



ISSN: 0976-3376

Available Online at <http://www.journalajst.com>

ASIAN JOURNAL OF
SCIENCE AND TECHNOLOGY

Asian Journal of Science and Technology
Vol. 10, Issue, 02, pp.9454-9459, February, 2019

RESEARCH ARTICLE

SIGNAL STRENGTH AND QUALITY OF SIGNAL OF SOME CELLULAR NETWORKS IN OGOINI, SOUTH – SOUTH NIGERIA

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ARTICLE INFO

Article History:

Received 08th November, 2018
Received in revised form
15th December, 2018
Accepted 12th January, 2019
Published online 28th February, 2019

Key words:

Signal Strength, Quality of Signal,
MTN Nigeria, Airtel, Globacom,
9Mobile

ABSTRACT

As the erratic nature of the cellular network services in Nigeria become increasingly worrisome, the signal strengths and qualities of four (4) available cellular networks operating in Ogoni, South – South Nigeria are compared to ascertain the network with a better signal strength and quality. Measurement of signal strength (γ) and quality of signal (Z) at one-hour intervals were made for the four networks using a GSM signal monitor, version 3.24 for android (a software to monitor and analyse the received signal strength index (RSSI) and quality of signal of the cellular networks). Results showed that the network with the highest values of signal strength has the best quality of service. The average mean signal strengths for the four networks obtained were of $-86.25dB\mu V/m$, $-86.33dB\mu V/m$, $86.71dB\mu V/m$ and $-86.42dB\mu V/m$ for MTN Nigeria, Airtel, Globacom and Etisalat (9Mobile) respectively. Also, the average mean quality of signal for the four networks obtained were 43.38%, 43.33%, 43.25% and 43.25% for MTN Nigeria, Airtel, Globacom and 9Mobile respectively. The study also showed that fluctuations in signal strength and quality of the cellular networks of interest were more profound during the off-peak hours of the day. Therefore, MTN was thought of as providing a better cellular network service in Ogoni as it had better signal strength and better quality of signal throughout the period of carrying out this research.

Citation: Prince S. Nwiyor, Onengiyeofori A. Davies and Dein H. Davies. 2019. "Signal Strength and Quality of Signal of Some Cellular Networks in Ogoni, South – South Nigeria", *Asian Journal of Science and Technology*, 09, (02), 9454-9459.

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INTRODUCTION

Cellular phones are electronic devices that use 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). They operate through cellular networks which are responsible for generating and distributing radio signals over wide geographic area (Dunlop, 2017; Parikh, 2010). Signal strength is the level of received signal or field strength (Popoola et al., 2009). Weak signal strength can be caused by destructive interference of the signal from local towers or by the construction materials in some buildings causing rapid attenuation of signal strength (Hahn, 2008; Itam, 2008; Okoro et al., 2008). Also, the weather may affect the strength of a signal, due to the changes in radio wave propagation caused by clouds (particularly tall and dense thunderclouds which cause signal reflection), precipitation and temperature inversions (Eyo et al., 2003; Huurdeman, 2003).

Others are *dead zones*, usually areas where mobile phone service is not available because the signal between the handset and mobile site antennas is blocked or severely reduced, usually by hilly terrain, dense foliage, or physical distance (Hahn, 2008). Therefore, in recent times there is a rising need to analyze the quality of these network signal with a view to determining the network with better signal quality and at what period of the day signal is strongest as services rendered by these cellular networks have been epileptic (Bakare, 2018). Many wireless service providers work continually to improve and upgrade their networks in order to minimize drop calls, access failure and dead zones. This research is therefore geared towards carrying out an investigation in Ogoni area, Rivers State, South-eastern Nigeria, on four cellular networks, namely: MTN Nigeria, Globacom, Airtel and 9Mobile, to determine the signal strengths and qualities of these cellular networks operating in the area.

Location/climate of study area: The location of the study area is Ogoni, River State – Nigeria on the coast of the Gulf of Guinea, East of the city of Port Harcourt. It extends across the four local Government Areas namely Khana, Gokana, Eleme and Tai. Ogoni lies on the latitude of $4^{\circ}44' N$ and the

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longitude of **7°13' E** (Lindén, 2013). This city has tropical climate. Ogoni has significant rainfall most months with a short dry season. The average annual temperature is **26.4°C** and average precipitation of **300 mm** (Bassey, 2012). The least amount of rainfall occurs in January with an average of **40mm** while precipitation reaches its peak with an average of **463mm** in July. The temperature is highest on average in February at about **27.5°C** while it is about **25.3°C** on average in July (UNEP, 2011)

MATERIALS AND METHOD

The material needed for analysis of the signal strength include a GSM signal monitor, version 3.24 for android (a software to monitor and analyze the Received Signal Strength Index (RSSI) and quality of signal of the cellular networks); laptops, cell phones with sim cards, the various satellite mast that links cellular phone to their base transmission stations, meter rule and clock. The data were collected by measuring the varying signal strength in a repeated pattern to have accurate result. Four different stations were picked within the study area. The stations were the local government headquarters of Eleme, Khana, Gokhana and Tai. The handset or mobile phone device was set up at the height of 1.5m above the ground (this is the average height of most GSM users). The signal strength (generally ranging from -30dB μ V/m to -110dB μ V/m for cellular networks with the closer the signal is to zero. the better the signal) and the quality of signal for MTN, Airtel, Globacom and 9Mobile networks were measured simultaneously at a particular station using Techno D3, cellular phone installed with a GSM signal monitor version 3.24 by Alex Kozyukov. Measurements were taken at time interval of 1 hour for a total of 5 days. The results of the primary data obtained were tabulated and subjected to statistical analysis using *GraphPad Prism 7*. Microsoft excel was used in generating graphs of measured quantities against time. Results obtained for each network was compared to see the performance of each GSM network operators in the study areas.

RESULTS AND DISCUSSION

Results obtained for the various mobile networks are tabulated below. The parameters measured in the entire network under consideration are signal strength (γ) in decibel micro volt per meter (dB μ V/m) and quality of signal (Z) in percentage (%). The signal strength variation with time across the networks are dissimilar i.e. do not follow the same pattern or manner as seen in *Figure 1*. This could be attributed to the fact that signal strengths are influenced by distance from the Base Transmitting Station (BTS) and obstacle hence it varies randomly. There is a distinction in the way signal strength varies with time of the day and night.

This shows that factors such as network congestion affects signal strength and data transmission within the network (Eyo, 2003; Hurdeman, 2003; Ziemer, 2006; Nguyen, 2014). Observation of the quality of signal with time across the network also reveals a dissimilar pattern as seen in *Figure 2*. The reason for these dissimilarities may be as a result of the quality of signal, which may be influenced by environmental and physical factors such as clouds precipitation, trees, temperature inversions, multipath losses and proximity to base transmitting stations (BTS). Other factors may include the volume of network traffic, mass call event leading to overload of radio channels, roaming, interference by signal from local tower (Okoro, 2008; Garcia-Hernández, 2007; Savas, 2012). The comparative analysis of the data results obtained for the four (4) GSM networks reveal that MTN has the highest mean signal strength of -86.25 dB μ V/m with Globacom having the least signal strength, -86.71 dB μ V/m, as seen in *Table 9*. Similarly, MTN has the highest mean quality of signal of 43.38% compared with Airtel's with 43.33%, Globacom's 43.25% and 9Mobile's 43.25% respectively. This implies that for the networks under investigation MTN is the most efficient

Table 1. Data on signal strength for MTN network

Time (Hour)	Signal strength, γ (dB μ V/m)					
	Day 1 (γ_1)	Day 2 (γ_2)	Day 3 (γ_3)	Day 4 (γ_4)	Day 5 (γ_5)	Average (γ_{AV})
0000	-81.00	-79.00	-83.00	-80.00	-82.00	-81.00
0100	-89.00	-90.00	88.00	-90.00	-88.00	-89.00
0200	-88.00	-89.00	-90.00	-88.00	-90.00	-89.00
0300	-80.00	-78.00	-79.00	-80.00	-78.00	-79.00
0400	-80.00	-79s.00	-81.00	-78.00	-82.00	-80.00
0500	-81.00	-84.00	-84.00	-83.00	-83.00	-83.00
0600	-84.00	-86.00	-85.00	-86.00	-84.00	-85.00
0700	-82.00	-84.00	-83.00	-83.00	-83.00	-83.00
0800	-83.00	-86.00	-86.00	-85.00	-85.00	-85.00
0900	-85.00	-86.00	-87.00	-87.00	-85.00	-86.00
1000	-85.00	-86.00	-84.00	-86.00	-84.00	-85.00
1100	-86.00	-87.00	-85.00	-86.00	-86.00	-86.00
1200	-87.00	-86.00	-88.00	-86.00	-88.00	-87.00
1300	-86.00	-85.00	-87.00	-85.00	-87.00	-86.00
1400	-79.00	-78.00	-80.00	-78.00	-80.00	-79.00
1500	-86.00	-86.00	-86.00	-87.00	-85.00	-86.00
1600	-100.00	-99.00	-98.00	-99.00	-99.00	-99.00
1700	-79.00	-79.00	-79.00	-78.00	-80.00	-79.00
1800	-99.00	-98.00	-100.00	-97.00	-101.00	-99.00
1900	-77.00	-76.00	-78.00	-75.00	-79.00	-77.00
2000	-83.00	-83.00	-83.00	-84.00	-82.00	-83.00
2100	-91.00	-88.00	-88.00	-91.00	-87.00	-89.00
2200	-93.00	-96.00	-96.00	-93.00	-97.00	-95.00
2300	-99.00	-100.00	-101.00	-100.00	-100.00	-100.00

Table 2. Data on quality of signal for MTN network

Time (Hour)	Quality of signal, Z (%)					
	Day 1 (Z ₁)	Day 2 (Z ₂)	Day 3 (Z ₃)	Day 4 (Z ₄)	Day 5 (Z ₅)	Average (Z _{AV})
0000	50.00	52.00	51.00	50.00	52.00	51.00
0100	40.00	38.00	42.00	41.00	39.00	40.00
0200	41.00	39.00	40.00	42.00	38.00	40.00
0300	56.00	56.00	56.00	55.00	57.00	56.00
0400	55.00	56.00	57.00	56.00	56.00	56.00
0500	49.00	49.00	52.00	50.00	50.00	50.00
0600	46.00	49.00	49.00	47.00	49.00	48.00
0700	49.00	50.00	51.00	48.00	52.00	50.00
0800	47.00	49.00	48.00	49.00	47.00	48.00
0900	45.00	46.00	47.00	46.00	46.00	46.00
1000	48.00	48.00	48.00	47.00	49.00	48.00
1100	46.00	47.00	45.00	44.00	48.00	46.00
1200	45.00	45.00	45.00	44.00	46.00	45.00
1300	47.00	48.00	43.00	46.00	46.00	46.00
1400	54.00	57.00	57.00	56.00	56.00	56.00
1500	47.00	46.00	45.00	47.00	45.00	46.00
1600	11.00	12.00	13.00	10.00	14.00	12.00
1700	56.00	56.00	56.00	55.00	57.00	56.00
1800	12.00	12.00	12.00	11.00	13.00	12.00
1900	65.00	65.00	65.00	65.00	65.00	65.00
2000	51.00	50.00	49.00	52.00	48.00	50.00
2100	41.00	41.00	38.00	41.00	39.00	40.00
2200	26.00	27.00	28.00	27.00	27.00	27.00
2300	08.00	06.00	07.00	07.00	07.00	07.00

Table 3. Data on signal strength for AIRTEL network

Time (Hour)	Signal strength, γ (dB μ V/m)					
	Day 1 (γ_1)	Day 2 (γ_2)	Day 3 (γ_3)	Day 4 (γ_4)	Day 5 (γ_5)	Average (γ_{AV})
0000	-80.00	-79.00	-78.00	-81.00	-77.00	-79.00
0100	-87.00	-87.00	-87.00	-88.00	-86.00	-87.00
0200	-92.00	-86.00	-88.00	-90.00	-88.00	-89.00
0300	-82.00	-82.00	-82.00	-80.00	-79.00	-81.00
0400	-87.00	-85.00	-86.00	-83.00	-84.00	-85.00
0500	-80.00	-82.00	-81.00	-82.00	-80.00	-81.00
0600	-85.00	-85.00	-85.00	-85.00	-85.00	-85.00
0700	-81.00	-81.00	-81.00	-81.00	-81.00	-81.00
0800	-85.00	-86.00	-87.00	-87.00	-85.00	-86.00
0900	-84.00	-89.00	-88.00	-86.00	-88.00	-87.00
1000	-85.00	-85.00	-85.00	-85.00	-85.00	-85.00
1100	-85.00	-87.00	86.00	-87.00	-85.00	-86.00
1200	-87.00	-86.00	-85.00	-86.00	-88.00	-87.00
1300	-83.00	-88.00	-87.00	-87.00	-85.00	-86.00
1400	-79.00	-82.00	-82.00	-82.00	-80.00	-81.00
1500	-86.00	-86.00	-86.00	-87.00	-85.00	-86.00
1600	-100.00	-99.00	-98.00	-99.00	-99.00	-99.00
1700	-103.00	103.00	103.00	-104.00	-102.00	-103.00
1800	-99.00	-99.00	-99.00	-99.00	-99.00	-99.00
1900	-92.00	-97.00	-96.00	-95.00	-95.00	-95.00
2000	-83.00	-83.00	-83.00	-82.00	-84.00	-83.00
2100	-89.00	-89.00	-89.00	-89.00	-89.00	-89.00
2200	-73.00	-77.00	-76.00	-74.00	-76.00	-75.00
2300	-78.00	-76.00	-77.00	-79.00	-75.00	-77.00

Table 4. Data on quality of signal for AITEL network

Time (Hour)	Quality of signal, Z (%)					
	Day 1 (Z ₁)	Day 2 (Z ₂)	Day 3 (Z ₃)	Day 4 (Z ₄)	Day 5 (Z ₅)	Average (Z _{AV})
0000	56.00	56.00	56.00	55.00	57.00	56.00
0100	45.00	44.00	46.00	46.00	44.00	45.00
0200	40.00	38.00	42.00	41.00	39.00	40.00
0300	51.00	51.00	51.00	51.00	51.00	51.00
0400	48.00	49.00	47.00	48.00	48.00	48.00
0500	51.00	53.00	49.00	50.00	52.00	51.00
0600	48.00	48.00	48.00	48.00	48.00	48.00
0700	51.00	51.00	51.00	51.00	51.00	51.00
0800	46.00	47.00	45.00	44.00	48.00	46.00
0900	44.00	46.00	45.00	44.00	46.00	45.00
1000	48.00	48.00	48.00	48.00	48.00	48.00
1100	47.00	48.00	43.00	46.00	46.00	46.00
1200	45.00	47.00	43.00	44.00	46.00	45.00
1300	45.00	46.00	47.00	46.00	46.00	46.00
1400	51.00	52.00	50.00	50.00	52.00	51.00
1500	46.00	46.00	46.00	46.00	46.00	46.00
1600	12.00	13.00	11.00	12.00	12.00	12.00
1700	05.00	05.00	04.00	06.00	05.00	05.00
1800	12.00	12.00	12.00	12.00	12.00	12.00
1900	27.00	27.00	27.00	28.00	26.00	27.00
2000	51.00	51.00	48.00	50.00	50.00	50.00
2100	40.00	40.00	40.00	40.00	40.00	40.00
2200	66.00	67.00	65.00	65.00	67.00	66.00
2300	65.00	66.00	64.00	64.00	66.00	65.00

Table 5. Data on signal strength for GLOBACOM network

Time (Hour)	Signal strength, γ (dB μ V/m)					
	Day 1 (γ_1)	Day 2 (γ_2)	Day 3 (γ_3)	Day 4 (γ_4)	Day 5 (γ_5)	Average (γ_{AV})
0000	-79.00	-79.00	-79.00	-80.00	-78.00	-79.00
0100	-77.00	-77.00	-77.00	-75.00	-79.00	-77.00
0200	-89.00	-89.00	-89.00	-89.00	-89.00	-89.00
0300	-88.00	-81.00	-82.00	-79.00	-80.00	-81.00
0400	-83.00	-82.00	-84.00	-84.00	-82.00	-83.00
0500	-81.00	-80.00	-82.00	-82.00	-82.00	-81.00
0600	-86.00	-86.00	-86.00	-84.00	-84.00	-85.00
0700	-95.00	-95.00	-95.00	-95.00	-95.00	-95.00
0800	-85.00	-87.00	-86.00	-85.00	-87.00	-86.00
0900	-86.00	-86.00	-86.00	-86.00	-86.00	-86.00
1000	-82.00	-83.00	-84.00	-84.00	-82.00	-83.00
1100	-86.00	-85.00	-87.00	-87.00	-85.00	-86.00
1200	-87.00	-88.00	-88.00	-91.00	-91.00	-89.00
1300	-85.00	-86.00	-87.00	-87.00	-85.00	-86.00
1400	-83.00	-83.00	-83.00	-83.00	-83.00	-83.00
1500	-86.00	-86.00	-86.00	-86.00	-86.00	-86.00
1600	-99.00	-99.00	-99.00	-99.00	-99.00	-99.00
1700	-103.00	-104.00	-102.00	-102.00	-104.00	-103.00
1800	-92.00	-97.00	-96.00	-94.00	-96.00	-95.00
1900	-95.00	-95.00	-95.00	-95.00	-95.00	-95.00
2000	-83.00	-84.00	-82.00	-82.00	-84.00	-83.00
2100	-89.00	-89.00	-89.00	-89.00	-89.00	-89.00
2200	-85.00	-85.00	-85.00	-85.00	-85.00	-85.00
2300	-77.00	-78.00	-76.00	-76.00	-78.00	-77.00

Table 6. Data on quality of signal for GLOBACOM network

Time (Hour)	Quality of signal, Z (%)					
	Day 1 (Z_1)	Day 2 (Z_2)	Day 3 (Z_3)	Day 4 (Z_4)	Day 5 (Z_5)	Average (Z_{AV})
0000	57.00	57.00	54.00	54.00	56.00	56.00
0100	64.00	64.00	67.00	67.00	65.00	64.00
0200	38.00	42.00	40.00	40.00	40.00	40.00
0300	51.00	51.00	51.00	51.00	51.00	51.00
0400	48.00	52.00	50.00	49.00	50.00	51.00
0500	50.00	52.00	51.00	50.00	51.00	52.00
0600	48.00	48.00	48.00	47.00	48.00	49.00
0700	28.00	27.00	26.00	28.00	27.00	26.00
0800	44.00	48.00	46.00	46.00	46.00	46.00
0900	46.00	47.00	45.00	45.00	46.00	47.00
1000	47.00	53.00	51.00	50.00	50.00	49.00
1100	45.00	47.00	46.00	46.00	46.00	46.00
1200	40.00	40.00	40.00	39.00	40.00	41.00
1300	47.00	46.00	45.00	46.00	46.00	46.00
1400	49.00	51.00	50.00	50.00	50.00	50.00
1500	45.00	46.00	47.00	46.00	46.00	46.00
1600	12.00	11.00	13.00	12.00	12.00	12.00
1700	05.00	05.00	05.00	04.00	05.00	06.00
1800	27.00	28.00	26.00	26.00	27.00	28.00
1900	27.00	27.00	27.00	27.00	27.00	27.00
2000	50.00	50.00	50.00	50.00	50.00	50.00
2100	40.00	40.00	40.00	40.00	40.00	40.00
2200	50.00	47.00	47.00	47.00	48.00	49.00
2300	67.00	64.00	64.00	64.00	65.00	66.00

Table 7. Data on signal strength for 9MOBILE network

Time (Hour)	Signal strength, γ (dB μ V/m)					
	Day 1 (γ_1)	Day 2 (γ_2)	Day 3 (γ_3)	Day 4 (γ_4)	Day 5 (γ_5)	Average (γ_{AV})
0000	-83.00	-82.00	-84.00	-84.00	-82.00	-83.00
0100	-84.00	-85.00	-86.00	-86.00	-84.00	-85.00
0200	-86.00	-86.00	-86.00	-86.00	-86.00	-86.00
0300	-85.00	-86.00	-84.00	-85.00	-85.00	-85.00
0400	-87.00	-87.00	-87.00	-87.00	-87.00	-87.00
0500	-87.00	-86.00	-88.00	-88.00	-86.00	-87.00
0600	-86.00	-86.00	-86.00	-85.00	-87.00	-86.00
0700	-79.00	-80.00	-79.00	-78.00	-79.00	-79.00
0800	-81.00	-81.00	-81.00	-80.00	-82.00	-81.00
0900	-88.00	-90.00	-89.00	-88.00	-90.00	-89.00
1000	-91.00	-89.00	-87.00	-86.00	-92.00	-89.00
1100	-79.00	-81.00	-77.00	-79.00	-82.00	-79.00
1200	-81.00	-81.00	-81.00	-79.00	-78.00	-80.00
1300	-84.00	-82.00	-83.00	-83.00	-83.00	-83.00
1400	-84.00	-86.00	-85.00	-85.00	-85.00	-85.00
1500	-89.00	-89.00	-89.00	-89.00	-89.00	-89.00
1600	-95.00	-94.00	-96.00	-96.00	-94.00	-95.00
1700	-103.00	-103.00	-103.00	-103.00	-103.00	-103.00
1800	-100.00	-99.00	-98.00	-98.00	-100.00	-99.00
1900	-79.00	-78.00	-80.00	-79.00	-79.00	-79.00
2000	-99.00	-99.00	-99.00	-99.00	-99.00	-99.00
2100	-77.00	-75.00	-79.00	-78.00	-76.00	-77.00
2200	-81.00	-84.00	-84.00	-84.00	-82.00	-83.00
2300	-85.00	-87.00	-86.00	-87.00	-85.00	-86.00

Table 8. Data on quality of signal for 9MOBILE network (MISSING ENTIRELY)

Time (Hour)	Quality of signal, Z (%)					Average (Z _{AV})
	Day 1 (Z ₁)	Day 2 (Z ₂)	Day 3 (Z ₃)	Day 4 (Z ₄)	Day 5 (Z ₅)	
0000	50.00	50.00	50.00	50.00	50.00	50.00
0100	48.00	48.00	48.00	48.00	48.00	48.00
0200	45.00	46.00	47.00	46.00	46.00	46.00
0300	47.00	48.00	49.00	49.00	47.00	48.00
0400	45.00	46.00	44.00	45.00	45.00	45.00
0500	45.00	45.00	45.00	45.00	45.00	45.00
0600	46.00	45.00	47.00	47.00	45.00	46.00
0700	56.00	56.00	56.00	56.00	56.00	56.00
0800	49.00	52.00	50.00	50.00	52.00	51.00
0900	41.00	39.00	40.00	40.00	39.00	40.00
1000	38.00	41.00	41.00	41.00	39.00	40.00
1100	56.00	56.00	56.00	56.00	56.00	56.00
1200	56.00	56.00	57.00	57.00	55.00	56.00
1300	50.00	50.00	50.00	50.00	50.00	50.00
1400	48.00	47.00	49.00	49.00	47.00	48.00
1500	40.00	40.00	40.00	39.00	41.00	40.00
1600	27.00	27.00	27.00	26.00	28.00	27.00
1700	5.00	4.00	6.00	05.00	05.00	5.00
1800	11.00	12.00	13.00	12.00	12.00	12.00
1900	56.00	56.00	56.00	56.00	56.00	56.00
2000	12.00	12.00	12.00	12.00	12.00	12.00
2100	65.00	65.00	65.00	64.00	66.00	65.00
2200	49.00	50.00	51.00	48.00	52.00	50.00
2300	46.00	46.00	46.00	46.00	46.00	46.00

Table 9. Statistical analysis for average values of signal strength for the four mobile networks (carried out with GraphPad Prism 7)

Mobile Network	MTN	AIRTEL	GLOBACOM	9MOBILE
Minimum	-100.0	-99.00	-103.0	-103.0
Maximum	-77.00	-75.00	-77.00	-77.00
Mean	-86.25	-86.33	-86.71	-86.42
Std. Deviation	6.462	6.882	6.643	6.763
Std. Error of Mean	1.319	1.405	1.356	1.380

Table 10. Statistical analysis for quality of signal strength for the for mobile networks (carried out with GraphPad Prism 7)

Mobile Network	MTN	AIRTEL	GLOBACOM	9MOBILE
Minimum	7.000	5.000	6.000	5.000
Maximum	65.00	66.00	66.00	65.00
Mean	43.38	43.33	43.25	43.25
Std. Deviation	14.72	15.10	14.34	14.93
Std. Error of Mean	3.005	3.083	2.926	3.048

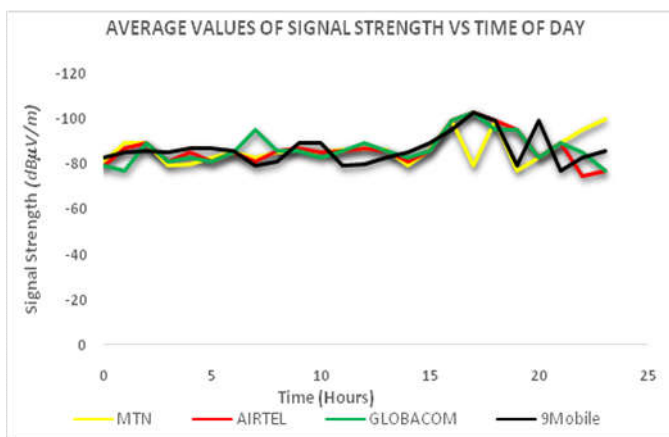


Figure 1. Plot of Average Values of Signal Strength VS Time of Day

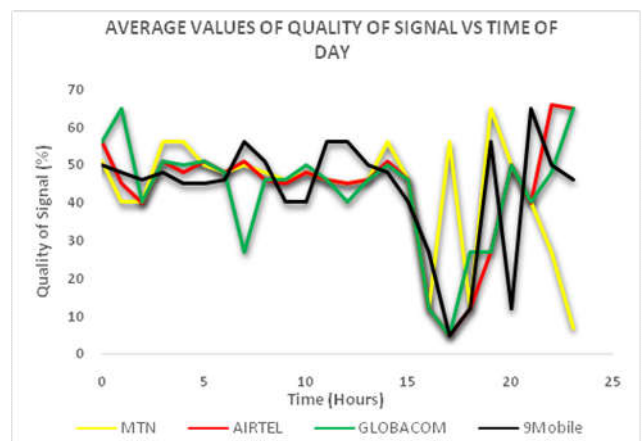


Figure 1. Plot of Average Values of Quality of Signal VS Time of Day

followed by Globacom and Airtel while 9Mobile is the least efficient. Finally, Figures 1 and 2 shows the adverse effect of off-peak hours on signal strength and signal quality, though of varying degrees, for the cellular networks under investigation.

Conclusion

This study was carried out to compare and determine the most reliable cellular service provider in Ogoni area in Rivers State Nigeria. Four cellular networks (MTN, Airtel, Globacom and 9Mobile) were investigated. It was discovered that signal strength is affected by peak hour activities as the measured signal strength and signal quality of these networks varied with time throughout the period of investigation. There is also a strong positive correlation between the received signal strength and quality of signals of the cellular network as these determine the extent of reliability and stability of each network. Of the four cellular network service providers investigated, MTN provided a better cellular network service in Ogoni as it had better signal strength and better quality of signal throughout the period of carrying out this research.

Acknowledgements

Our sincere gratitude goes to Prof. Victor I. Obianwu of the Department of Physics, University of Calabar, Nigeria, for his invaluable contribution throughout the period of this research.

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