



Development of a Crowdsourced-based Mobile Application for Measuring Quality of Internet Service Offered by Mobile Network Operators

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Authors' contributions

This work was carried out in collaboration among all authors. Author TMA performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors OOO and Author FMD designed the study, managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Wireless mobile internet is migrating towards an integrated system of internet and mobile communication network to fulfill the future of mobile network requirement: ubiquitous communication, where mobile users move freely almost anywhere and have access to the internet, communicate with anyone, anytime with any application using the best service available. This demands rapid progress in mobile communication networks and their internet technologies. This research project on the analysis of the Quality of Service (QoS) provided by Mobile Network Operators (MNOs) in the cellular internet networks. It aims to analyze and address the QoS of the internet network experienced by the user. QoS monitoring and analysis require the processing of large amounts of data and knowledge of which kinds of applications the traffic is generated by. To obtain satisfactory QoS based on internet network analysis, some network metrics must be measured and monitored at a regular time interval. In this research work, the network metric that will be measured for the internet service are signal strength, download speed, upload speed, and network transaction latency. This network metrics data will be collected from the consumer's mobile

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device by the use of a crowdsourcing mobile application that is installed on the consumer's mobile device. The investigation will cover mobile communication network providers in Nigeria. The data collated is then evaluated and analyzed.

Keywords: Mobile technology; global system for mobile communication; Mobile Network Operators (MNO); quality of service; android-based smartphones applications.

1. INTRODUCTION

Mobile technology evolution started with analog cellular technologies e.g. advanced mobile phone service (AMPS) and Total Access Communications System (TACS). The second-generation (2G) led by the digital technology global system for mobile communication (GSM) re-evaluated the concept of mobile telephony, with the rapid evolution of services. Then the 2.5G prepared its way with a packet-switched (PS) extension of the GSM network called General Packet Radio Service (GPRS) technology, providing quality in form of speed and efficient use of the network. Other technologies succeeded up to the arrival of the 3G Universal Mobile Telecommunication System (UMTS) and Code Division Multiple Access CDMA 2000. With this advancement in mobile technology, Data service has experienced a huge increase in terms of data transmission capabilities. Today end users just need an IP access connection, e.g. via a wireless local area network hotspot, a digital subscriber line DSL connection, or a GPRS/UMTS network to have access to these services. The success of Skype and other VoIP/ multimedia over IP provides in faces of dropping IP connectivity prices in providing evidence of this view. With the progress of these IP providers of networks, the competition of IP-based (telecommunication) services is growing and we can witness a changing value chain in connectivity charging decreases in favor of applications and content charging. The multiple IP telecommunication trends demand the outstanding provision of quality of service and also motivates the provision of service experience to users, to fulfill their expectations [1]. As the number of users on the internet and other telecommunication network grows, it becomes very clear that real-time applications become more difficult to implement because of erratic queuing and packet loss. With this increasing importance of internet service, it is important to do a comprehensive study on the quality of internet service offered by the mobile network operators, therefore, this project analyzes the quality of service provided by the IP providers to their consumers.

1.1 Previous Effort in Measuring Quality of Internet Service Offered by Mobile Network Operators

Related literature shows that previous studies have concentrated on the wireless cellular network in general. As a result, our literature review did not return any studies that are directly linked to our area of study i.e. understanding the QoS of internet service provided by the mobile operator from a user's perspective by the help of a Crowdsourced-based mobile application. In the following section, we highlight a few of the studies that we found to be close to our study.

A Quantitative Approach for Evaluating QoS in Wireless Cellular Networks done by Lawrence et al. in [2], was motivated by the need to quantitatively evaluate the quality of service of wireless cellular networks to make an informed decision about the state of the network for users and operators. The basic criteria used to evaluate the QoS were throughput, latency, data loss, and jitter - these factors indicate the state of each network's responsiveness, reliability, and speed at any particular location. The output provided by the AHP approach is used as a unified measurement of the perceived QoS by users on different networks.

Mobile Device-Based Cellular Network Coverage Analysis Using Crowd Sourcing done by Jaymin et al. [3], they were motivated by the need for cellular network coverage analysis using crowdsourcing. The approach uses an application running on standard consumer mobile devices to measure various network and device parameters available to the mobile devices. These parameters include the level of received signal strength, coupled with accurate location information and automatically uploaded to a central server. The use of real measurement data makes this approach more accurate and the use of existing consumer mobile devices through crowdsourcing results in a large network measurement dataset. The implementation of this approach provides High Accuracy Coverage Mapping, Improved Cell Boundary Identification,

Detailed Cell Performance Measurements, and Dynamic Network Coverage Analysis, but the work was not fully implemented, the application use was a prototype therefore the measurement was taking in a fixed location.

How existing mobile devices can be used to monitor the performance of mobile Internet services over cellular networks illustrated by Almudena, et al. [4], In order to achieve this, a mobile application called SymPA (Symbian Protocol Analyzer) was developed; SymPA is a tool which provides valuable information about user perceptions in relation to the availability and performance of applications running on mobile devices. This tool was implemented on Symbian OS. It makes it possible to analyze protocol which deals with the issue of identifying problems related to the behavior of IP based protocols on mobile communications by incorporating IP packet sniffing features into mobile devices. The tool has been tested in real networks. It is use to analyze the performance of video streaming services over mobile networks. The result of the analysis shows lost packets due to cell reselection. However, the tool is limited to only mobile device with Symbian OS platform.

QoS in cellular network by analyzing the different schemes for providing QoS in cellular networks, its advantages and disadvantage presented by Dushyanth [5], The author also dealt with an important aspect of QoS which is the Individual QoS (iQoS). From the result of iQoS, it was seen that users who were not close to the Base Station (BS) were not getting good signal and the location of the users played a major role.

A model for crowdsourcing the evaluation of the Quality of Service (QoS) provided by Mobile Network Operators (MNOs) in cellular data/voice network proposed by Kolawole [6], it aims to address the gap between the reported technical capabilities of the telecoms infrastructure and the QoS experienced by the user. The work focused on measuring KPIs using subscribers' mobile devices used in accessing the network, which led to the development of an android app that successfully measured some KPIs for voice service such as call setup success rate, channel congestion, traffic peak periods, average signal strength and cell handover rate. It is believed that the successful deployment of this app will enhance the ease, accuracy and size of data collated. However, the app could not successfully

measure call drop rates and could not distinguish between stand-alone channel congestion and traffic channel congestion. More detailed measurements and data analysis was not also carried out due to time constraints.

A QoS assessment methodology for cellular communication networks by Kostanic, et al. [7], based on data collected through drive testing which is focused on the end user perception of service quality and independent of access technologies implemented by the cellular networks. QoS assessment for both the circuit switched and packet switched of the network was studied. The end goal of the proposed methodology is QoS comparison between cellular networks implementing different cellular technologies. However, the authors fail to provide QoS measurements as a function of both voice and data services simultaneously.

Strategies for improving QoS of GSM in Nigeria presented by Obata and Agbo [8], They develop a model of service quality and a set of dimension for comparative evaluation which could provide useful direction to regulators and service providers. At the end of the research work a recommendation on how to improve both the QoS in the country in order to enhance the mass-connectivity was made.

A methodology for evaluating the quality of the FTP data service in cellular (UMTS) networks based on data collected through drive testing and can be easily extended to other cellular data services by Weissberger, et. al. [9], In their work, the authors specify user experience as a key factor in determining the network operator's success. However, the proposed methodology concentrates on evaluating end-user experience based only on data services on a single network.

2. METHODOLOGY

Relevant literature in the area of QoS of data service was reviewed, their contributions to knowledge and limitations were highlighted. The purpose of this research is to analyze the quality of internet service provided by the four mobile network operators (MNO 1, MNO 2, MNO 3, and MNO 4) in major cities and towns in Nigeria. A wide range of Key Performance Indicator (KPIs) measurements for internet service was captured during the research including download speed, upload speed, and network transaction latency. KPIs measurements data were collected using a mobile application developed running on an

android smartphone and the data collected will be forwarded to a web server for proper evaluation and analysis. The overall design for the research methodology is illustrated in Fig. 1.

The metrics collected are: Internet services KPIs: including download speed, upload speed, network transaction latency and received signal strength, Location parameters: Latitude and Longitude and Network information: Network Operator Name, Location Area Code (LAC), Cell ID (ID of serving base transceiver station BTS) and Network Type (GPRS, EDGE, CDMA, UMTS, HSDPA, HSUPA, HSPA) are collected for each data samples.

Fig. 1 provides the overall system design used in this research from the application development to results through the following steps: Android software development, data collection, and data

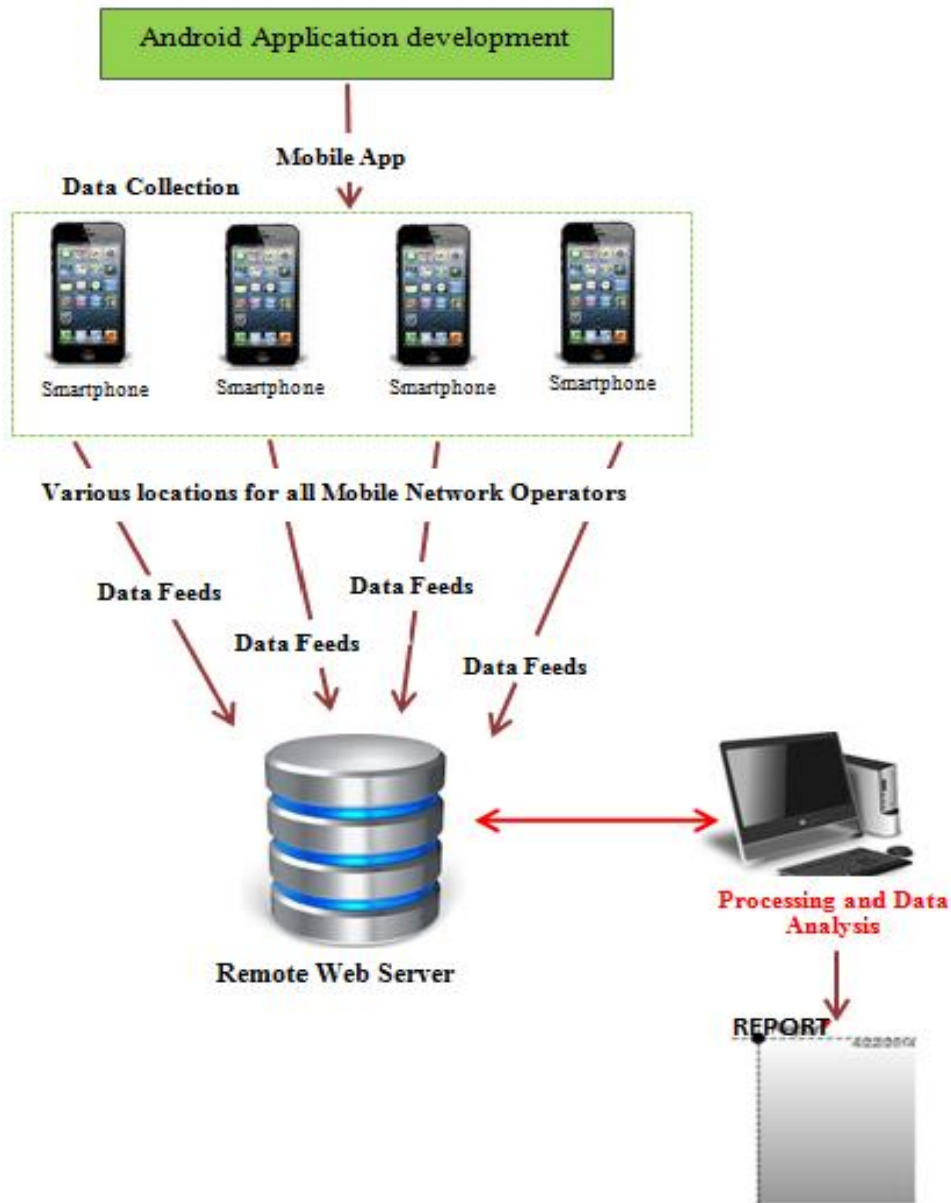


Fig. 1. System overall design

2.1 Android Application Development

The QoS application used for data collection is developed using Java programming language with the aid of the Android Studio tool, Android Standard Development Kit (SDK) and Java SDK. The prototype developed sits at the application layer utilizing the underlying layers. The Android software stack is subdivided into five layers: The kernel and low-level tools, native libraries, the Android Runtime, the framework layer and on top of all the applications. The android operating system is a stack of software components that is roughly divided into five sections and four main layers.

The specific metrics collected by the QoS application are:

Internet services KPIs: Including download speed, upload speed, network transaction latency and Received Signal Strength (The current received signal strength in dBm).

Location parameters: Latitude and Longitude.

Network information: Network Operator Name, Location Area Code (LAC), Cell ID (ID of serving base transceiver station BTS), and Network Type (GPRS, EDGE, UMTS, HSDPA, HSUPA, HSPA). Location parameters were recorded by employing the GPS capabilities of the smartphone. If a GPS signal is not available, then the network location will be used. Also, other important data that will be collected are device-related information (device brand and SIM id) used to tag each data collected.

Web server/web interface: The web application developed using ASP.NET and visual studio 2012 hosted online receives all measured data and the data are then loaded into MySQL database. Data is accessible through the web interface. Quality of Service for any of the mobile network operators or customers can be queried through the web interface which will aid ease in data evaluation and analysis.

3. SYSTEM IMPLEMENTATION

The DataQoS Android application is the implementation of the Methodology specified in the previous chapter. The previous chapters focused on the smartphone application development and an overview of measuring specific parameters for the quality of internet services offered by mobile network operators and the methodology used to collect and transmit data between the Mobile Application (DataQoS Manager) and the Central Server hosted on the internet. The conceptual framework and workflow

were also covered. The DataQoS smartphone application is fully developed and distributed to various volunteers' smart mobile devices. The main goal was to collect data to be used to measure the quality of data service of mobile network operators in Nigeria. The DataQoS App was developed base on android version 4.2, so any volunteers' smart mobile devices with android version 4.2 and above can easily install it on their device.

The following figures show some of the screenshots for the DataQoS manager application developed.

Fig. 2 shows the home page of the app, which has six buttons: Signal strength, Mast details, Data history, Analyse data, my device and App settings, and also the traffic stats.

The Signal Strength Page is to displays the signal strength currently received by the device. Fig. 3 shows the screenshot of the Signal Strength Page.

The mast detail page is to displays mast information like the mast area code which the phone receives from and the mast id. It also displays the current location of the device. Fig. 4 shows the snapshot of the mast detail page.

The data history page is to displays the history of the network measurement. It displays the date/time the measurement was taken, the current longitude and latitude of the device, received signal strength, mast id, mast area code, network type, network operator, SIM id(Subscriber Identity Module), country code, device brand, device CPU, device model, latency, upload speed, and download speed. Fig. 5 shows the snapshot of the data history page.

The analyze data page is to displays the analysis of the total record taken by the device. It displays the Total data, Average upload rate, Average download rate, Average latency rate, Total GPRS connections, Total EDGE connections, Total EVDO connections, Total HSDPA connections, Total HSUPA connections, Total HSPA+ connections and Total HSPA connections. Fig. 6 shows the snapshot of the analyzed data page.

My device page is to display the device information, like the IMEI, device type, IMSI, SIM state, device brand, CPU, manufacturer, model, and SDK number. Fig. 7 shows the snapshot of the My device page.



Fig. 2. Home page

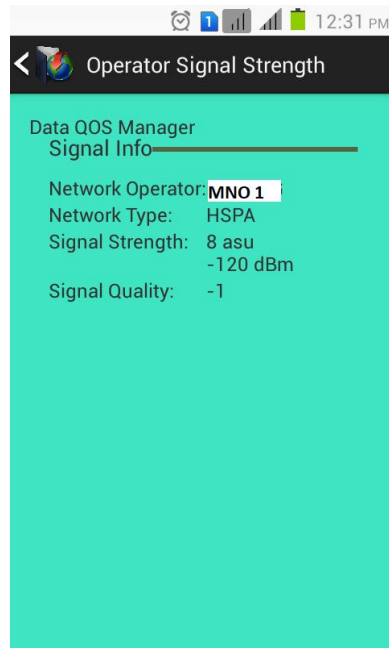


Fig. 3. Signal strength

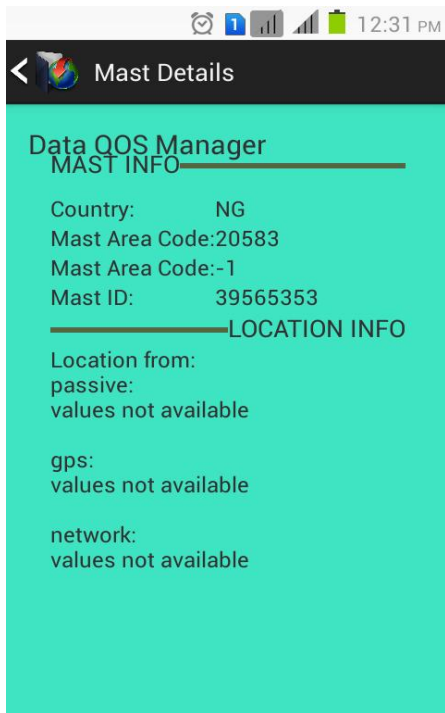


Fig. 4. Page mast details

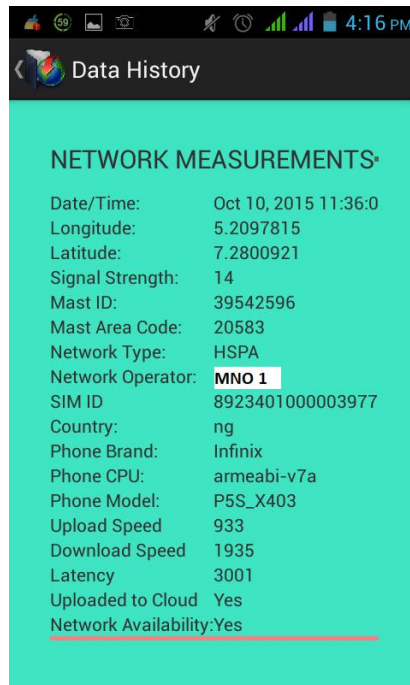


Fig. 5. Data history

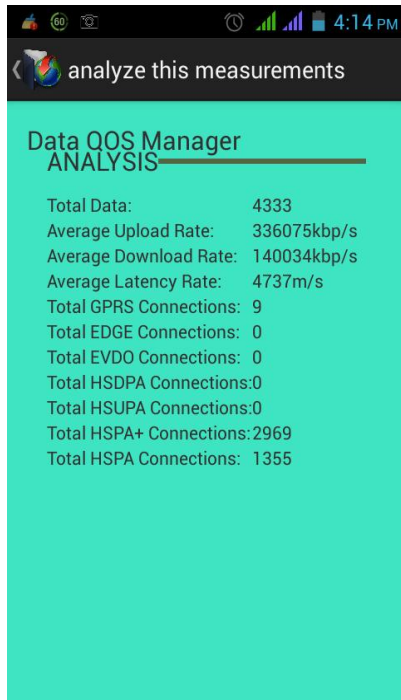


Fig. 6. Analyze data page



Fig. 7. My device page

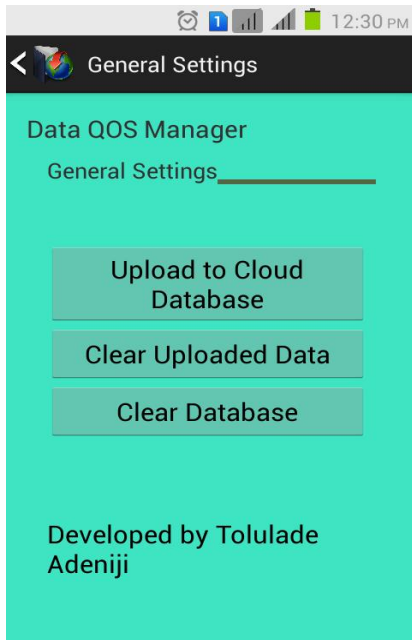


Fig. 8. App settings page

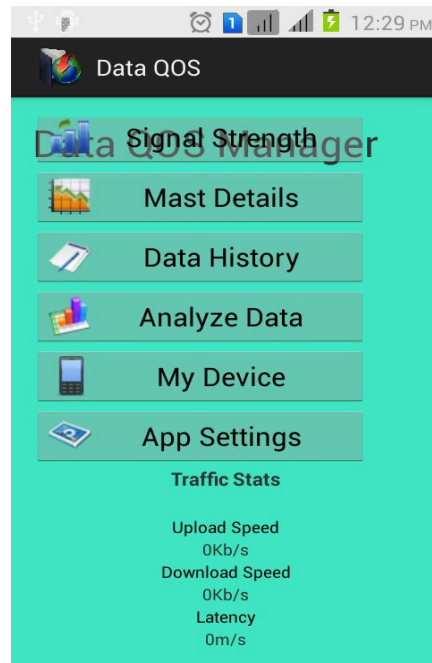


Fig. 9. Traffic stats page

Table 1. Data collected for internet service KPIs

	FUTA Akure	Akure /Ilesa road, Akure	Ijapo estate ,Akure	Omotola street, Ibadan	UI road, Ibadan	Apata, Ibadan	Hughes Avenue, Lagos	LASU- Isheri road, Lagos	Fola agoro, Lagos	Zabutu, Nasara wa	Karudu, Nasaraw a	Gwagw alada, Abuja	Total
MNO 1	607	728	854	738	769	812	926	672	752	591	580	604	8,6333
MNO 2	580	630	773	477	654	651	710	534	644	600	635	540	7,428
MNO 3	439	460	465	394	413	507	461	445	565	438	515	482	5,584
MNO 4	573	652	628	693	573	702	657	543	714	685	728	702	7,850
Total	2,199	2,470	2,720	2,302	2,409	2,672	2,754	2,194	2,675	2,314	2,458	2,328	29,495

The app settings page is to displays the general setting for the application. Fig. 8 shows the snapshot of the My device page.

The Traffic stats display the download, upload, and latency statistic. Figure 9 shows the snapshot of the My device page.

4. RESULTS NAD DISCUSSION

Significant effort was taken to ensure all the four operators were collected from the close locations and at a close range of time. More than 29,495 internet service, KPIs measurements were captured from at least 50 volunteers' devices during the specific period in twelve locations where volunteers were based. This is summarized in Table 1.

After completion of modeling and system implementation, the app was evaluated to determine if the Data QoS app was delivering the expected results. The procedure described above was used during the implementation to answer the research questions. The results of the research were stored in the hosting server

and analysis performed on the same data. The data analysis was done base on the specific internet KPIs used.

Signal strength: The target of the signal strength is -95dBm. If the signal strength is too high i.e. -95dBm, signal distortion may occur, leading to erratic connections.

Generally, a very strong signal is approximate -40dBm down to -75dBm. A weak signal is -95dBm or lower.

All the operators met the target in all locations and times as shown in Figs. 10 and 11 above. But operator like MNO 3 has relatively weak signal strength in all location apart from Lagos this is because MNO 3 has more base station in Lagos compare to the other place and also MNO 1 has weaker signal strength in Nasarawa compare to other operators. It was observed that the period of the day affects the signal strength this is due to the increase in electromagnetic interference or noise in the environment during the day.

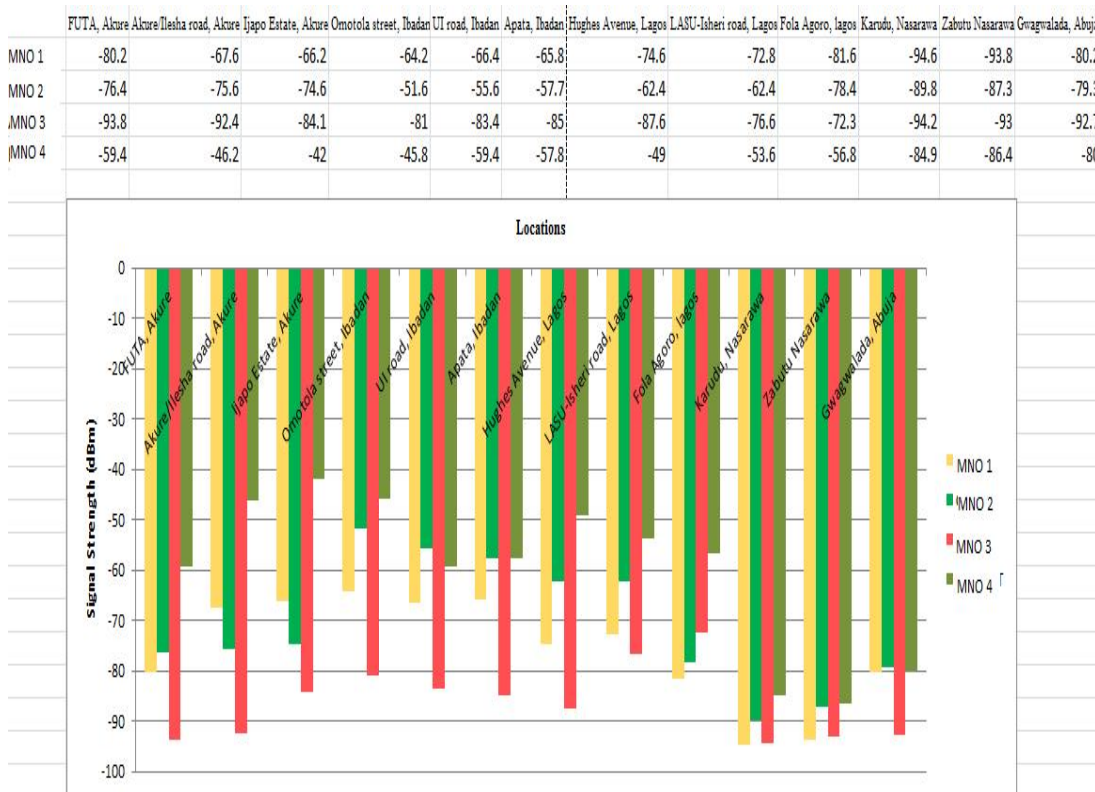


Fig. 10. Average signal strength provided by operator at particular location

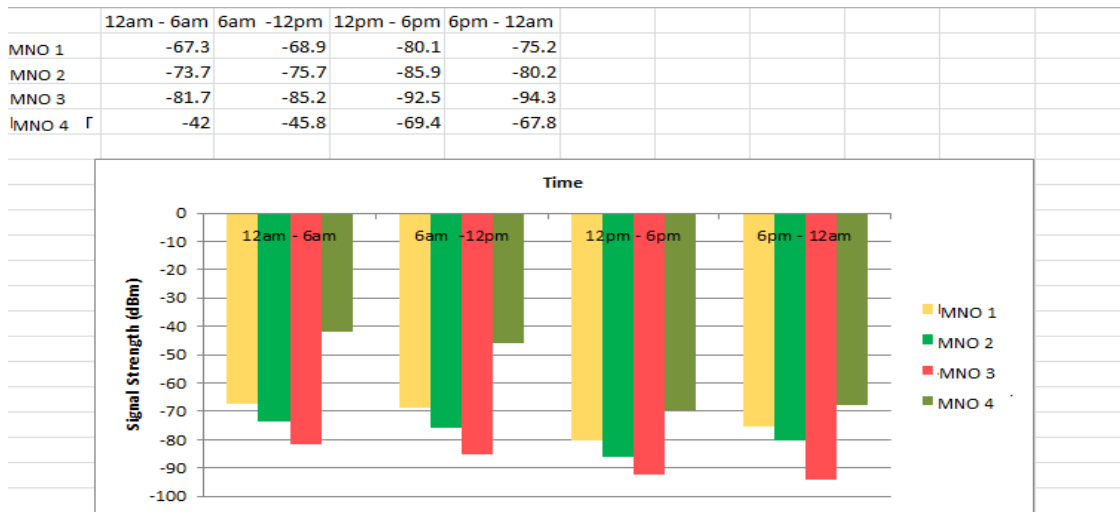


Fig. 11. Average signal strength provided by operator at a particular time

Download speed: Speed is an important parameter as it is an indication of the waiting times consumers experience when performing tasks such as downloading files, web browsing, chatting, watching movies.

	FUTA, Akure	Akure/Ilesha road, Akure	Ijapo Estate, Akure	Omotola street, Ibadan	UI road, Ibadan	Apata, Ibadan	Hughes Avenue, Lagos	LASU-Isheri road, Lagos	Fola Agoro, Lagos	Karudu, Nasarawa	Zaburu Nasarawa	Gwagwalada, Abuja
MNO 1	128.3	145.5	264.2	266.9	324.3	257.6	220.2	189.4	193.5	192.5	175.3	295
MNO 2	112.7	133.8	101.2	116.18	133.9	192.4	127.3	138	151.6	264.7	248.2	195
MNO 3	63.9	69.2	52.8	98.8	131.7	135.8	143.6	140	137.2	154	137.4	148.2
MNO 4	100.8	119.8	173	173.8	145.5	228.5	182.4	241	173.6	244.2	251.9	264.1

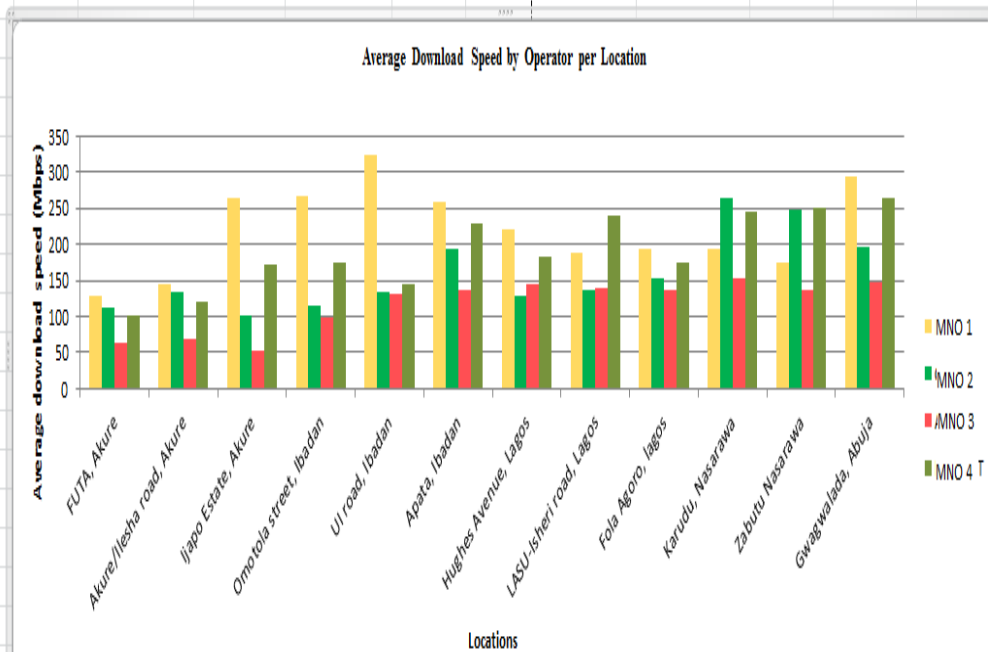


Fig. 12. Average download speed provided by operator at particular location

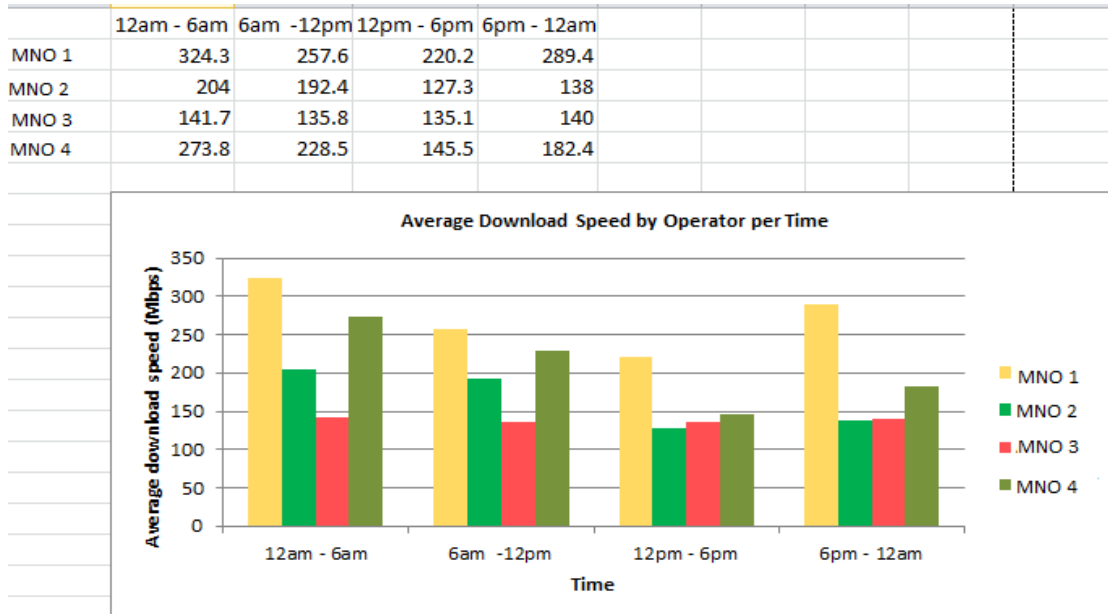


Fig. 13. Average download speed provided by operator at particular time

During the data collection period, download speed was measured by using the Data QoS Manager app from volunteers’ devices to know the general download speed of the device when the internet service of the device is on and is being used. Fig. 12 shows MNO 1 has a very high downstream throughput in locations like Ibadan, Abuja and MNO 4 also have high downstream in a location like Lagos, Nasarawa also followed by MNO 2 with MNO 3 performing the worst in most location. In Nasarawa downstream throughput for MNO 2 and MNO 4 are in close range.

MNO 1 delivered the fastest download speeds with an average of 324.3 Mbps, which was 36% faster than the average measured for MNO 2 and 52% faster than MNO 3.

Fig. 13 also shows that generally all operators have a good downstream between the hours of 12 am to 6 am due to less congestion on the network during this period. MNO 1 and MNO 4 have a high downstream throughput within the 24 hours followed by MNO 2 with MNO 3 performing the worst at some time due to the bad signal strength MNO 3 has generally.

Upload speed: Fig. 14 shows the average upload speed measured across all four operators in the different locations. MNO 1 delivered the

fastest upload speeds with an average of 220 Kbps.

The average upstream performance on MNO 1 and MNO 4 was more than 30% faster than the services from MNO 3 and MNO 2.

Fig. 15 shows the average upload speed measured across all four operators at different times. All operators have a good upstream between the hours of 12 am to 6 am.

Network latency: Network Latency is the time it takes a single packet of data to travel from a user’s device to a third-party server and back again. Most commonly measured in milliseconds.

Figs. 16 and 17 above shows results of the latency data collected. During the data collection period, network latency was measured by the use of the Data QoS app to measure latencies that occur when the internet service of the device is on and is being used. Low latency is critical for an acceptable quality of service offered to users of such applications that make use of the internet service of the device. The average network latency measured across all operators was 2339.1ms. The best network latency was observed on MNO 4 with an average of 1518ms. No operator had latency less than 1000ms across all locations and time under study as shown in Figs. 16 and 17.

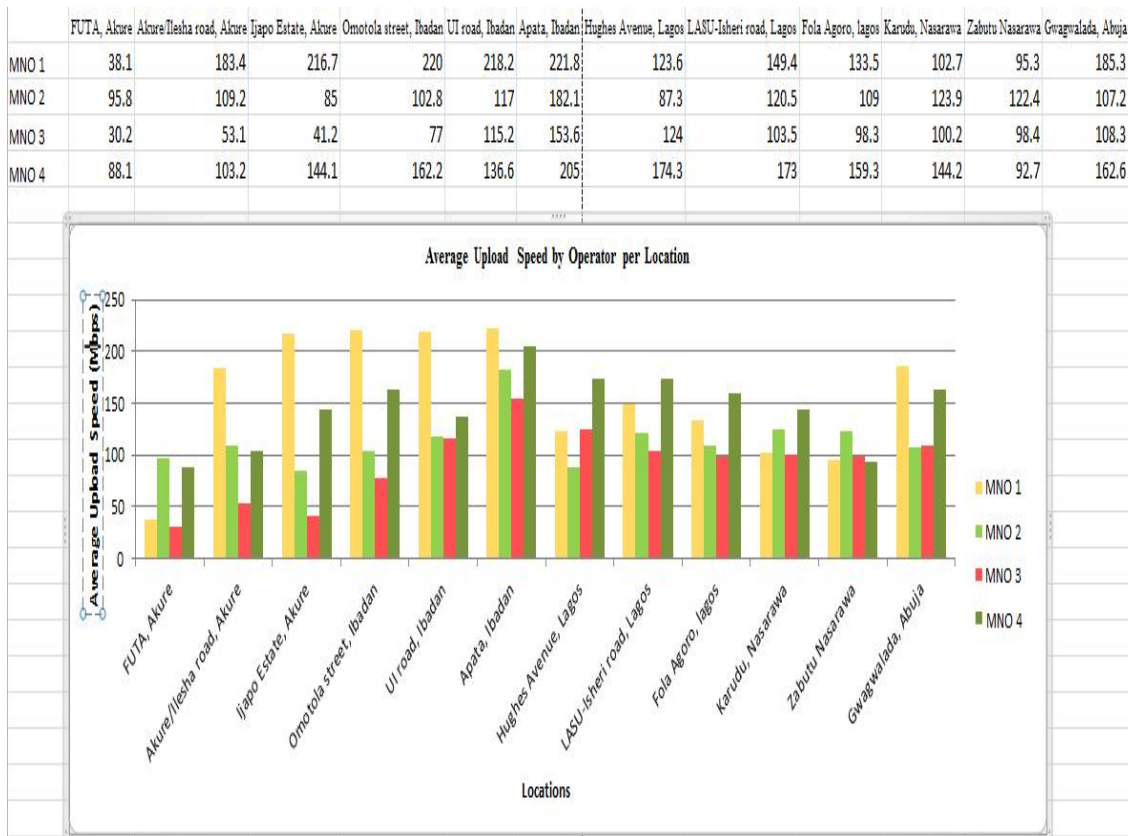


Fig. 14. Average upload speed provided by operator at particular location

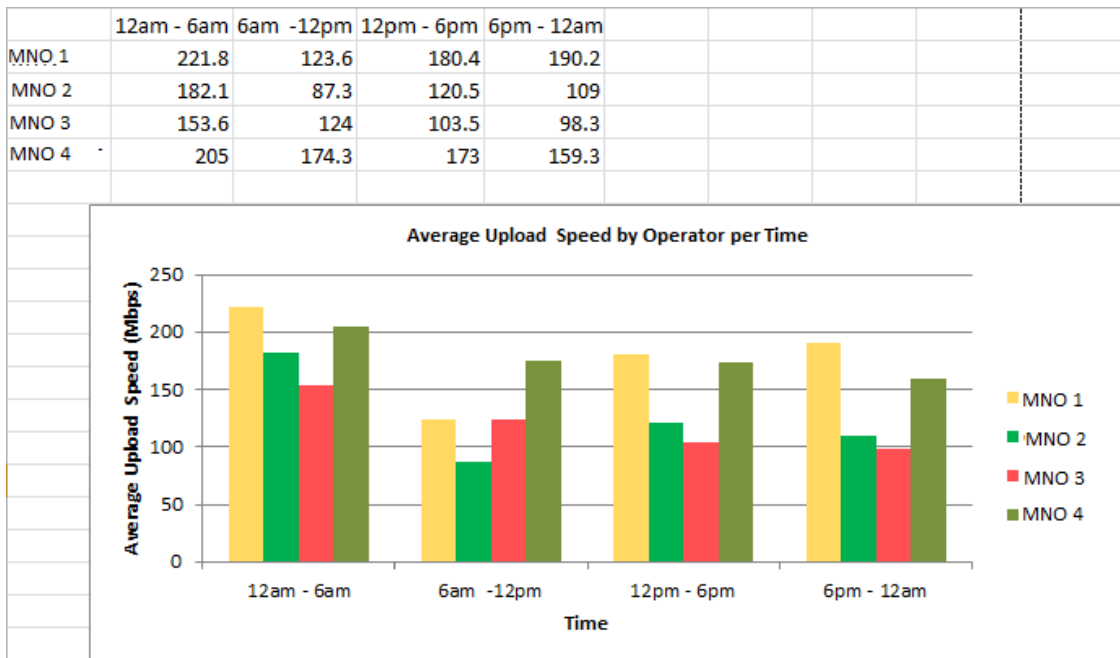


Fig. 15. Average upload speed provided by Operator at particular time

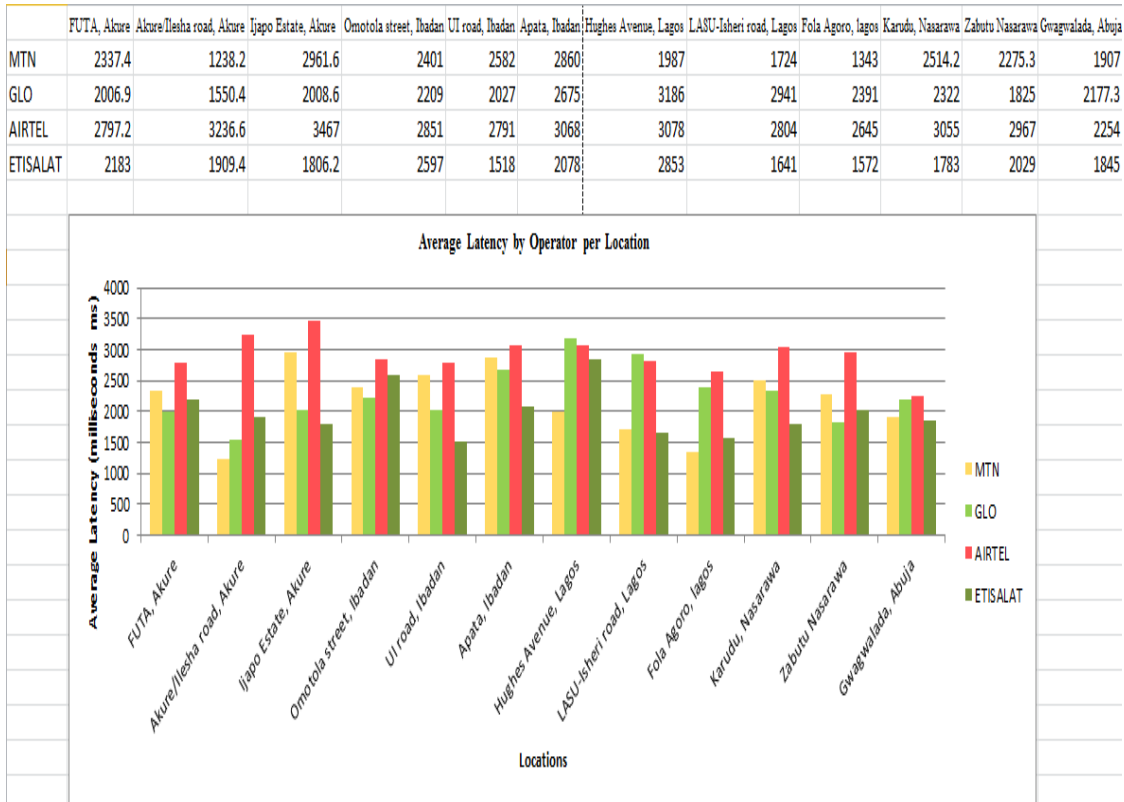


Fig. 16. Average latency provided by operator at particular location

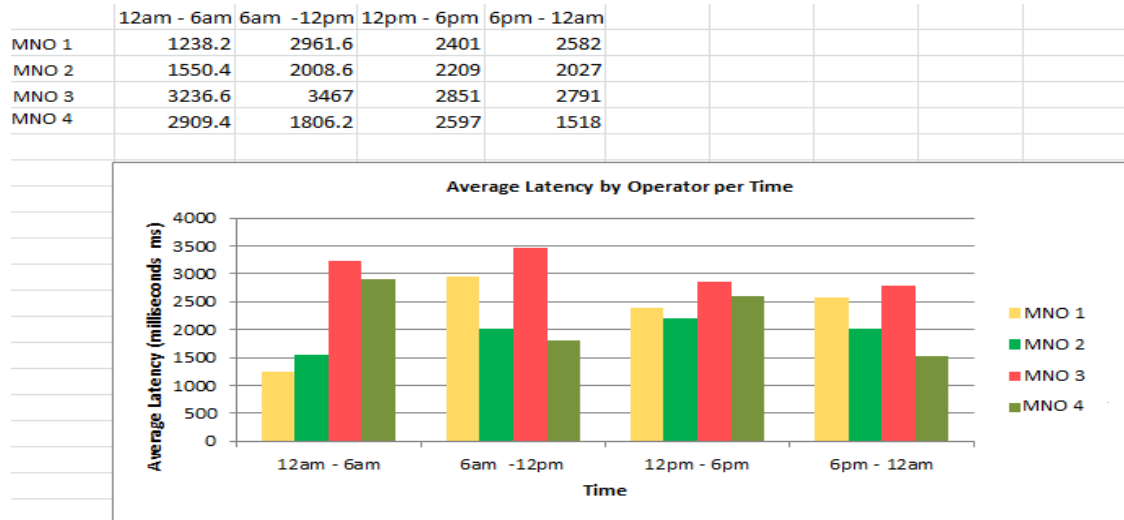


Fig. 17. Average latency provided by operator at particular location

4.1 The Critical Evaluation Made

Across all the locations and time under study, all operators had good signal strength on average,

meeting conditions set by the regulator which says (the target of the signal strength is -95dBm). It, therefore, means that signal strength is not the only factor determining the download speed and

upload speed. The number of users on the network and the bandwidth of the network can also determine it.

Also, signal strength is not the only factor determining the quality of service, some other factors that determine the quality of service are the bandwidth provided by the operators, types of device been use, and the distance of base station the user has access to.

Across all the location MNO 1 had a high download and upload speed compared to other operators this is because MNO 1 has more base station compared to other operators; MNO 4 had good network latency, this is probably due to lesser congestion on the network.

Base on time it is seen that download and upload speed for all network is better and higher between 12 am and 6 am compared to the period between 12 pm and 6 pm this is because there is more congestion on the network during the period of 12 pm and 6 pm which greatly affects the internet speed. GSM operators must be compelled to purchase enough bandwidth so that their service quality doesn't dwindle when users increase on the network.

5. CONCLUSION

We have presented the results of the study of the quality of service of mobile network operators in twelve specific locations in Nigeria. Our results suggest the following: One, smartphone applications can be used to measure the quality of services offered by mobile network operators; Two, across all the twelve location understudy all operators had an average good signal strength meeting conditions set by the regulator. It, therefore, means signal strength is not the only factor determining the quality of service. Three, across all the locations MNO 1 had high download speeds compared to other operators; MNO 4 had good network latency.

We recommend that the regulator should check if mobile network operators meet key performance indicators related to data (internet). We also recommend the use of smartphone applications to be used by consumers to measure if the operator is providing them the kind of service they promised and which providers provide good quality of service.

From the study we have five main statements to make; first, data analysis suggested that all

operators met the target set on Signal strengths. Secondly, signal strength is not only the determining factor to have a better quality of service. Thirdly, internet service performance varied across all operators with only two operators having a better quality of service. Fourthly, network latency is not only the limiting factor in download speeds (i.e. throughputs).

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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