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# Empirical study of Cellular Network and Signal Strength in Calabar, Cross River State, Nigeria

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**ABSTRACT:** An Empirical study of Cellular Network and Signal Strength in Calabar was carried out. The cellular signal monitor/analyzer is used to measure the signal strengths and quality of signals of these networks. The materials used for this research are computer system and cellular phones. Objectives of the study are to find out if off-peak and peak hour affects the signal strengths of the networks and to ascertain if there is a distinctive difference in the pattern of signal variation between the GSM networks and CDMA networks. The investigation was done in Calabar, South Eastern Nigeria on six cellular networks, namely MTN-Nigeria, Globacom, Airtel, Etisalat, Visafone and Starcoms. Based on the analyses, the most used Signal Monitor is GSM Signal Monitoring though CDMA Signal Monitoring is sparingly used. The reason is that GSM networks are more in number, popular and are good choice for cellular users due to their availability rate. It was discovered that MTN-Nigeria has the best signal strength with better stability when compared with other networks. The CDMA networks however show smaller range in their signal strengths thereby maintaining more stable signals than the GSM networks. This means that the spread spectrum approach of cellular transmission is more stable than the digital time division multiple access approach.

**Key Words:** Cellular Network, CDMA networks, GSM networks and Signal Strength

### 1.1Background of the Study

Cellular phones have become the order of the day. We continuously make use of cellular phones in voice calls, sending of short message services (SMS), sending of e-mails, in e-commerce, e-banking, e-learning and watching movies. These cellular phones operate through cellular networks. The cellular network is the network used in generating and distributing radio signals that are used by cellular phones over wide geographic areas. This research will however compare the signal strengths of these cellular networks, in which case we will discuss the quality of their signals with a view to determining the network with better signal quality and at what period of the day the signal strength is strongest, Allay (2005), Beauchamp (1990), Bissell (1997), Bolanle (2001), Carey (1989), Cavalcanti (1939), Christopher, (1993), Clair (1985),

### 1.2Cellular Network Technology

In cellular services there are different network technologies which make the transmission and reception of signals possible. These technologies are mainly two: Global System for Mobile Communication and Code Division Multiple Access. In Nigeria, major carriers MTN-Nigeria and Globacom use Global System for Mobile Communication (GSM) technology while Visafone, Starcoms and Multilink use Code Division Multiple Access (CDMA) technology, Allay (2005), Beauchamp (1990), Bissell (1997), Bolanle (2001), Brown (1984) Carey (1989).

### 1.3Types of Cellular Networks

Cellular network is divided into four types. These are namely

(i) Code Division Multiple Access (CDMA)
(ii) Global System for Mobile Communication (GSM)
(iii) Integrated Digital Enhanced Network (IDEN)
(iv) Time Division Multiple Access (TDMA)

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In Nigeria, only the CDMA and GSM are operational.

### 1.3.1Code Division Multiple Access (CDMA)

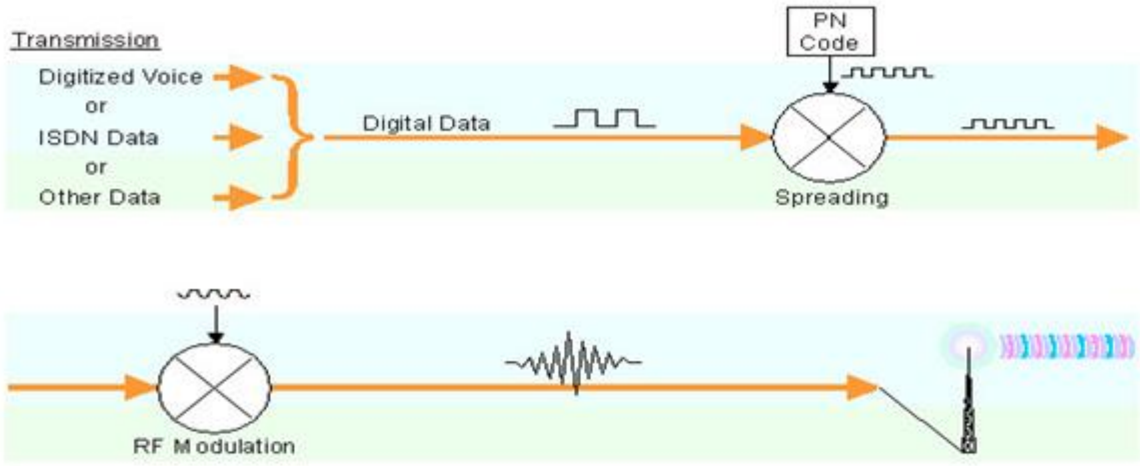
This is a form of access scheme that has been widely used within 3G cellular telecommunications systems. CDMA uses spread spectrum technology with different codes to separate different stations or users rather than different frequencies of time slot. The first CDMA system was launched in September 1995 by Hutchison Telephone Co. Ltd. in Hong Kong, and SK Telecom in Korea soon followed along with networks in the United States of America. Each user in a CDMA system uses a different code to modulate the signal. Choosing the codes used to modulate the signal is very important in the performance of CDMA system, Encarta Dictionary (2009), Faithpraise (2007), Frank, K. (2004), George, G. (1981), Gick, P. C. (1979), Hahn, H. and Kibora, L. (2008), Herbert and Donal (1986), Hsu (1995). According to them, the best performance will occur when there is good separation between the signal of a desired user and the signal of other users

In general, Spread Spectrum communications is distinguished by three key elements:

1 . The signal occupies a bandwidth much greater than that which is necessary to send the information. This results in many benefits, such as immunity to interference and jamming and multi-user access.
2. The bandwidth is spread by means of a code which is independent of the data. The independence of the code distinguishes this from standard modulation schemes in which the data modulation will always spread the spectrum.
3. The receiver synchronizes the code to recover the data. The use of an independent code and synchronous reception allows multiple users to access the same frequency band at the same time.

Nelkon and Parker (1998), Nwankwere (2008), Nwosu (1981), Obi (1994), Okoro and Menkiti (2003), Okoro (2006), Patrick (1982), Pepple (2001), stressed that in order to protect the signal, the code used is pseudo-random. It appears random, but is actually deterministic, so that the receiver can reconstruct the code for synchronous detection. This pseudo-random code is also called pseudo-noise (PN).

A sample of spread spectrum system and complex CDMA modulator are shown in Figs 1.1 and 1.2 respectively.



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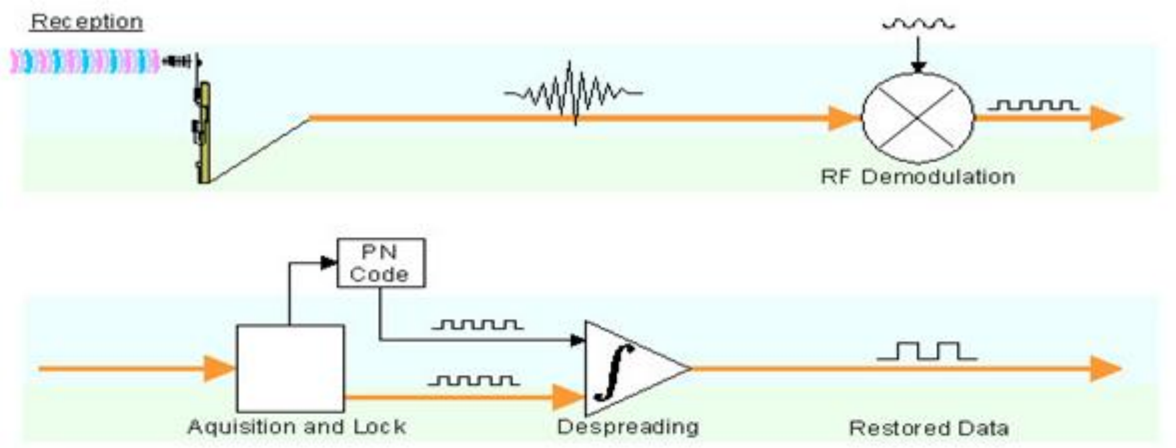


**FIG. 1.1**: Direct sequence spread spectrum system

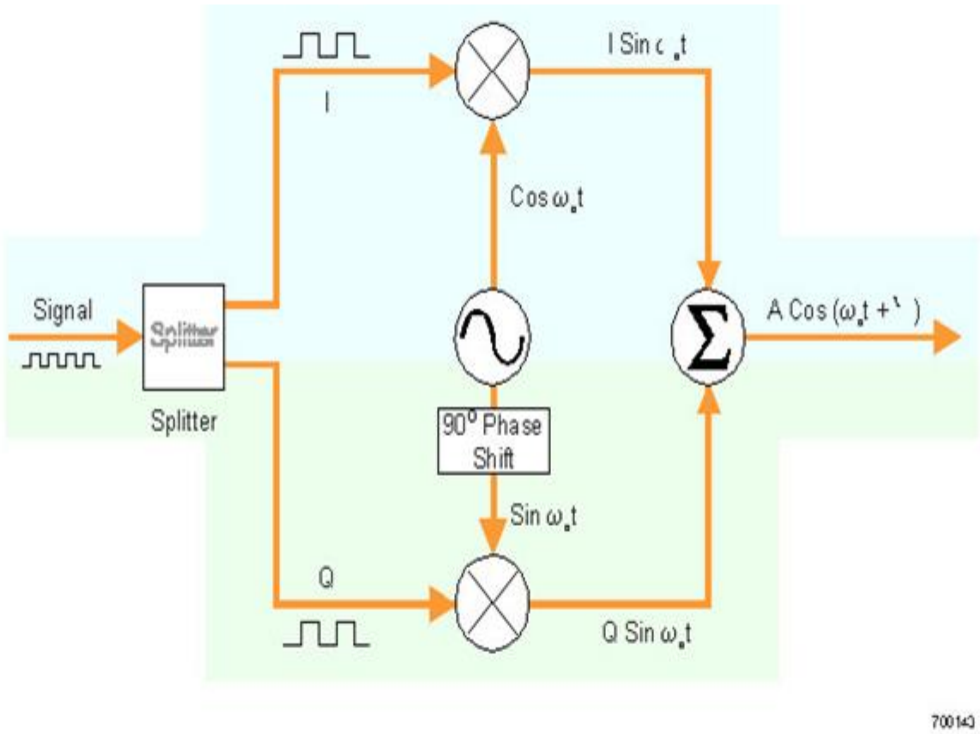


**FIG.1.2**: Complex CDMA modulator

**1.3.2Global system for Mobile Communication (GSM)**

This is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe technologies for second generation (2G) digital cellular networks. GSM uses a digital Time Division Multiple Access approach which allows more users to be accommodated within the available bandwidth. In addition to this, ciphering of the digitally encoded speech is adopted to retain privacy. The standard which was first deployed in 1991 was expanded over time to include first circuit data transport and packet data transport via General Packet Radio Service (GPRS). Packet data transmission speeds were later increased via Enhanced Data rates for GSM Evolution (EDGE). The GSM standard is succeeded by the third generation (3G) Universal Mobile Telecommunications System (UMTS) Standard developed by the 3rd Generation Partnership Projects (3GPP). GSM networks will evolve further as they begin to incorporate fourth generation (4G) Long Term Evolution (LTE) Advanced standards. GSM' is a trademark owned by the GSM Association, Kennedy and Davis (2008), John (2001), Maurice (1985),Osang et. al. (2013), (2017), (2016) Nelkon and Parker (1998), Nwankwere (2008), Nwosu (1981), Obi (1994), Okoro and Menkiti (2003).

A typical architecture of GSM system and block diagram of GSM basics are shown in Figs 1.3 and 1.4 respectively

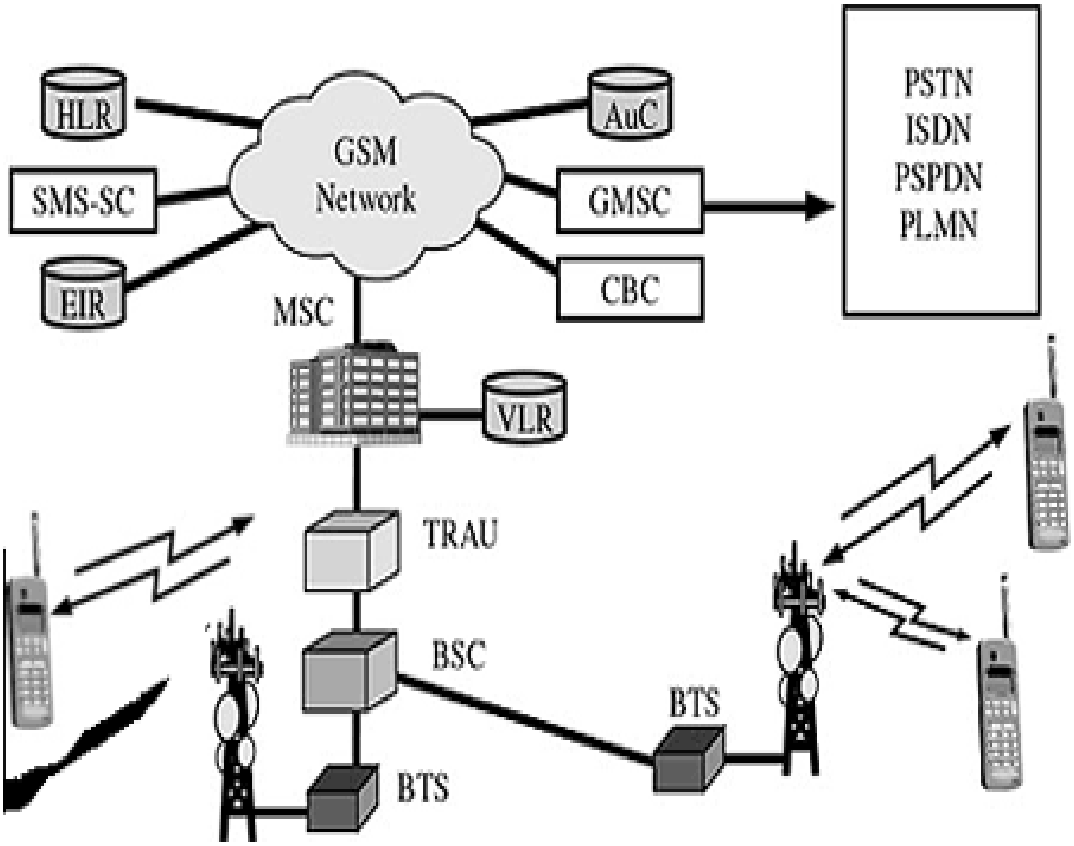


**FIG.1.3:** Architecture of GSM system

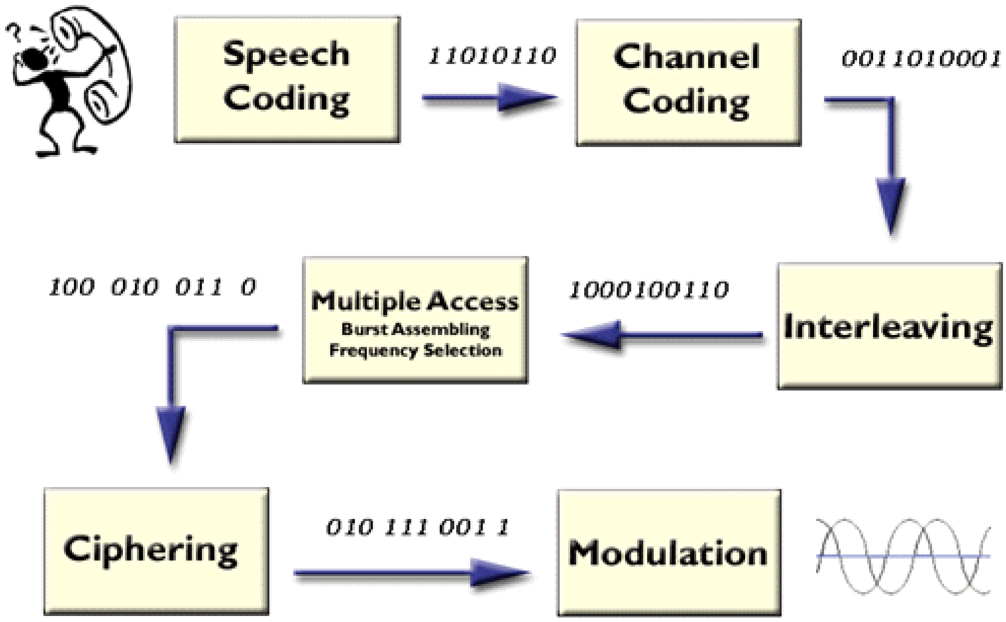


**FIG. 1.4:** Block diagram of GSM basics

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### 1.3.4 Integrated Digital Enhanced Network (IDEN)

This is a mobile telecommunication technology, developed by Motorola, which provides its users the benefits of a trunked radio and a cellular telephone. IDEN places more users in a given spectral space, compared to analog cellular and two-way radio systems, by using speech compression and Time Division Multiple Access (TDMA), Mablin, G. (2001), Macline (1993), Osang et. al. (2013), (2017), (2016)Uchendu (2006). Van and Michael (1988), Young and Freedman (2005), Yarthut (1991), Zhili (2005).

### 1.3.5Time Division Multiple Access (TDMA)

This is a technology used in digital cellular telephone communication that divides each cellular channel into three time slots in order to increase the amount of data that can be carried. TDMA is used by Digital-American Mobile Phone service, Mablin, G. (2001), Nwankwere (2008),Uquetan et. al. (2017), Osang et. al. (2013), Okoro (2006).

### 1.7 Forms of Cellular Networks

Cellular network is divided into two major forms depending on the mode of connection.
These are
(i) Cable networks
(ii) Wireless networks

### 1.7.1 Cable **Networks**

Cable networks are programming services that deliver packages of information or entertainment by satellite to local cable systems. The cable system then redistributes the network programs, through wires, to individual residences in their local franchise areas. The number of cable networks carried by any particular cable system varies, and is based on the channel capacity of the system, Patrick (1982), Pepple (2001),Osang et. al. (2016) Peter and Jane (2008) Uchendu (2006), Yarthut (1991), Zhili (2005).

### 1.7.2 Wireless Network

This refers to any type of computer network that is not connected by cables of any kind. It is a method by which houses, telecommunication networks and enterprise (business) installations avoid the costly process of introducing cables into a building. Wireless telecommunications networks are generally implemented and administered using a transmission system called radio waves. This implementation takes place at the physical level (Layer) of the network structure, Kracaver (1960), Mablin, G. (2001), Macline (1993), Mandu (1984), Mark (1992), Mark (1990), Maurice(1985),Osang et. al. (2013), (2017), (2016) Nelkon and Parker (1998), Nwankwere (2008).
In a general sense, wireless networks offer a vast variety of uses to both business and home users.

### 1.8 Cellular Network Standard

3G or 3rd generation mobile telecommunications is a generation of standards for mobile phones and mobile communications services fulfilling the International Mobile Telecommunications-2000 (IMT-2000) specifications by the International Telecommunication Union. Application services include wide-area wireless voice telephone, mobile Internet access, video calls, and mobile television, all in a mobile environment Nwosu (1981), Obi (1994), Uquetan et. al. (2017), (2016), Okoro and Menkiti (2003), Okoro (2006), Patrick (1982), Pepple (2001).
The following are some of the notable cellular standards.

(i) The Universal Mobile Telecommunications System (UMTS) standard:This was first offered in 2001, standardized by 3GPP, used primarily in Europe, Japan, China (however with a different radio interface) and other regions predominated by GSM 2G system infrastructure, Roddy and Coolean (1997), Shannon (1983), Sheilder (1991), Stephen (1996), Thompson (1999), Todd (2007).

(ii) The CDMA 2000 system standard: This was introduced in 2002, standardized by 3GPP2, used especially in North America and South Korea, Sharing infrastructure with the IS-95 2G standard, Tugal and Tudal (1998), Uchendu (2006). Van and Michael (1988), Young and Freedman (2005), Yarthut (1991), Zhili (2005).

### 1.9 Cellular Network Speeds

Bandwidth is the primary measure of network speed, and it is the data rate supported by a network connection or interface. Virtually everyone knows the bandwidth rating of their modem or their internet service that is prominently advertised on network products sold today. In networking, bandwidth represents the overall capacity of the connection. Bandwidth is the amount of data that passes through a network connection over time as measured in bytes per second, Hahn, H. and Kibora, L. (2008), Herbert and Donal (1986), Hsu (1995), James, B. (2008).
In this research, the cellular phone and computer system are used for measurement and analytical purposes. This makes it a necessity to review the

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basic literatures related to cellular phone and computer system.

### 2.1 Definitions of Terms

According to Jerry (1993), John and Irwin (1965), Kennedy and Davis (2008), John (2001), Kahn (1984), Uquetan et. al. (2016), Kenyon (2002), Peter and Jane (2008), Philip (1991), Raines (2009), Robenson (1999), the computer system has been defined by many authors in various ways depending on their purpose. Some of these definitions are as follows:

- Zhili (2005), defined computer system as a device that works under the control of stored programs having the abilities to accept, store and process data to produce information as the result. The underlining fact is that it functions under stored program.
- Another definition of the computer system is that it is a machine that performs tasks, such as calculations or electronic communication, under the control of a set of instructions called a program (Encarta Dictionary, 2009). Programs usually reside within the computer and are retrieved and processed by the computer's electronics.

### 1.10.1 Cellular

The word cellular has been used invarious quarters to mean different things.In communications, cellular is defined as a low – powered, light weight radio transceiver (combination of transmitter and receiver) that provides voice telephone (Encarta Dictionary, 2009).

Kennedy and Davis (2008) in their book "Electronic Communication Systems" simply put cellular to be organized as a system of cells especially for radio communication.

Cellular or cellular phone is a device that can make and receive telephone calls over a radio link whilst moving around a wide geographic area (http://en.wikipedia.org/wiko/moble-phone, 2011).

### 1.10.2 Network

Network has many definitions some of which are discussed below;

From http://en.wikipedia.org/wiki/computer_network (2011) network has been defined as a collection of hardware components and computers interconnected by communication channels that allow sharing of resources and information.

Technically, network is defined as "if at least one process in one computer is able to send/receive data to/from at least one process residing in a remote computer, then the two computers are said to be in network. "Network maybe classified according to a wide variety of characteristics such as the medium used to transport the data, communication protocol used, scale, topology and organizational scope, Faithpraise (2007), Frank, K. (2004), Uquetan et. al. (2017), (2016), George, G. (1981), Gick, P. C. (1979).

### 1.10.3 Cables

The word cable is a word with diverse meanings. For instance it could mean a strong thick rope or steel wire, used for lifting, pulling, towing, or securing things. It also has the definition of being a group of wires for transmitting electrical signals that are bound together and usually have shared or common insulation.

A cable is a lengthy object composed of one or more electric conductors, covered by insulation and sometimes a protective sheath, used for communications systems,Encarta Dictionary(2009), Obi et. al. (2013), (2017).

The cables used in networking have basic cable parameters like attenuation, characteristic impedance,and signal-noise ratio. In his view Todd (2007) said that the quality of signals received at the receiving end of transmission depends greatly on the parameters of the cable and thus the integrity of transmitted data is a function of the cables'resistant to tapping.

### 1.10.4 Wireless/Wave

The Encarta English dictionary defines wireless as lacking wires, and wave as a line, shape, surface, or pattern that curves in one direction and then another. Comparing these definitions with that of Young and Freedman (2005) that wave is an oscillation that travels through a medium by transferring energy from one particle or point to another without causing any permanent displacement of the medium, we can say that wave is wireless. In his view, Zhili (2005), Obi et. al. (2013), (2016), (2017), stated that wireless is simply the use of radio signals rather than wires.

### 1.10.5 Interference

Interference is an unwanted signal that disrupts radio, telephone, or television reception (Encarta Dictionary, 2009). Interference occurs as a result of spurious voltages which travel along with the desired signals. This opposes or disrupts the perfect reconstruction of the signal at the receiving end of a transmission. Young and Freedman (2005) put interference to be an effect that occurs when two or more waves overlap or intersect. When signals

(Waves) interfere with each other, the amplitude of the resulting wave depends on the frequencies and relative phases (relative positions of the crests and troughs), and amplitudes of the interfering waves, Ewona et. al. (2013), (2014), (2016).

**1.10.6 Noise**

In physics, noise is an acoustic, electric, or electronic signal consisting of a random mixture of wavelengths (Gick, 1979).Philip (1991) described noise as the term that designates a signal that contains no information. That is to say that it is the part of a received signal that has no logical meaning.In acoustics, “white” noise consists of all audible frequencies, just as white light consists of all visible frequencies, Encarta Dictionary, (2009), Ewona et. al. (2014), Ushie et. al. (2014).

Noise is also a subjective term referring to any unwanted sound. Noise also has the definition of being a random disturbance in an electric circuit that interferes with the reception of signal. In this regard, George (1981) found out that noise plays a crucial role in communication systems. According to him it determines the theoretical capacity of the channel and in practice it determines the number of errors occurring in a digital communication, Uchendu (2006), Pekene et. al. (2015), Udoimuk et. al. (2014).

**1.10.7 Congestion**

Uchendu (2006) defined congestion in cellular communication as a situation in which the amount of information to be transferred is greater than the amount that the data communication path can carry.

Van and Michael (1988), Udoimuk et. al. (2014) and Egor et. al. (2016) described congestion as what occurs when a link or node is carrying so much data that it’s quality of service deteriorates. Typical effects include queuing delay, packet loss or the blocking of new connections.

**1.10.8 Transmission Error**

According to Herbert and Donal (1986), Agbor et al. (2013) and Ojar et. al. (2014), Network is responsible for transmission of data from one device to another device. The end to end transfer of data from a transmitting application to a receiving application involves many steps, each subject to error. These errors are called transmission errors. Data can be corrupted during transmission. For reliable communication, errors must be detected and corrected. They described transmission error as the failure of a transmitting system to produce an anticipated result. They went further to explain that these errors can be controlled using error control processes, James, B. (2008), Jerry (1993), John and Irwin (1965), Kennedy and Davis (2008), John (2001), Kahn (1984), Kenyon (2002), Kracaver (1960), Mablin, G. (2001).

**1.10.9 Signal Strength**

In telecommunications, particularly radio, signal strength refers to the magnitude of the electric field at a reference point that is a significant distance from the transmitting antenna. It may also be referred to as received signal level or field strength. Typically, it is expressed in voltage per length or signal power received by a reference antenna. For very low-power systems, such as the cellular phones, signal strength is usually expressed in dB-microvolt per metre (dBμV/m).Signal strength as that which defines more or less the quality of the signal so transmitted in that if the signal is weak, there is the tendency that the signal can lose some data, Herbert and Donal (1986) and Ekpo et. al. (2013).

**1.10.10 Data Coding and Transmission**

Data coding is defined as the process of arranging data into an organized system or code. In communication, data are usually coded for easy transmission. This is of great importance as it guards against intruders from tapping the information being transmitted, Cavalcanti (1939), Christopher, (1993), Clair (1985), Clark (1983). Douglas (1997), Dunlop and Smith (1994).

On the other hand, data transmission is the physical transfer of data (adigital bit stream) over a point-to-point or point-to-multipoint communication channel. The data are represented as an electromagnetic signal, such as an electrical voltage, radio wave, microwave or infrared signal.

**1.10.11 Data Security and Confidentiality**

Data security refers to the techniques developed to safeguard information and information systems. Peter and Jane (2008) defined data security as the practice of keeping data protected from corruption and unauthorized access. On the other hand, data confidentially is an ethical principle which ensures that the disclosure of data handled by a system would be limited in strict accordance with the wishes of the owner of the data or information (Stephen, 1996).

**1.10.12 Data Clarity**

Data Clarity is defined by the Encarta dictionary as the quality of being clear in sound or image. In cellular communication, data clarity is of great importance as signal interference, noise and other factors tend to affect the clarity of data. Peter and Jane (2008) explained in their work that most issues of data clarity in cellular communication arise from areas not being properly covered by the network signal. They went further to explain that this situation can be improved by using cellular amplifiers and cell phone repeaters.

**1.10.13 Cell**

The word cell has diverse definitions which suit diverse areas of study. Herbert and Donal (1986) defined the cell to be the area covered by one of the transmitters in a mobile telephone system that automatically switches a traveling user between short-range radio stations.

Robenson (1999) defined cell in a cellular radio network to be the coverage area of each tower that receives and transmits calls from mobile telephones. The cells according to him are arranged in a honeycomb pattern, and they overlap so that the system can handle increases in anticipated telephone traffic volume. Obi (1994) went further to explain that every call in a cellular network, originates within a cell. He called this the cell of origin.

**1.10.14 Signal**

The term signal has many definitions some of them include the following.

English Encarta dictionary defines signal as a piece of information communicated by an action, gesture, or sign.

Bolanle (2001) defined signal in communication as an information transmitted by means of a modulated current or an electromagnetic wave and received by telephone, telegraph, radio, television, or radar. According to this definition, signal is modulated which means that the received signal is a mixture of audio and radio waves. Hsu (1995) defined signal as any quantity measurable through time or over space. Within a complex society, any set of human information or machine data can also be taken as a signal. Such information or machine data must all be part of systems existing in the physical world either living or non-living.

**1.10.15 Antenna**

Zhili (2005) defined antenna as a metallic piece of equipment of variable shape, used in the sending and receiving of television or radio signals. From this definition, antenna is made in different shapes to suit the exact type of signal it is to send or receive.

The Microsoft Encarta defines Antenna as an aerial device used to radiate and receive radio waves through the air or through space. Antennas are used to send radio waves to distant sites and to receive radio waves from distant sources. Many wireless communication devices, such as radio broadcast television sets, radar and cellular phones use antenna. Raines (2009) defined antenna as an electrical device which converts electric currents into radio waves, and vice versa. He further explained that an antenna in usually used with a radio transmitter or radio receiver.

**1.10.16 Broadcast**

Broadcast is defined by Carey (1989), Mandu (1984), Mark (1992), Mark (1990), Maurice(1985), Todd (2007), Tugal and Tudal (1998) as the distribution of audio and video contents to a dispersed audience via any audio visual medium. The receiving parties may include the general public or a relatively large subset thereof. It could also be for the purpose of private recreation, non-commercial exchange of massages, experimentation, self-training and emergency communications.

Thompson (1999) divided broadcast into kinds which are Analog and digital broadcasts.

## MATERIALS AND METHOD

**Materials**

As cellular phones gain grounds in our everyday activities, there is need for the cellular networks being used to be examined to find out the range of their signal strengths and how they vary with different times of the day. To achieve this, a cellular signal monitor/analyzer is used to measure the signal strengths and quality of signals of these networks. The materials used for this research are computer system and cellular phones.

**Cellular Signal Monitor/Analyzer**

This is a written software to monitor and analyze the signal strengths and quality of service of cellular networks. This monitoring software includes GSM Signal Monitor 7.0 and CDMA signal Monitor

**The Computer System**

The computer system has been defined earlier as a programmable machine capable of accepting data, processing data and giving an output on demand. Since this work is based on comparing the cellular network technologies using either the computer system or the cellular phones, we will consider the types of computer configurations on ground. For this purpose many personal and public computers were assessed and it was discovered that they are of different configurations for convenience. For example most of the computers used in the University of Calabar are Pentium IV computers whereas those used in MTN-Nig office in Calabar are Dual core computers.

**The Cell Phone/SIM Card**

The cell phone (also known as cellular phone) is a device that can initiate and receive telephone calls over a radio link while moving around a wide geographical area. It does so by connecting to a cellular network provided by a mobile phone operator, allowing access to the public telephone network (Hahn and Kibora, 2008).

The modern cell phones support a wide variety of services such as text messaging, multimedia services, E-mail, internet access, short-range wireless communications (infrared, Bluetooth), business applications, gaming and photography. Cell phones that offer these and more general computing capabilities are referred to as Smartphones.

The common components found on cell phones are:

1. A battery, providing the power source for the phone's functions.
2. Input mechanisms to allow the user interact with the phone. The most common input mechanism is the keypad, but touch screens are also found in some high-end Smartphones.
3. All GSM phones use SIM cards to allow accounts to be swapped among devices. Some CDMA devices also have similar cards called Removable User Identity Modules (R-UIMs).
4. Individual cell phones are uniquely identified by International Mobile Equipment Identity (IMEI) numbers.

On the other hand, a Subscriber IDENTIFICATION module (SIM) is an Integrated Circuit that securely stores the International Mobile Subscriber Identity (IMSI) and the related key used to identify and authenticate subscribers on mobile telephone devices (such as cell phones and computers) (Gaby, 2006)

A SIM is embedded into a removable SIM card, which can be transferred between different mobile devices. The SIM cards have the same thickness as full-size cards, but their length and width are 25mm x 15mm. The SIM card contains it's unique serial number (ICCID), internationally unique number of the mobile user (IMSI), security authentications and ciphering information, temporary information related to the local network, a list of services the user has access to and two passwords (personal identification number (PIN) for ordinary use and a personal unblocking code (PUK) for PIN unlocking).

**Satellite Mast**

The satellite mast is very significant in cellular networking as it links the cellular phones to their base stations and to the communication satellites in the orbits around the Earth.Mast is a tall broadcasting antenna holder deployed to extend the coverage of cellular networks. In cellular communications, antenna mastsare principally connected to Amplifiers and Repeaters.

**Microwave Link**

A microwave link is a communication system that uses a beam of radio waves in the microwave frequency range to transmit video, audio, or data between two metres and several kilometres apart (Brown 1984). Microwave links are commonly used by cellular network to transmit information.

Some of the uses of microware links are

1. In communications between satellites and base stations
2. As backbone carriers for cellular systems
3. In short range indoor communications
4. In Telecommunications, for linking remote and regional telephone exchanges to larger (main) exchanges without the need for copper/optical fibre lines.

**Satellite Phones**

According to Okoro (2006), Patrick (1982), Pepple (2001), a satellite phone is a type of mobile phone that connects to orbiting satellites instead of terrestrial cell sites. It provides similar functionality to terrestrial mobile phones and low-bandwidth internet access is supported through most systems.

Depending on the architecture of a particular system, coverage may include the entire earth or only specific regions.

The satellite phone also known as terminal varies widely. Early Satellite phones had sizes and weights comparable to those of late 1980s mobile phones, but usually with large retractable antennas. More recent satellite phones are similar in size to regular cellular phones while some prototype satellite phones have no distinguishable difference from ordinary Smartphones. Satellite phones are popular on expeditions into remote areas where terrestrial cellular service is unavailable.

**Flyaway Units**

Flyaway units are essentially the same technology and the same equipment as vehicle mounted automatic pointing mobile satellite units, but have been made portable by installation into one or more ruggedized shippable water proof cases (James, 2008). These units are designed to be transported to anywhere for broadband connectivity.

**C-Band Satellite range**

The C-band is a name given to certain portions of the electromagnetic spectrum, including wavelengths of microwaves that are used for long-distance radio telecommunications. The IEEE C-band (with its slight variations) contains frequency ranges that are used for many satellite communication transmissions, some Wi-Fi devices, some cordless telephones, and some weather radar systems. For satellite communication, the microwave frequencies of the C-band perform better under adverse weather conditions in comparison with Ku band (11.2 GHz to 14.5 GHz) microwave frequencies, which are used by other large sets of communication satellites. The adverse weather conditions are collectively referred to as rain fade, and have to do with moisture in the air, including rain and snow, Kahn (1984), Kenyon (2002), Kracaver (1960), Mablin, G. (2001), Macline (1993), Mandu (1984), Mark (1992), Mark (1990).

**Ku-Band Satellite range**

The ku-band is a portion of the electromagnetic spectrum in the microwave range of frequencies. It is primarily used for satellite communications, most notably for fixed and broadcast services and for specific applications such as ISS communications. Ku-band satellites are also used for backhauls and particularly for satellites from remote locations. The band is split into multiple segments that vary by geographical region by the International Telecommunication Union (ITU).

Compared with C-band, ku-band is not restricted in power to avoid interference with terrestrial microwave systems and the power of its uplinks and downlinks can be increased.

**Network Cables**

This work which is a comparative study of cellular network technologies will consider the types of cables used for networking. These cables are coaxial cable and optical fibre cable.

**Coaxial Cable**

Coaxial cable consists of an inner core and an outer flexible braided tube, both of conductive material separated by an insulator, used to transmit high frequency signals at high speeds. Coaxial cables are typically classified according to their impedance. However there are two types of coaxial cables which are thin and thick (coaxial cables).

Although coaxial cable is difficult to install, it is highly resistant to signal interference. In addition, it can support great cable lengths between network devices (Okoro, 2006).

**Optical Fibre Cable**

Optical Fibre cable is a very fine glass rod of diameter 125μm. It is made up of a core surrounded by a glass cladding of smaller refractive index than the core. It is also dielectric waveguide used for the propagation of electromagnetic energy at optical frequencies. Optical fibre cables do not transmit electrical signals, instead the signals must be converted to light signals, hence the use of media converters. Also, at the end of the cable the light signal must be converted back to electrical signal. It also has a high bandwidth and immunity from electromagnetic interference, Roddy and Coolean (1997), Yarthut (1991), Zhili (2005).

**Server**

Server is a computer that supplies services or data to other machines on a Local Area Network or Wide Area Network such as the internet. Some servers run administrative software that control access to all or part of the network and its resources (such as disk drives or printers), provide files, applications or world wide web pages.A server could be dedicated or shared. A dedicated server is one that performs a specific task in a given network environment. The performance of dedicated server is better when compared to the shared server. On the other hand the shared server's performance is relatively poor due to the continuous interruption made to its operating system to provide service to multiple users, which decreases the actual capacity available to the system (Okoro, 2006), Peter and Jane (2008). Philip (1991), Raines (2009), Robenson (1999).

**Study Location**

The location for the study is Calabar,South Eastern Nigeria. Calabar is the capital city of Cross River State and is located on latitude $4^0$50'N, longitude $8^0$015'E. The city is covered by six cellular networks namely MTN-Nigeria, Globacom, Airtel, Etisalate, Visafone and Starcoms.

**Mast Availability**

The availability of mast is a big factor in ascertaining the coverage area of cellular network signals. Presently in South Eastern Nigeria, there is a good number of network masts mostly in the urban centres. The rural areas have limited numbers of network masts that can hardly cover the whole area. For this reason, some rural areas are yet to be covered by any cellular network.

At a closer look at the available network masts, it can be seen that about ninety percent of them are owned by GSM operators. In most rural

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areas, there is no CDMA operator coverage at all. This tends to leave the users with no option than to make do with GSM operators since they happen to be the only network available.

**Measurement**

The research took measurements of signal strengths and quality of signals of the available cellular networks at specific time intervals. Graphs of the measured quantities against time were plotted to find out the lowest and the peak values and their effect on the network.

The overall measurement is done by the use of software called GSM/CDMA Signal Monitor which is installed in Samsung GT-S5300 and connected to a computer system. The software functions only with android phones. At any time the program is loaded, it automatically starts monitoring and analyzing the corresponding data as specified by the administrator.

**Analysis**

This research was carried out on six cellular networks. The network monitor/analyzer is used to monitor the signal strength levels and corresponding quality of signal of all the networks. Matlab and SPSS were used in analyzing the measured quantities.

The following analysis was carried out on these networks.

(i) The signal strengths of these networks as they vary with time.
(ii) The quality of signal provided by these networks as their signal strengths vary.
(iii) The mean signal strength and quality of signal for each network.
(iv) The standard deviation in signal strength and quality of signal for each network.
(v) The variance in signal strength and quality of signal for each network.
(vi) The regression between signal strength and quality of signal for each network.
(vii) The network with more stable signal strength.
(viii) The way signal strength is affected by peak hour's activities.
(ix) The hours of the day with higher level of signal strength.

## RESULTS

**Measured values**

Results obtained from the various networks are recorded using tables. The parameters measured in all the networks under consideration are signal strength (SS) in decibel micro volt per metre (dBµV/m) and quality of signal (QOS) in percentage (%). These parameters are measured at particular time intervals and graphs for the corresponding data plotted.

### 4.1.1 MTN-Nigeria

GSM Signal Monitoring was used in measuring the parameters of this network. Table 4.1 shows the average maximum signal strength (SS) as high as-79dBµV/m at7:00 hours and average minimum signal strength as low as -99dBµV/m at17:00 hours. An average maximum quality of signal (QOS) as high as 56% at 7:00 hours and average minimum as low as 12% at 17:00 hour. A regression coefficient of 0.972 was found between signal strength and quality of signal. Figures 4.1 and 4.2 show that signal strength varies between -77dBµV/m and -99dBµV/m while quality of signal vary between 58% and 12%. The figures also show a more consistency period between the hours of 14:00 and 16:00.

TABLE 4.1
Regression between signal strength (Y) and quality of signal (Z) for MTN-Nigeria

| Time[In Hours] (X) | Signal Strength[In dBµV/m] (Y) | Quality of Service[%] (Z) | YZ | $Y^2$ | $Z^2$ | r |
|---|---|---|---|---|---|---|
| 00:00 | -81.00 | 51.00 | -4131.0 | -6561.0 | 2601.0 | **0.972** |
| 01:00 | -87.00 | 46.00 | -4002.0 | -7569.0 | 2116.0 | |
| 02:00 | -83.00 | 50.00 | -4150.0 | -6889.0 | 2500.0 | |
| 03:00 | -81.00 | 51.00 | -4131.0 | -6561.0 | 2601.0 | |
| 04:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 05:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 06:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 07:00 | -79.00 | 56.00 | -4424.0 | -6241.0 | 3136.0 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 08:00 | -81.00 | 51.00 | -4131.0 | -6561.0 | 2601.0 | |
| 09:00 | -86.00 | 46.00 | -3956.0 | -7396.0 | 2116.0 | |
| 10:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 11:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 12:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 13:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 14:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 15:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 16:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 17:00 | -99.00 | 12.00 | -1188.0 | -9801.0 | 144.0 | |
| 18:00 | -83.00 | 50.00 | -4150.0 | -6889.0 | 2500.0 | |
| 19:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 20:00 | -77.00 | 58.00 | -4466.0 | -5929.0 | 3364.0 | |
| 21:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 22:00 | -95.00 | 26.00 | -2470.0 | -9025.0 | 676.0 | |
| 23:00 | -95.00 | 26.00 | -2470.0 | -9025.0 | 676.0 | |
| **Total** | **-2079.00** | **1004.00** | **-85570.0** | **-180835.0** | **44804.0** | |
| **Range** | **22.00** | **46.00** | | | | |
| **Maximum** | **-77.00** | **58.00** | | | | |
| **Minimum** | **-99.00** | **12.00** | | | | |
| **Mean** | **-86.6250** | **41.8333** | | | | |
| **Std. Error** | **1.15910** | **2.25355** | | | | |
| **Variance** | **32.245** | **121.884** | | | | |
| **Std. Deviation** | **5.67843** | **11.04011** | | | | |

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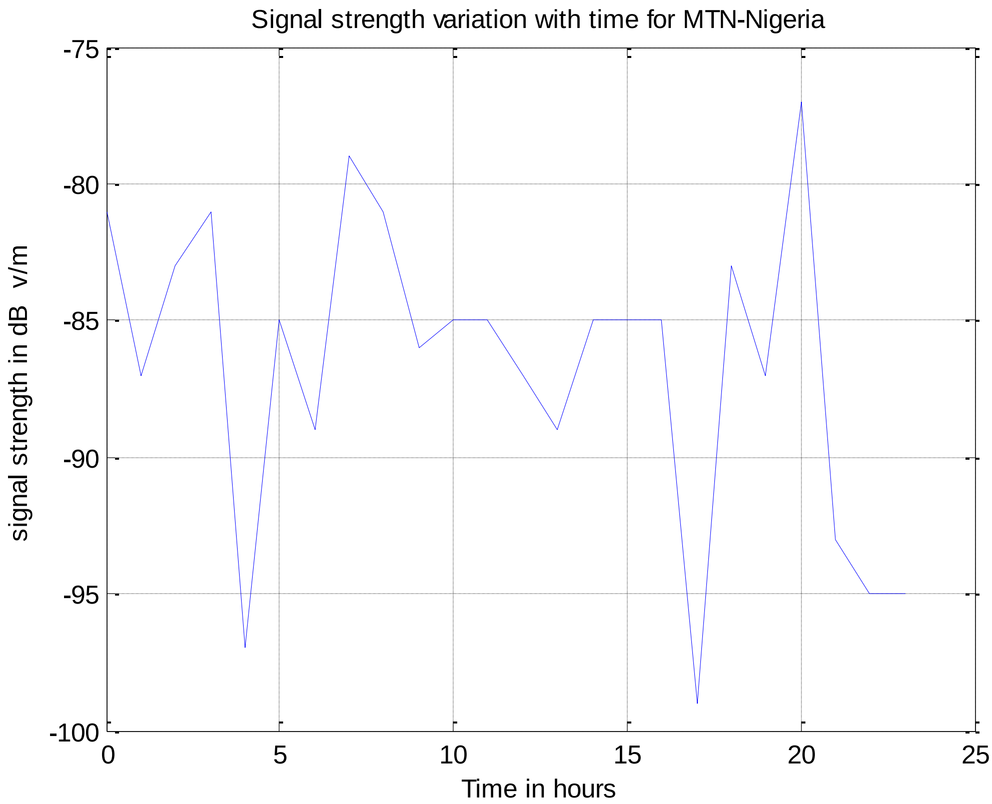


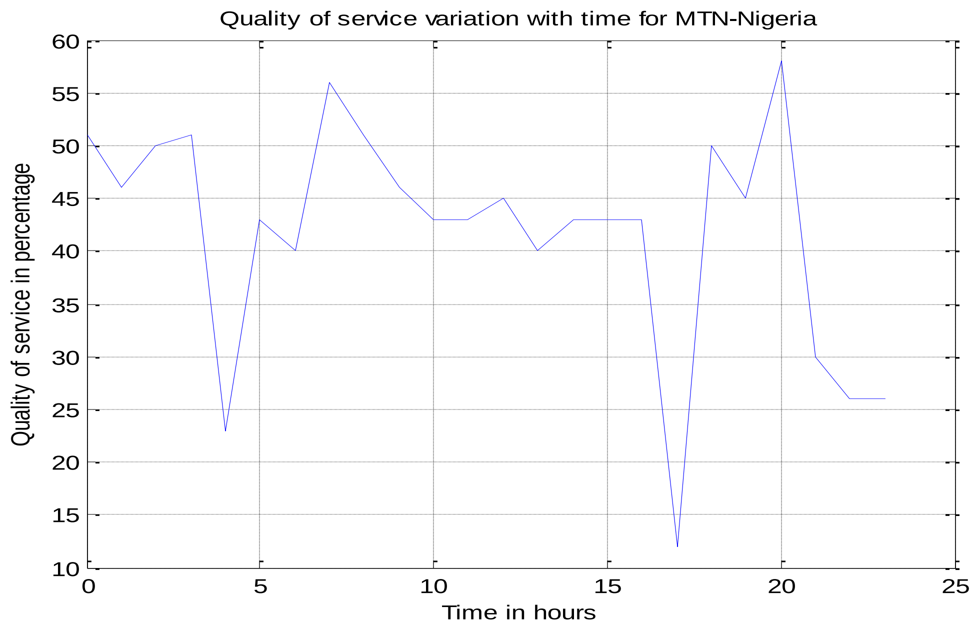


Fig. 4.2: Quality of signal variation with time for MTN Nigeria

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TABLE 4.2
Regression between signal strength (Y) and quality of signal (Z) for Airtel

| Time[In Hours] (X) | Signal Strength[In dBμV/m] (Y) | Quality of Service[%] (Z) | YZ | $Y^2$ | $Z^2$ | R |
|---|---|---|---|---|---|---|
| 00:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | **0.986** |
| 01:00 | -86.00 | 46.00 | -3956.0 | -7396.0 | 2116.0 | |
| 02:00 | -85.00 | 45.00 | -3825.0 | -7225.0 | 2025.0 | |
| 03:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 04:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 05:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 06:00 | -103.00 | 10.00 | -1030.0 | -10609.0 | 100.0 | |
| 07:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 08:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 09:00 | -103.00 | 10.00 | -1030.0 | -10609.0 | 100.0 | |
| 10:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 11:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 12:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 13:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 14:00 | -83.00 | 50.00 | -4150.0 | -6889.0 | 2500.0 | |
| 15:00 | -83.00 | 50.00 | -4150.0 | -6889.0 | 2500.0 | |
| 16:00 | -91.00 | 32.00 | -2912.0 | -8281.0 | 1024.0 | |
| 17:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 18:00 | -91.00 | 32.00 | -2912.0 | -8281.0 | 1024.0 | |
| 19:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 20:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 21:00 | -83.00 | 50.00 | -4150.0 | -6889.0 | 2500.0 | |
| 22:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 23:00 | -103.00 | 10.00 | -1030.0 | -10609.0 | 100.0 | |
| **Total** | **-2197.00** | **820.00** | **-73242.0** | **-201991.0** | **31946.0** | |
| **Range** | **20.00** | **40.00** | | | | |
| **Maximum** | **-83.00** | **50.00** | | | | |
| **Minimum** | **-103.00** | **10.00** | | | | |
| **Mean** | **-91.5417** | **34.1667** | | | | |
| **Std. Error** | **1.25539** | **2.66803** | | | | |
| **Variance** | **37.824** | **170.841** | | | | |
| **Std. Deviation** | **6.15014** | **13.07060** | | | | |

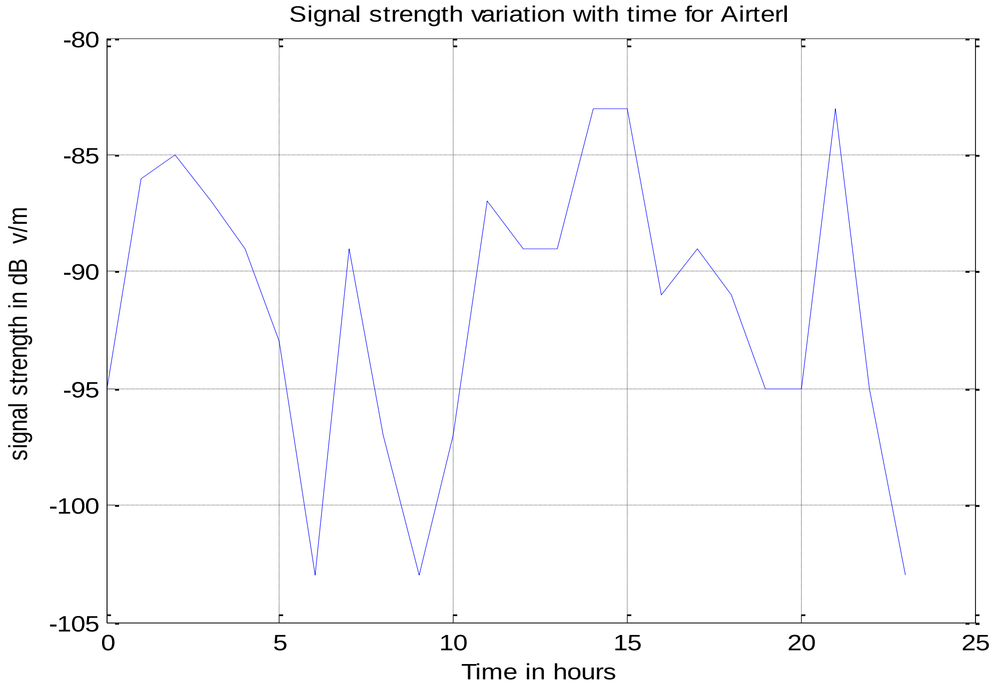


Fig. 4.3: Signal Strength Variation with time for Airtel


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**Fig. 4.4:** Quality of signal variation with time for Airtel

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TABLE 4.3
Regression between signal strength (Y) and quality of signal (Z) for Globacom

| Time[In Hours] (X) | Signal Strength[In dBµV/m] (Y) | Quality of Service[%] (Z) | YZ | $Y^2$ | $Z^2$ | r |
|---|---|---|---|---|---|---|
| 00:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | **0.981** |
| 01:00 | -83.00 | 50.00 | -4150.0 | -6889.0 | 2500.0 | |
| 02:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 03:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 04:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 05:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 06:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 07:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 08:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 09:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 10:00 | -81.00 | 51.00 | -4131.0 | -6561.0 | 2601.0 | |
| 11:00 | -79.00 | 56.00 | -4424.0 | -6241.0 | 3136.0 | |
| 12:00 | -79.00 | 56.00 | -4424.0 | -6241.0 | 3136.0 | |
| 13:00 | -83.00 | 50.00 | -4150.0 | -6889.0 | 2500.0 | |
| 14:00 | -103.00 | 10.00 | -1030.0 | -10609.0 | 100.0 | |
| 15:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 16:00 | -103.00 | 10.00 | -1030.0 | -10609.0 | 100.0 | |
| 17:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 18:00 | -91.00 | 32.00 | -2912.0 | -8281.0 | 1024.0 | |
| 19:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 20:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 21:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 22:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 23:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| **Total** | **-2168.00** | **869.00** | **-76519.0** | **-196866.0** | **35455.0** | |
| **Range** | **26.00** | **46.00** | | | | |
| **Maximum** | **-79.00** | **56.00** | | | | |
| **Minimum** | **-103.00** | **10.00** | | | | |
| **Mean** | **-90.3333** | **36.2083** | | | | |
| **Std. Error** | **1.36024** | **2.688536** | | | | |
| **Variance** | **44.406** | **173.476** | | | | |
| **Std. Deviation** | **6.66377** | **13.17105** | | | | |

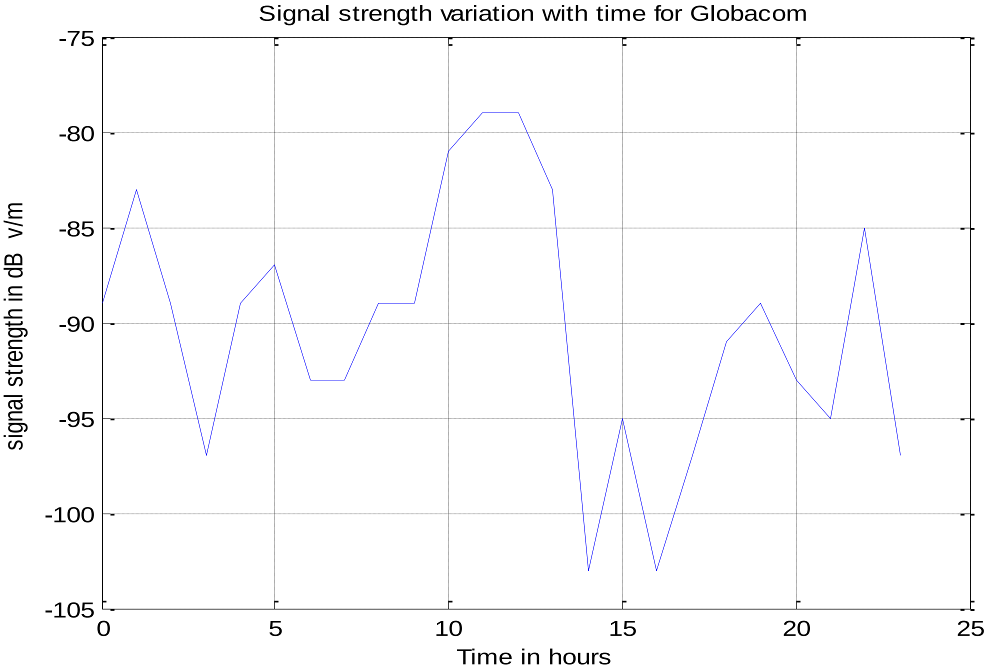


**Fig. 4.5:** Signal Strength Variation with time for Globacom

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TABLE 4.4
Regression between signal strength (Y) and quality of signal (Z) for Visafone

| Time[In Hours] (X) | Signal Strength[In dBµV/m] (Y) | Quality of Service[%] (Z) | YZ | $Y^2$ | $Z^2$ | R |
|---|---|---|---|---|---|---|
| 00:00 | -86.00 | 43.00 | -3698.0 | -7396.0 | 1849.0 | **0.981** |
| 01:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 02:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 03:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 04:00 | -83.00 | 50.00 | -4150.0 | -6889.0 | 2500.0 | |
| 05:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 06:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 07:00 | -87.00 | 46.00 | -3915.0 | -7569.0 | 2116.0 | |
| 08:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 09:00 | -110.00 | 06.00 | -660.0 | -12100.0 | 36.0 | |
| 10:00 | -109.00 | 06.00 | -654.0 | -11881.0 | 36.0 | |
| 11:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 12:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 13:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 14:00 | -79.00 | 56.00 | -4424.0 | -6241.0 | 3136.0 | |
| 15:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 16:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 17:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 18:00 | -91.00 | 32.00 | -2912.0 | -8281.0 | 1024.0 | |
| 19:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 20:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 21:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 22:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 23:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| **Total** | **-2204** | **808** | **-72090** | **-203585** | **30808** | |
| **Range** | **31.00** | **50.00** | | | | |
| **Maximum** | **-79.00** | **56.00** | | | | |
| **Minimum** | **-110.00** | **06.00** | | | | |
| **Mean** | **-91.8333** | **33.6667** | | | | |
| **Std. Error** | **1.46291** | **2.55566** | | | | |
| **Variance** | **51.362** | **156.754** | | | | |
| **Std. Deviation** | **7.16675** | **12.52013** | | | | |

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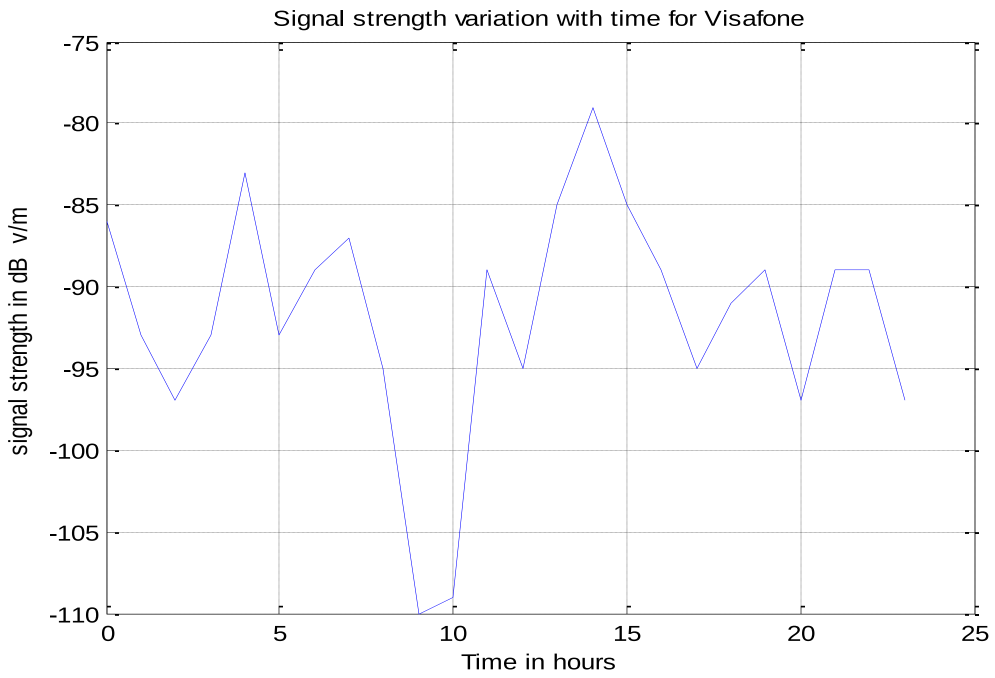


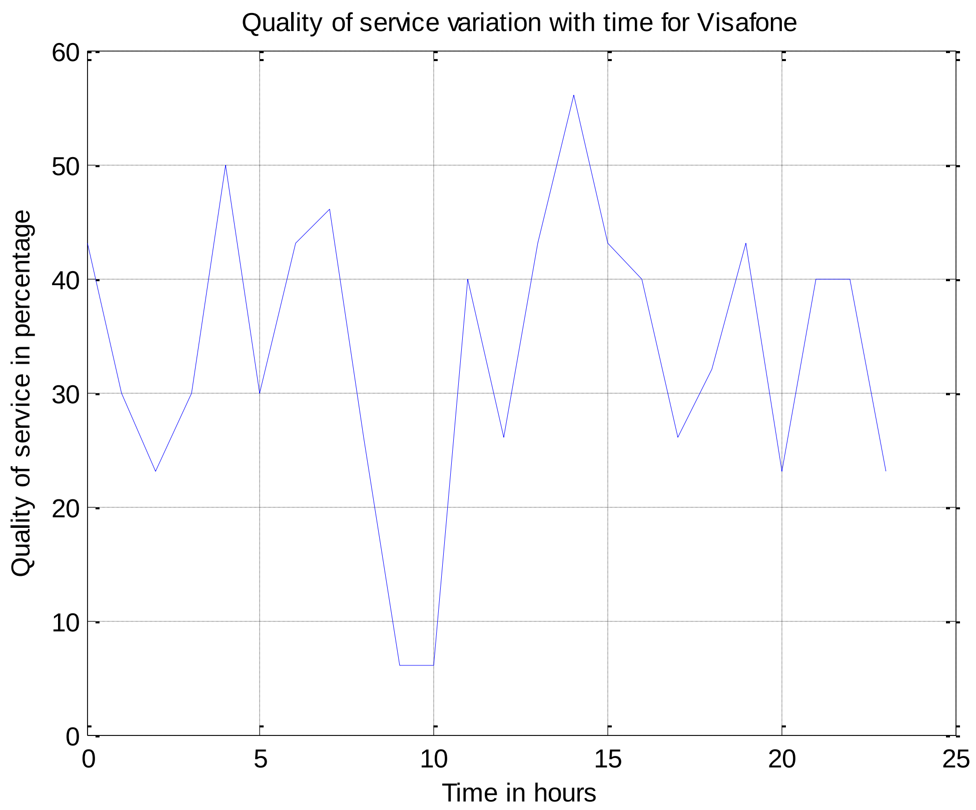

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TABLE 4.5
Regression between signal strength (Y) and quality of signal (Z) for Etisalat

| Time[In Hours] (X) | Signal Strength[In dBµV/m] (Y) | Quality of Service[%] (Z) | YZ | $Y^2$ | $Z^2$ | R |
|---|---|---|---|---|---|---|
| 00:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | **0.975** |
| 01:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 02:00 | -87.00 | 46.00 | -3915.0 | -7569.0 | 2116.0 | |
| 03:00 | -85.00 | 45.00 | -3825.0 | -7225.0 | 2025.0 | |
| 04:00 | -81.00 | 51.00 | -4131.0 | -6561.0 | 2601.0 | |
| 05:00 | -85.00 | 45.00 | -3825.0 | -7225.0 | 2025.0 | |
| 06:00 | -85.00 | 45.00 | -3825.0 | -7225.0 | 2025.0 | |
| 07:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 08:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 09:00 | -91.00 | 32.00 | -2912.0 | -8281.0 | 1024.0 | |
| 10:00 | -86.00 | 46.00 | -3956.0 | -7396.0 | 2116.0 | |
| 11:00 | -80.00 | 57.00 | -4560.0 | -6400.0 | 3249.0 | |
| 12:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 13:00 | -91.00 | 32.00 | -2912.0 | -8281.0 | 1024.0 | |
| 14:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 15:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 16:00 | -109.00 | 6.00 | -654.0 | -11881.0 | 36.0 | |
| 17:00 | -103.00 | 10.00 | -1030.0 | -10609.0 | 100.0 | |
| 18:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 19:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 20:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 21:00 | -85.00 | 45.00 | -3825.0 | -7225.0 | 2025.0 | |
| 22:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 23:00 | -81.00 | 51.00 | -4131.0 | -6561.0 | 2601.0 | |
| **Total** | **-2148.00** | **915.00** | **-79949.0** | **-193260.0** | **38465.0** | |
| **Range** | **29.00** | **51.00** | | | | |
| **Maximum** | **-80.00** | **57.00** | | | | |
| **Minimum** | **-109.00** | **6.00** | | | | |
| **Mean** | **-89.5000** | **38.1250** | | | | |
| **Std. Error** | **1.35401** | **2.54689** | | | | |
| **Variance** | **44.000** | **155.679** | | | | |
| **Std. Deviation** | **6.63325** | **12.47715** | | | | |

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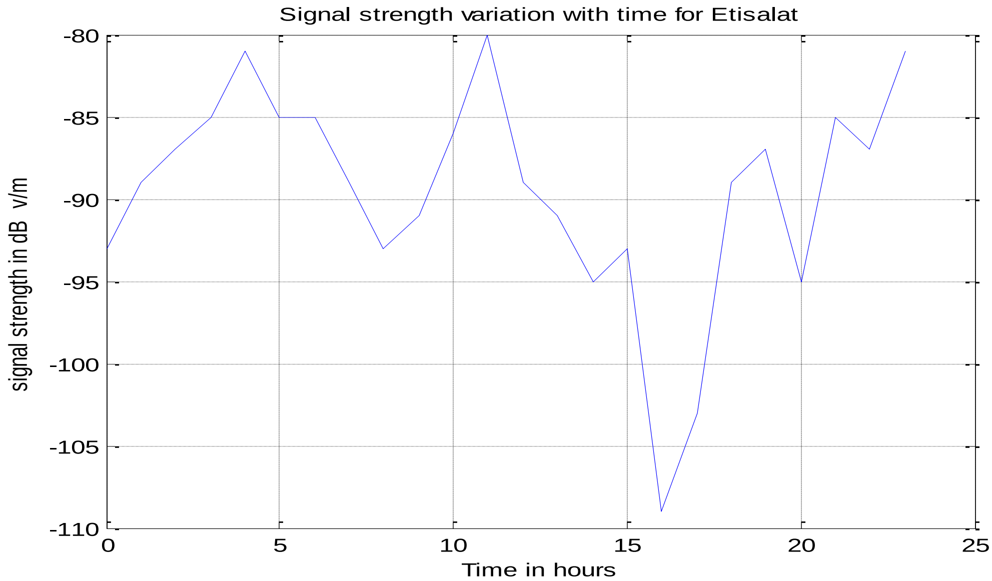


Fig. 4.9: Signal Strength Variation with time for Etisalat

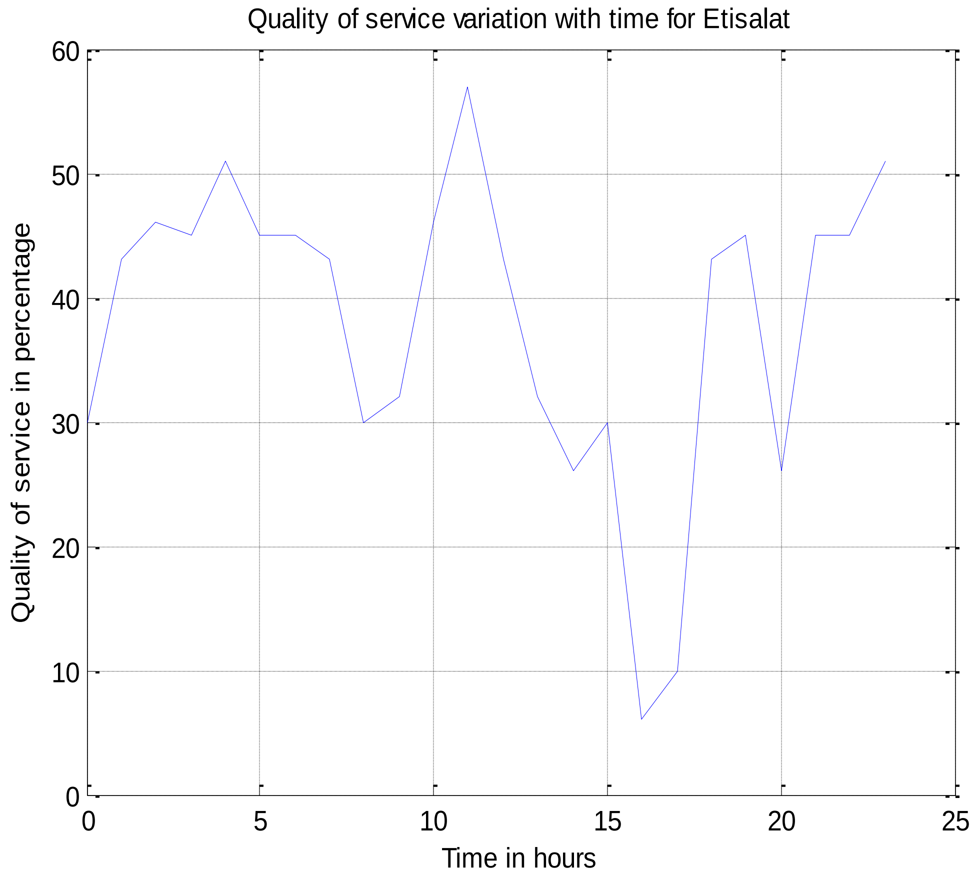


**Fig. 4.10:** Quality of signal variation with time for Etisalat

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TABLE 4.6
Regression between signal strength (Y) and quality of signal (Z) for Starcoms

| Time[In Hours] (X) | Signal Strength[In dBµV/m] (Y) | Quality of Service[%] (Z) | YZ | $Y^2$ | $Z^2$ | r |
|---|---|---|---|---|---|---|
| 00:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | **0.969** |
| 01:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 02:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 03:00 | -86.00 | 46.00 | -3956.0 | -7396.0 | 2116.0 | |
| 04:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 05:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 06:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 07:00 | -89.00 | 40.00 | -3560.0 | -7921.0 | 1600.0 | |
| 08:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 09:00 | -99.00 | 10.00 | -990.0 | -9801.0 | 100.0 | |
| 10:00 | -86.00 | 46.00 | -3956.0 | -7396.0 | 2116.0 | |
| 11:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 12:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 13:00 | -107.00 | 07.00 | -749.0 | -11449.0 | 49.0 | |
| 14:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 15:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 16:00 | -89.00 | 43.00 | -3827.0 | -7921.0 | 1849.0 | |
| 17:00 | -97.00 | 23.00 | -2231.0 | -9409.0 | 529.0 | |
| 18:00 | -95.00 | 26.00 | -2470.0 | -9026.0 | 676.0 | |
| 19:00 | -87.00 | 45.00 | -3915.0 | -7569.0 | 2025.0 | |
| 20:00 | -85.00 | 43.00 | -3655.0 | -7225.0 | 1849.0 | |
| 21:00 | -91.00 | 32.00 | -2912.0 | -8281.0 | 1024.0 | |
| 22:00 | -93.00 | 30.00 | -2790.0 | -8649.0 | 900.0 | |
| 23:00 | -86.00 | 46.00 | -3956.0 | -7396.0 | 2116.0 | |
| **Total** | **-2201.00** | **792.00** | **-71204.0** | **-202573.0** | **29158.0** | |
| **Range** | **22.00** | **39.00** | | | | |
| **Maximum** | **-85.00** | **46.00** | | | | |
| **Minimum** | **-107.00** | **07.00** | | | | |
| **Mean** | **-91.7083** | **33.0000** | | | | |
| **Std. Error** | **1.14125** | **2.33979** | | | | |
| **Variance** | **31.259** | **131.391** | | | | |
| **Std. Deviation** | **5.59098** | **11.46260** | | | | |

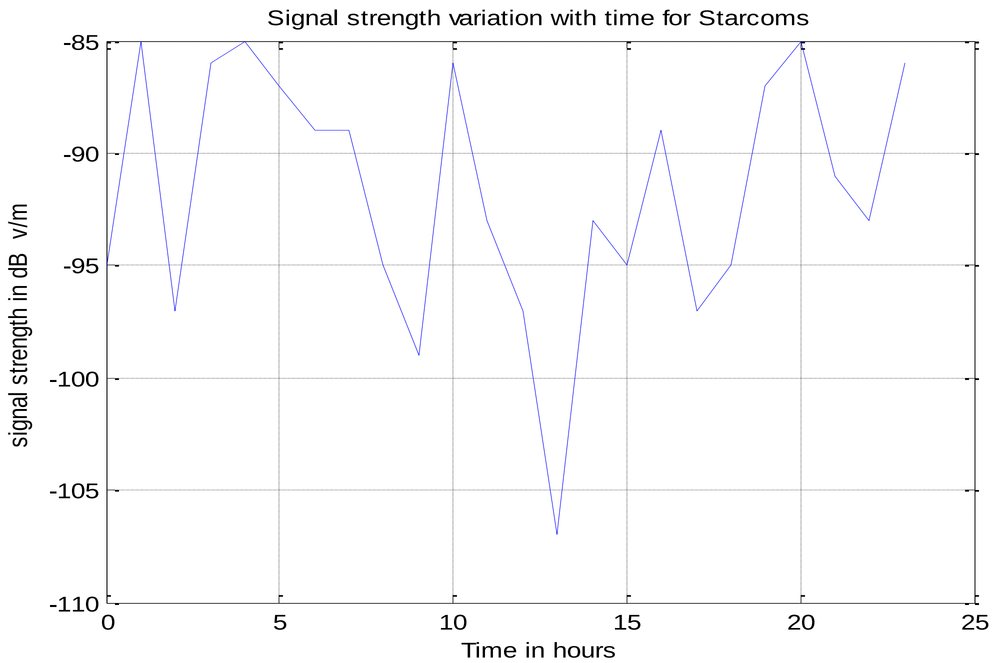


**Fig. 4.11**: Signal Strength Variation with time for Starcoms

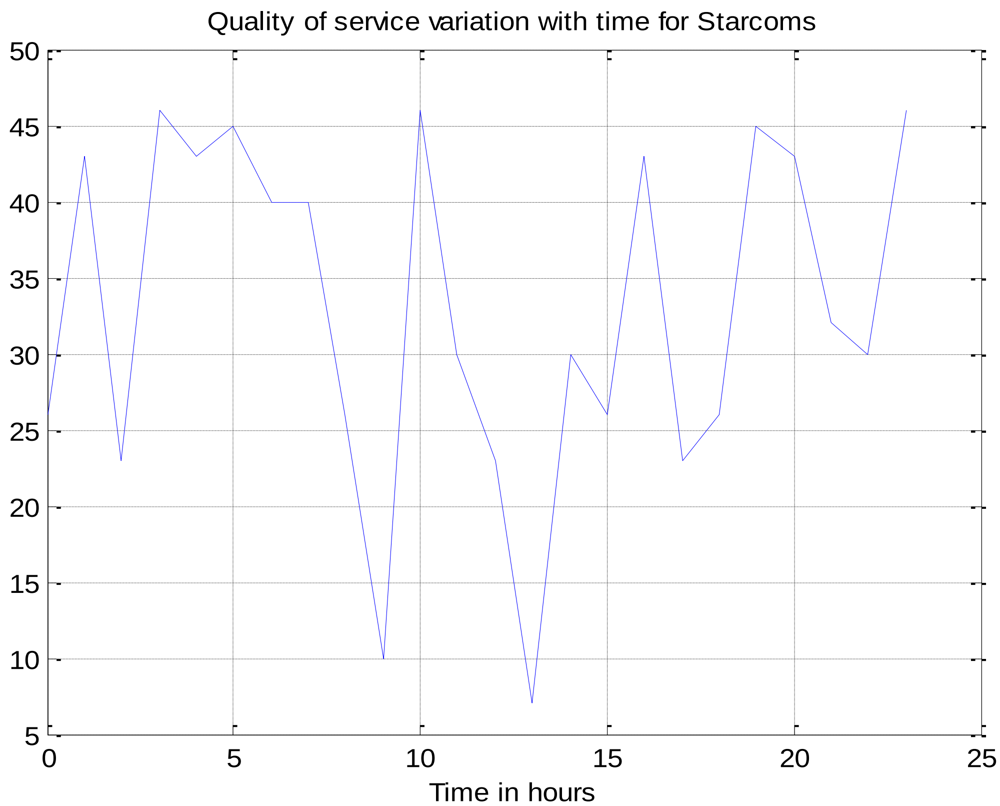


**Fig. 4.12**: Quality of signal variation with time for Starcoms

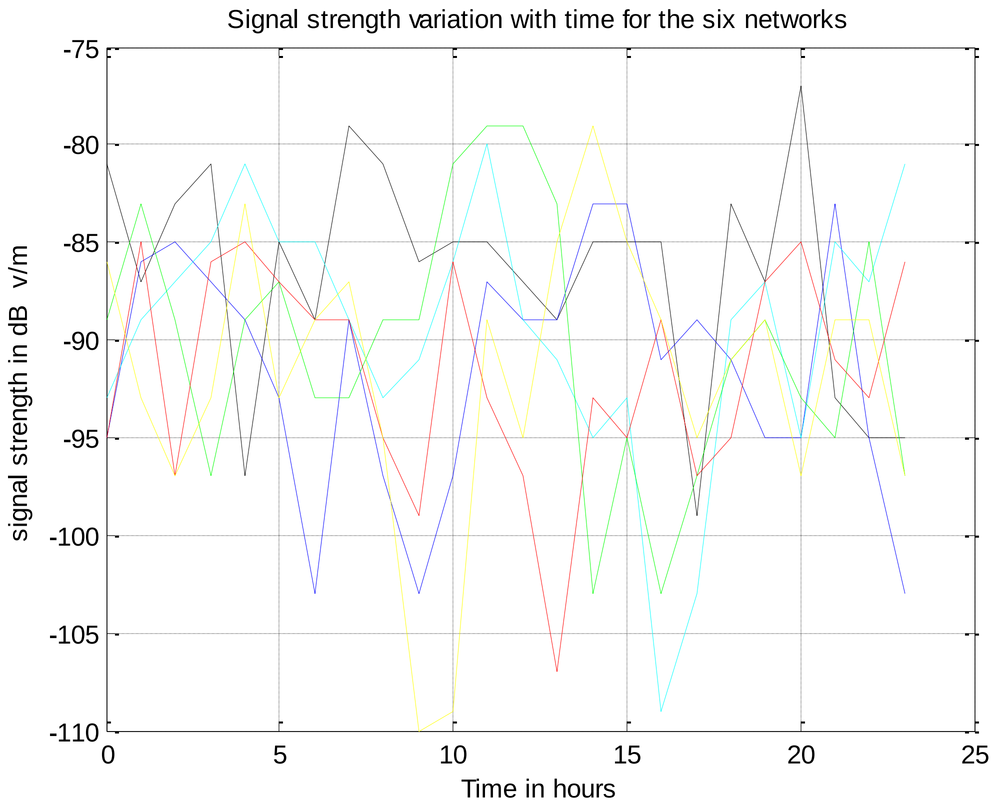


**FIG. 4.13:** Signal strength variation with time for the six Networks

- MTN Nigeria
- Airtel
- Etisalat
- Globacom
- Starcoms
- Visafone

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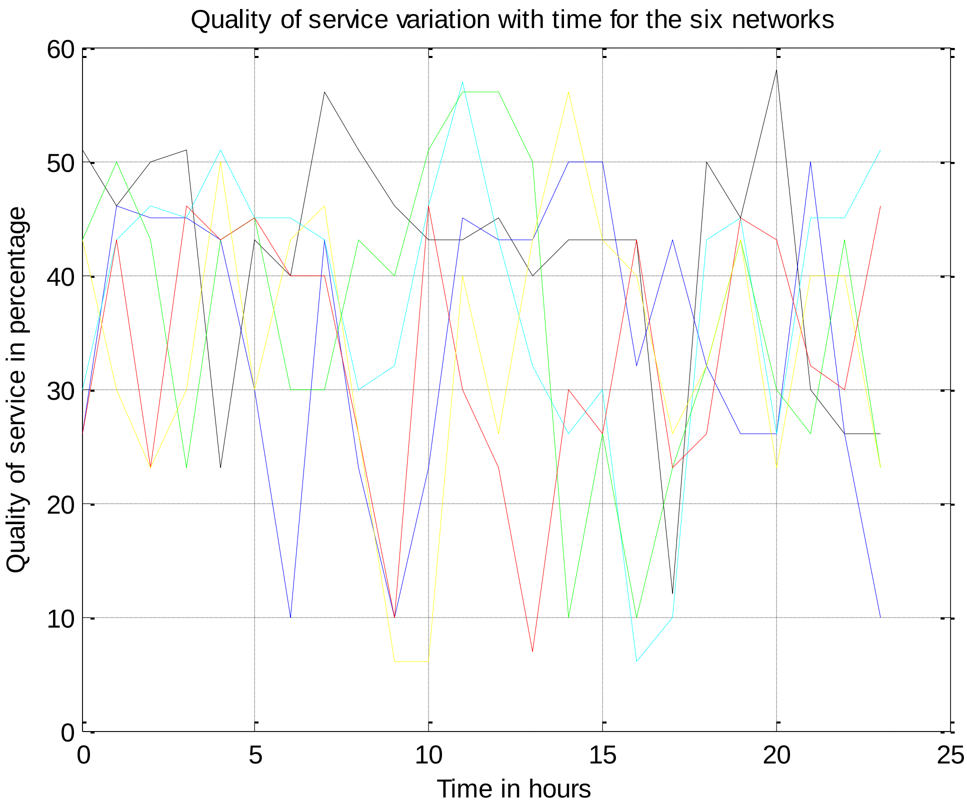


FIG. 4.14: Quality of Signal variation with time for the six Networks

- MTN Nigeria
- Airtel
- Etisalat
- Globacom
- Starcoms
- Visafone

**Airtel**

The parameters of this network were measured using GSM Signal Monitoring. Table 4.2 shows the average maximum signal strength (SS) as high as -83dBμV/m at 14:00, 15:00 and 21:00 hours and average minimum signal strength as low as -103dBμv/m at 9:00 and 23:00 hours; an average maximum quality of signal (QOS) as high as 50% at 14:00, 15:00 and 21:00 hours, and average minimum quality of signal as low as 10% at 9:00 and 23:00 hours, with a regression coefficient of 0.986 between signal strength and quality of signal. Figures 4.3 and 4.4show that the range for signal strength is 20dBμv/m while that of quality of signal is 40%.

**Globacom**

GSM Signal Monitoring was used in measuring the parameters of this network. Table 4.3 shows the average maximum signal strength (SS) as high as -79dBμV/m at 11:00 and 12:00 hours and average minimum signal strength as low as -103dBμV/m at 14:00 and 16:00 hours; an average maximum quality of signal (QOS) as high as 56% at 11:00 and 12:00 hours and average minimum quality of signal as low as 10% at 14:00 and 16:00 hour. A regression coefficient of 0.981 was found between signal strength and quality of signal. Figure 4.5and 4.6 shows that the range for signal strength is 26dBμV/m while that of quality of service is 46%. The figures also show a more consistency period between 6:00 – 7:00 hours and 11:00 – 12:00 hours.

**Visafone**

The parameters of this network were measured using CDMA Signal Monitoring. Table 4.4 shows the average maximum signal strength (SS) as high as -83dBμV/m at 4:00 hours and

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average minimum signal strength as low as -110dBμv/m at 9:00 hours; an average maximum quality of signal (QOS) as high as 50% at 4:00 hours, and average minimum quality of signal as low as 6% at 9:00 hours. A regression coefficient of 0.981 was found between signal strength and quality of signal. Figure 4.7 and 4.8 shows that the range for signal strength is 31dBμV/m while that of quality of signal is 50%. The figures also show a more consistency period between the hours of 21:00 and 22:00.

**Etisalat**

GSM Signal Monitoring was used in measuring the parameters of this network. Table 4.5 shows the average maximum signal strength (SS) as high as -80dBμV/m at 11:00 hours and average minimum signal strength as low as -109dBμV/m at16:00 hours; an average maximum quality of signal (QOS) as high as 57% at 11:00 andhours and average minimum quality of signal as low as 6% at 16:00 hour. A regression coefficient of 0.975 was found between signal strength and quality of signal. Figure 4.9 and 4.10 shows that the range for signal strength is 29dBμV/m while that of quality of signal is 51%. The figures also show a more consistency period between the hours of 5:00 and 6:00.

**Starcoms**

The parameters of this network were measured using CDMA Signal Monitoring. Table 4.6 shows the average maximum signal strength (SS) as high as -85dBμV/m at 4:00 and 20:00 hours and average minimum signal strength as low as -107dBμV/m at 13:00 hours; an average maximum quality of signal (QOS) as high as 50% at 20:00 hours, and average minimum quality of signal as low as 7% at 13:00 hours. A regression coefficient of 0.969 was found between signal strength and quality of signal. Figure 4.11 and 4.12 shows that the range for signal strength is 22dBμV/m while that of quality of signal is 39%. The figures also show a more consistency period between the hours of 6:00 and 7:00.

## DISCUSSION, SUMMARY AND CONCLUSION

**Discussion**

The most used Signal Monitor is GSM Signal Monitoring though CDMA Signal Monitoring is sparingly used. The reason is that GSM networks are more in number, popular and are good choice for cellular users due to their availability rate. They are also easy to handle as their SIM cards can be swapped without difficulty.

The signal strength across the networks varies in the same manner (Figs. 4.1, 4.3, 4.5, 4.7, 4.9, 4.11). The figures depict that the network technology used has no influence on the signal strength. The reason is because signal strengths are influenced by distance from base transmitting stations and obstacles not the network technology used. For instance, Figs.4.1, 4.3, 4.5, and 4.9 represent signal strengths of GSM networks, yet they are not similar in any way and when compared with Figs. 4.7 and 4.11, which are the signal strengths of CDMA networks, it will be noticed that they all vary randomly in such a way that one cannot distinguish GSM signals from CDMA signals.

Nwankwere (2008) conducted a wide range of surveys on signal strengths of cellular networks and discovered that those of GSM networks are of higher values when compared with those of CDMA networks but fluctuate more rapidly while those of CDMA networks tend to be more stable. This is clearly seen in Fig. 4.13.

Comparing Figs. 4.1, 4.3, 4.5, 4.7, 4.9 and 4.11 with Figs. 4.2, 4.4, 4.6, 4.8, 4.10 and 4.12 it is found that signal strength is directly proportional to the quality of signal because the higher the signal strength, the higher the quality of signal. This is in accordance with Uchendu (2006) who stated that in order to have a good quality of signal, the signal strengths must be relatively high as they are directly proportional to each other.

From Fig. 4.13 there is no distinction in the way signal strength varies with time in the day and at night. This shows that day time factors such as network congestion do not affect the signal strength rather they may affect data transmission within the network. However, to achieve a better signal strength in areas with poor signal strength, it is recommended that external antenna, signal booster and signal repeaters should be used. These equipments increase signal strengths tremendously.

## SUMMARY

Cellular networking has occupied a prominent position in today's information technology sector. These cellular networks in Nigeria are operated using two network technologies called Global System for Mobile Communication (GSM) and Code Division Multiple Access (CDMA). From this research work, it has been found that six different networks (MTN-Nigeria, Globacom, Airtel, Visafone, Etisalat and Starcoms) are operational in Calabar.

It was discovered that MTN-Nigeria has the best signal strength with better stability when compared with other networks. The CDMA networks however show smaller range in their signal strengths thereby maintaining more stable signals than the GSM networks. This means that the spread spectrum approach of cellular transmission is more stable than the digital time division multiple access approach.

A closer look also reveals that the GSM networks record higher values of signal strengths which implies that the digital time division multiple access approach of cellular transmission travels farther than the spread spectrum approach.

## CONCLUSION

It is shown from this study that the cellular network technology used has no effect on the signal strength. The factors affecting signal strengths such as distance from base transmitting stations and obstacles affect both technologies in the same manner.

Traffic congestion does not have any direct effect on the signal strength. This is evident from the fact that there is no distinction in signal strength pattern between hours of heavy traffic (peak hours) and hours of low traffic (off peak hours).

In choosing a cellular network, the signal strength should be considered seriously since the quality of signal provided by a network is a function of the signal strength of that network.

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