quality of Service,
Quality of Reception,
GSM Area Network,
Dutsin-Ma.

INTRODUCTION

Cellular phones are electronic devices that make use of the technology of Global System for Mobile communication (GSM) to provide basic data services, give voice services through digital network, store phone numbers, connection of information and allow a user to switch devices without needing to contact the service provider (Hahn, 2008). Without no doubt, communication is a key driver of the economy of any nation (Okoro *et al.*, 2008; Akinbolati *et al.*, 2018).

Received Signal Strength is the level of received power or field strength by a subscriber of any wireless signals (Akinbolati *et al.*, 2016; Akinbolati and Ajewole, 2020). Weak signal strength can be as a result of destructive interference of the signal from local towers or by the construction materials in some buildings causing rapid attenuation of signal strength (Hahn, 2008; Okoro *et al.*, 2008). The increasing demand for a more convenient communication system has led to the emergence of the Global System for Mobile Communication (GSM). GSM is a sophisticated two-way radio that uses Ultra-High Frequency (UHF) radio waves to communicate information (Bello, 2010).

GSM base stations are low powered system that serves only a limited geographic area, varying from a few hundred meters to several kilometers. When a GSM phone connects to the network, it uses radio signals to communicate with the nearest mobile phone site. All of the mobile phone sites in a network are interlinked by cable or microwave link, enabling phone calls to be passed from one cell to another automatically (Popoola *et al.*, 2009). GSM is one of the wildest growing and most demanding telecommunication applications in the world now and Nigeria. It presents a constantly growing telephone subscription around the globe. Nigeria is one of the major consumers of GSM Communication in Africa, over 60% of the whole populace in Nigeria depend on the GSM as the fastest means of communication.

There are four GSM providers in Nigeria with a subscription base of over 143.05 million people (National

Bureau of Statistics, 2015). Ever since the launch of mobile phone service in Nigeria in the early 2001, it has played a crucial role in the dissemination of information (communication, SMS and Data for internet usage). The sector had recorded an excessive growth from 2.27 million subscribers in 2002, when the first mobile permit was issued, to 143.05 million at the end of the first quarter of 2015 (NBS, 2015). The base station's mast is a free-standing structure which supports antennas at a height where they can transmit and get radio waves. A mast is usually 15m high and plays no part in the transmission of radio waves. The base stations are sites that enable mobile phones to work (Okeke, 2014; Parikh *et al*., 2010). They can be big or small and have transmitters and receivers in a cabin or cabinet attached to antennas (Bello, 2015). They can be mounted on a substantial pole or tower or in an existing building rooftop or street furniture such as street lamps, so without the base station, mobile phone will not work (Okereke and Abdullahi, 2006). The GSM telephone service first became available in Nigeria in 2001 in Lagos and Abuja. By mid-2002 there were approximately 2.27 million subscribers throughout Nigeria and has since risen to over 143.05 million (National Bureau of Statistics, 2015).

In this digital age, the need for qualitative voice calls and high-speed internet facilities for the socio-economic development of the citizenry cannot be over emphasized. This desire becomes frustrating when the Quality of Service (QoS) rendered by GSM providers is poor. There have been complaints by GSM subscribers especially by the members of the university community of the Federal University Dutsin-Ma, regarding the poor QoS rendered by all GSM operators in Dutsin-Ma. The focus of this study was to examine the causes of this problem and find ways of proffering solutions that will enhance the Quality of Reception (QoF) by subscribers over the Town. It equally aims at determining the coverage areas and the grades of coverage enjoyed by subscribers in different locations over Dutsin-Ma Town.
The choice of MTN was premised on the fact that the Network Provider has the highest number of subscribers in Nigeria and by extension in Dutsin-Ma Town (NBS, 2021). In addition, their technical crew were supportive by given useful technical details required for this study.

Theoretical backgrounds

Generations of GSM Network

First Generation of GSM (1G); these are the analog telecommunication standards that were introduced in 1980s and continued to be useful before they were replaced by second generation. The main difference is that first generation uses analog while the second generation were entirely Digital (www.britannica.com). Second Generation (2G) GSM; 2G (GSM) signal strength is defined by only one value; Received Signal Strength Indicator (RSSI); RSSI is a negative value, the closer to zero (0), the stronger the signal (Ref). Third Generation of Mobile GSM Network (3G Service). For 3G service mode, there are three relevant measurements but our concern is on RSS only; RSSI- Received Signal Strength Indicator; RSSI is a negative value, the closer to zero (0) the stronger the signal. EC/IO- indicates the downlink Carrier-to-Interference Ratio (signal quality) is also negative dBm, values closer to 0 are stronger signals. RSCP- indicates the Received Signal Code Power. Long Term Evolution 4G (LTE) Service; for a 4G service mode, there are four relevant measurements; but our concern is on RSS only; RSSI- Received Signal Strength Indicator. RSSI is a negative value, the closer to 0, the stronger the signal. RSRP- the Reference Signal Received Power is the power of the LTE Reference signal spread over the full bandwidth and narrowband. RSRQ- Reference Signal Quality is a type of measurement and it indicates the quality of the received Reference. SINR- Signal to Interference plus Noise Ratio (A minimum of -20 dB SINR is needed to detect RSRP/RSPQ). There are many different factors influencing signal strength and quality of service which include; Tower Load, Proximity to the Cellular Tower, Signal going through a cellular repeater Competing signal, Physical barrier (mountain, Building, trains etc) and weather. Therefore, measurements like signal strength (RSS) and signal quality do not incorporate all of the relevant factors to describe the quality of the connection (www.strike.com.au). You may have an excellent RSS value of -51 dBm, but the tower load (the number of mobile users) in your area is very high. In this case, even though you have a great signal value, you may not achieve maximum mobile data speed. Table 1, presents the classifications of signal qualities according to 3G-GSM communications.

Table 1: Classification of signal qualities according to third generation 3G-GSM (www.wiki.teltonika).

RSSI (dBm)	Signal Strength	Description
≥ -70	Excellent	Strong signal with maximum data speed
-86 ≤ RSS ≤ -70	Good	Strong signal with good data speed
-100 ≤ RSS ≤ -86	Fair	Fair but useful, fast and reliable data speed may be obtained, but marginal data with drop-out is possible
-110 ≤ RSS ≤ -100	Poor	Performance will drop drastically
RSS≤ -110	No signal	Disconnection

Electromagnetic Waves and Poynting Vector

Electromagnetic waves are transverse waves. The electric and magnetic fields are perpendicular to the direction of propagation. They carry both the electric and magnetic energy of the wave. The electric and the magnetic fields are in phase (Akinbolati *et al*., 2018). They are mutually perpendicular and their amplitudes are related by:

$$\bar{B}_0 = \frac{k}{\omega} E_0 = \frac{1}{c} E_0 \quad (1)$$

where k is the propagation constant, ω is the angular frequency of the wave, c is the speed of light in space and E_o is the magnitude of the electric field intensity. For a sinusoidal wave, the variation of the electric field intensity in space and time is represented as:

$$\bar{E}(r,t) = \vec{E}_0 e^{i(k.r-wt)}.\hat{n} \quad (2)$$

and the magnetic field strength

$$\bar{B}(r,t) = \frac{1}{c}\bar{E}_0 e^{i(k.r-wt)}.(\hat{k}.\hat{n}) \quad (3)$$

where $\hat{k}$ is the propagation vector, $\hat{n}$ is a unit vector in the direction of propagation of the wave called the polarization vector and r is the space coordinates (Akinbolati *et al*., 2018).

Power Density (The Inverse Square Law)

Power density can be defined as the radiated power per unit area. It is inversely proportional to the square of the distance from the source and directly proportional to the transmitted power (Akinbolati *et al*., 2018). That is, if the distance from a transmitter is doubled, the power density of the radiated wave at the new location is reduced to one-quarter of its previous value.

Therefore,

$$P_d \alpha \frac{P_t}{r^2} \quad (4)$$

$$P_d = \frac{P_t}{4\pi r^2} \quad (5)$$

where, P_d is the power density at a distance r (m), from the transmitter, $P_{t(w)}$ is the transmitted power.

Poynting Vector

The poynting vector describes the amplitude and direction of the power flow transported by the wave per square meter of surface parallel to the (x,y) plane, that is, the power density. The poynting vector is measured in watt per square meter (W/m$^{2)}$, and its instantaneous value is given as:

$$\bar{P} = \bar{E} \times \bar{H} \quad (6)$$

The average value of the poynting vector over a given period, which represents the real power transported by the wave, is more generally used, and is determined by the equation:

$$P_{ave} = (E_o\, H_o)/2 \quad (7)$$

where E_o and H_o are the magnitudes of the electric field and magnetic field intensities respectively.

MATERIALS AND METHOD

Materials

Table 2 describes the materials that were used for data collection in this study while Table 3 shows the transmission parameters of the experimental station.

Table 2: Materials used for data collection

S/N	Materials	Uses
1	Android Phone Samsung Galaxy Model A20 164Gig RAM	Used to measure the signal strength in dBm.
2	MTN SIM Card	To give the identity module of the selected network
3	Excel (Software)	The software is used for the calculation and plotting of graph
4	GPS GARMIN MAP 78S	To measure the locations longitude and latitude, the elevations above sea level and distance.
5	Field vehicle	For mobility

Table 3: Transmission characteristics of the experimental station

S/N	Parameter	Characteristics
1	Base station geographical coordinate	Lat.12.457, Long. 7.497
2	Base station elevation (AGL)	539 m
3	Base station frequency band	1800 MHz
4	Height of base station's tower	56 m

Study Location

This study was carried out over Dutsin-Ma, Town in Katsina State, North-Western Nigeria. Dutsin-Ma Local Government Area (LGA) lies on latitude 12°26'N and longitude 07°29'E. It is bounded by Kurfi and Charanchi LGAs to the north, Kankia LGA to the East, Safana and Dan-Musa LGAs to the West, and Matazu LGA to the Southeast. The climate is Sahel Savannah, the peak of the wet season spans from June to September while the dry season usually lasts longer for about eight months (Ati, 2016). Figure 1, presents the digital map of Dutsin-Ma town.

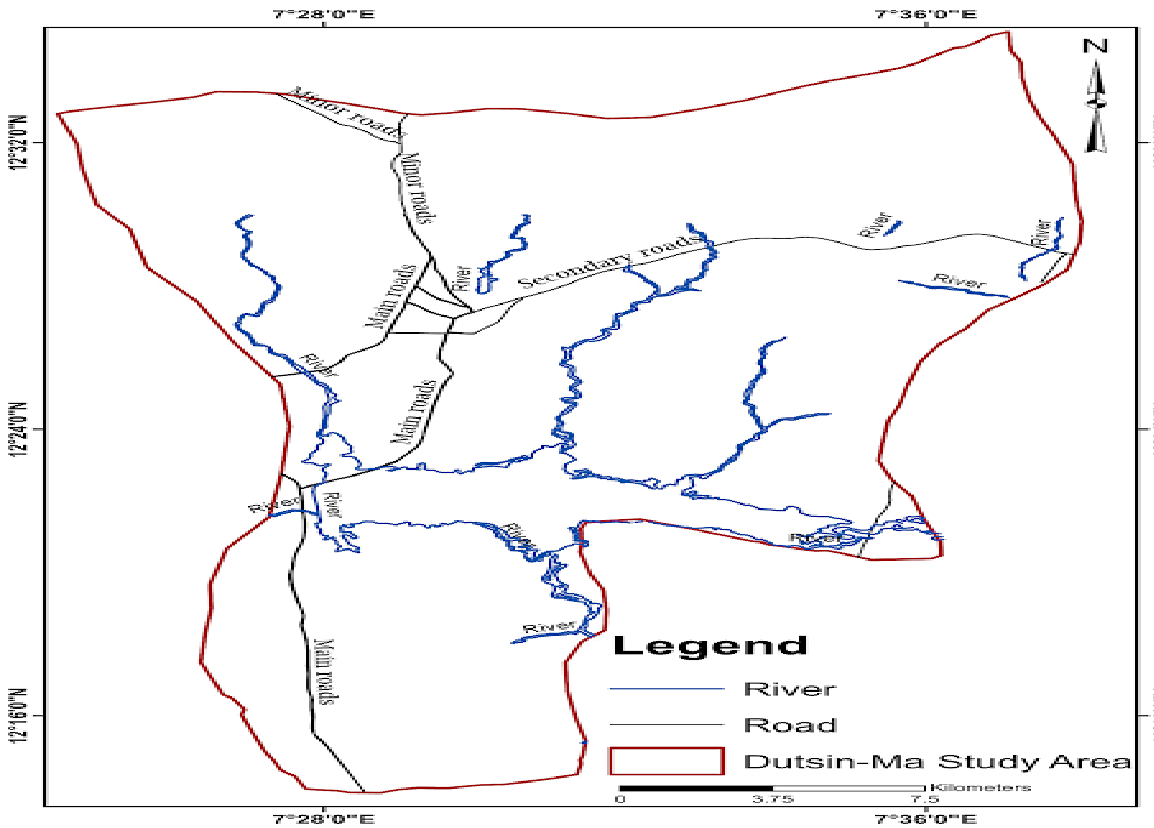

Figure 1: Digital Map of Dutsin-Ma Town (Researchgate.net)

Method of Data Collection

The measurement of signal strength of MTN network was carried out in October, 2021 over Dutsin-Ma Town, Katsina State, for about 8 days at different times; morning, afternoon and evening, by measuring 80 different locations. Measurements of the RSS and other data were carried out at intervals of 100 m using the main MTN Base Transmitting Station (BTS) located behind Unity Bank, Dutsin-Ma as reference point. This was done along four different routes up to about 2 km for each route. Table 4 depicts the description of the routes of measurement for the field work. The data were obtained using android software (network signal info pro) installed in Android Phones, Samsung Galaxy Model A20 164GB RAM with SIM card of MTN Mobile network carrier to obtain the signal strength of the selected locations. The corresponding distances and geographic coordinates of data locations were measured with the GPS using the BTS as reference.

Table 4: Routes categorization for the measurement campaign

S/N	Route	Description
1	A	From Base Station at Unity Bank Dutsin-Ma to Dabawa
2	B	From Base Station at Unity Bank Dutsin-Ma to Gizawa
3	C	From Base Station at Unity Bank Dutsin-Ma to NNPC Filling Station
4	D	From Base Station at Unity Bank Dutsin-Ma to Tsaskia Village

Data Analysis

The obtained data were sorted out for morning, afternoon and evening for all the routes A, B, C and D. The mean values for the RSS were determined for the three time periods considered in this work for the four routes. This clearly shows the variations in the mean values for the different periods of the day. The data were equally used to categorize the grades of coverage areas of the service provider over Dutsin-Ma Town using GSM standards for coverage areas categorization.

RESULTS AND DISCUSSION

Table 5 presents typical result obtained along route C during the measurement campaigns. It shows the necessary parameters that were measured and recorded for analysis. It can be observed that RSS values were stronger at locations closer to the base stations. RSS however decreases as distance increases though with few exemptions due to high altitudes of such locations. This observation is similar to the results of previous literature (Akinbolati *et al.*, 2016; Akinbolati and Ajewole, 2020).

Table 5: Typical data obtained in one of the routes (route C) during the measurement campaigns

S/N	Name of Location	LOS (km) from BTS	Lat. Nº	Long. Eº	Elevation (m)	Morning RSS (dBm) 7:00 AM to 10:30AM	Afternoon RSS (dBm) 12AM-30 PM	Evening RSS (dBm) 5PM-7:30PM	Mean RSS (dBm)
1	Behind Unity Bank (BTS)	0.01	12.466	7.492	541.0	-38.0	-55.0	-39.0	-44.0
2	Behind Rock I	0.10	12.466	7.498	540.0	-40.0	-58.0	-42.0	-47.0
3	Behind Rock II	0.20	12.466	7.496	539.0	-44.0	-63.0	-43.0	-50.0
4	Dan Rimi junction	0.30	12.466	7.498	534.0	-45.0	-66.0	-45.0	-52.0
5	Micro Finance Bank	0.40	12.466	7.895	535.0	-48.0	-76.0	-44.0	-56.0
6	Tsamiya I	0.50	12.466	7.495	547.0	-50.0	-80.0	-49.0	-61.0
7	Tsamiya II	0.60	12.466	7.497	535.0	-55.0	-89.0	-50.0	-65.0
8	Yandaka primary	0.70	12.466	7.494	543.0	-55.0	-95.0	-51.0	-67.0
9	Yarar Dole	0.80	12.466	7.494	541.0	-60.0	-100.0	-61.0	-73.0
10	Yarima Junction	0.90	12.466	7.494	535.0	-64.0	-105.0	-65.0	-78.0
11	Isa-Kaita Junction	1.00	12.466	7.489	538.0	-66.0	-110.0	-69.0	-82.0
12	First Bank	1.10	12.466	7.489	538.0	-70.0	-118.0	-72.0	-87.0
13	Central Mosque	1.20	12.466	7.503	542.0	-80.0	-119.0	-81.0	-93.0
14	Post Office	1.30	12.466	7.495	530.0	-81.0	-120.0	-85.0	-95.0
15	L.G. Store	1.40	12.466	7.495	533.0	-84.0	-128.0	-86.0	-99.0
16	VIO Office	1.50	12.466	7.486	530.0	-88.0	-129.0	-89.0	-102.0
17	First Bank	1.60	12.466	7.483	532.0	-90.0	-131.0	-92.0	-104.0
18	Karofi Motors	1.70	12.466	7.487	523.0	-91.0	-135.0	-98.0	-108.0
19	U.B.A Bank	1.80	12.466	7.483	525.0	-93.0	-139.0	-101.0	-111.0
20	Oshow Block	1.90	12.466	7.483	528.0	-94.0	-142.0	-115.0	-117.0
21	NNPC	2.00	12.466	7.488	526.0	-100.0	-145.0	-117.0	-120.0

The mean values for morning, afternoon and evening times for route A are; -62, -91 and -75 dBm respectively. For route B, the values are -71, -90 and -85 dBm respectively. Similarly, the values for route C, are -68, -99 and -83 dBm respectively while for route D, the values are -63, -93 and -83 dBm respectively. The overall mean values for morning, afternoon and evening times are -66, -93 and -82 dBm respectively. On the other hand, the overall mean values for routes A, B, C and D are -76, -82, -83 and -80 dBm respectively.

The mean value for the morning (-66 dBm) falls within the primary coverage network area. The implication of this is the availability of excellent signal strength for both calls and data services. Similarly, the mean value for the afternoon times (-93 dBm) falls within the tertiary coverage network area. The implication of this is that the signal quality during the afternoon is weak and not reliable. For the evening session, the mean value (-82 dBm) falls within the secondary coverage area network. Here, the signal is good and useful but may not be useful and reliable at all times. It can be deduced from the result that MTN Received Signal Strength is more reliable in the morning and evening times compared to the afternoon times. This could be attributed to highest tower load which characterizes the afternoon times (being the peak of socio-economic activities) compared to morning and evening times. There could be some weather-related factors; though not the focus of this study. Subscribers are therefore advised to make use of the morning and evening times to enjoy better quality of service from the network. On the other hand, MTN Nigeria is advised to site more Base Transmitting Stations (BTS) in Dutsin-Ma to reduce excessive load tower in the University Town to enhance Quality of Service QoS. Table 6 shows the categorization of locations; streets, areas and quarters in Dutsin-Ma that fall within the various Coverage Area Networks (CAN) based on 3G standard. The locations are presented to guide subscribers in the choice of areas with good network coverage so as to enhance their socio-economic lives.

Table 6: Categorization of locations within Dutsin-Ma according to grade of coverage based on the results of the measured 3G-GSM signal strength

Route	Primary Coverage Area (RSS ≥ -70 dBm)	Secondary Coverage Area -85 ≤ RSS ≤ -70 dBm	Tertiary Coverage Area -100≤ RSS ≤ -85dBm	Fringe Area -100≤ RSS ≤ -110dBm
A	Behind Unity Bank Area, Secretariat, General Hospital, Jalli Mosque, Jamu Institute, Shema House, Irrigation Office, M & M Eatery	Fudma 2nd gate, Fudma Main gate, Male Hostel Darawa	Darawa Town, NDLEA Office, Darawa Sec. School	Silos food reserved, Gonar Mallam I, Gonar Mallam II, Gonar Shehu, Kukar Aljana, Yar"Gona, Dabawa Sec. School
B	Behind unity bank, Mosque, Veterinary Clinic, Dan-Rimi junction, Abuja road, Motor park	Shema I, Shema II	Apostolic church, Area, Male Hostel Area, Public Library	Fire service office, Fudma Guest House, Khadija Bread, C.D.S.S, Kofa I, Kofa II, Gizawa I, Gizawa II, Designer farm, MallamShehu Farm
C	Behind Unity Bank, Behind Rock I, Behind Rock II, Dan Rimi junction, Micro Finance Bank, Tsamiya I, Tsamiya II	Yandaka primary, Yarar dole, First Bank, Central Mosque	Isa Kaita College of Education Area, L.G Store, VIO office, U B A bank	Karofi motors, Oshow Block, NNPC
D	Base Station, Bayan Area, Yaroba Mosque, Wednesday Market I, Wednesday Market II, Gawo I, Gawo II, Living Faith Church Area	Wednesday Market Area	KSTA motor park, Shema Petroleum	Jatau Farm I, Farm I, Farm II, Farm III, Farm IV, FarmV, Farm VI, Farm VII, Farm VIII, Dangani Farm, Dan Malam Farm Tsaskiya Road

This result will be useful to subscribers in Dutsin-Ma to know the locations where they can enjoy good calls and data services for their socio-economic activities. This could also inform their choice of business areas and even choice of residential areas especially for the students. Similarly, it will serve as a guide to the service provider (MTN) to know where to site new BTS that will enhance Quality of Reception (QoR) over the study areas.

CONCLUSION

The spatial distribution of MTN signal strength over Dutsin-Ma town has been investigated along four routes using the main BTS as reference. The investigations were carried out for morning, afternoon and evening sessions for daily variations. Results revealed that MTN Received Signal Strength is more reliable in the morning and evening times compared to the afternoon times over the study areas. Most of the locations within the town have been classified according to the grade of signal quality available in such locations. These results will be of good guide to enhance the socio-economic activities of MTN subscribers. The overall findings will be useful to the service provider by identifying locations for siting BTS in areas that are poorly serviced (especially the fringe or no signal area) and as well useful to both existing and intending subscribers to maximize QoS. MTN Nigeria is advised to site more base transmitting stations in Dutsin-Ma to improve the quality of service in the Town so as to enhance the agricultural and socio-economic activities of the agrarian community.

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