

Participatory Analysis of Cellular Network Quality of Service

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Abstract

This paper proposes a model for crowdsourcing the evaluation of the quality of service (QoS) provided by Mobile Network Operators (MNOs) in cellular data/voice network. It aims to address the gap between the reported technical capabilities of the telecoms infrastructure and the QoS experienced by the user. The analysis is based on sets of location-specific network measurements obtained from mobile devices of volunteer users within the network. A crowdsourcing platform was designed to gather a sufficiently large dataset of measurements obtained from the volunteer mobile devices. The data when was collated, evaluated and analyzed can be compared against the key performance indicators (KPI) benchmarks set by the Nigerian Communications Commission. Using various visualizations, QoS parameters as experienced by the user, cell level measurements, issues related with peak traffic hours are displayed as graphs/ maps/ charts. Finally, several recommendations and suggested further work to make the concept a reality.

Keywords: crowd sourcing app, cellular network, QoS analysis and evaluation, KPI

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INTRODUCTION

The foundation of modern wireless communications was laid when Marconi in 1895, transmitted the first Morse code over a few kilometers using electromagnetic waves. From then onwards, wireless communications has spawned into extents such as satellite transmission, radio and television broadcasting to

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the now ubiquitous mobile telephones. Wireless communications has and is still revolutionizing the way people communicate and function.

Cellular Telecommunications in Nigeria has come a long way. The licensing, rollout and upgrade of mobile networks technologies (2.5G (General Packet Radio Service, (GPRS)), al Exchanged Data Rates for Global/GSM Evolution (EDGE), Universal Mobile Telecommunication System (UMTS), High-Speed Packet Data Transmission (HSPA), HSPA+, High-Speed Uplink Packet Access (HSUPA), High-Speed Downlink Packet Access (HSDPA), Code Division Multiple Access Evolution of Data-only System (CDMA EV-DO) and the ongoing Broadband initiative) and the race to provide network coverage in order to reach customers has led to an explosion in the number of subscribers in Nigeria. Coupled with this is the introduction of affordable smart mobile devices with seamless capability to connect to the internet, which has been responsible for catapulting Nigeria into the top four largest African mobile markets [Rao, 2011].

Basic services such as making/receiving voice calls and SMS are no longer as costly. Cellular providers also make Internet connectivity available anywhere and anytime. This allows for instant access to social networks, employment Intranet, academic environments, shopping, Internet browsing, entertainment content, media streaming etc [Presidential Committee on Broadband, 2012].

From the user perspective, it is important that regardless of the access platform, there is a guarantee of the utility with respect to the experience. However, in spite the deep penetration and high technical limits, due to the complexities associated with the cellular networks, it is a frequent case that a user never sees the top performance of the underlying technology. Inability to set up calls, poor voice quality during calls, dropped calls, lost data packets or even data network non-accessibility are few of the frustrations subscribers have to bear with and often times pay for.

Quality of service (QoS) in cellular networks is defined as the capability of the network carriers to provide a satisfactory service which includes voice quality, signal strength, low call blocking and dropping probability, high data rates for multimedia and data applications etc. It is the overall performance of a network, particularly as seen by the users of the network. QoS is measured via a set of metrics called KPIs that relates to the subscriber's satisfaction in accessing network services. They allow cellular operators to maintain their networks so that the users remain satisfied. KPIs are calculated from measurements of various network parameters. KPIs represent equations based upon simple counters that are used to give a more meaningful measurement of performance. The KPIs used as standards in the assessment of QoS provided by Mobile Network Operators (MNOs) according to Nigerian Communication Commission (NCC) include: Call Set-Up Success Rate (CSSR), Radio Signal Quality and Strength (Rx), Dropped Call Rate (DCR), Traffic Channel Congestion (TCH-CONG), Stand-Alone Dedicated Control Channel Congestion (SDCCH-CONG) and Handover Success Rate (HSR) [Nigerian Communication Commission, 2015; Aninyie, 2012].

NETWORK PERFORMANCE EVALUATION

Ever since the society started relying on electronic communication devices (telegraph, fax, Morse code, telephones) as a major means of reaching others over long distances, as with any other technological invention, performance became of paramount importance. The main issues in this case are delay and quality.

The fact that whole societies depend heavily on Telecommunication companies to support the myriads of services (voice and data) that have become essential to life and work means a certain level of performance is required. Standardization of network protocols provided these companies with the minimum level of quality

expected. The competition involved in commercialization and privatization of networks means that service providers strive to deliver these services at higher quality than their rivals in order to draw more customers. On-going research and development in various areas of cellular technologies has revealed high potential such that subscribers to a MNO now expect to get maximum quality for their money.

From the user perspective, it is important that regardless of the access platform, there is a guarantee of the utility with respect to the experience. However, in spite the deep penetration and high technical limits, due to the complexities associated with the cellular networks, it is a frequent case that a user never gets to experience the top performance of the underlying technology. Inability to set up calls, poor voice quality during calls, dropped calls, lost data packets or even data network non-accessibility are few of the frustrations subscribers have to bear with and often times pay for. This has led to the adoption of an assessment standard that defines what users can expect from MNOs.

Network Evaluation

QoS in cellular network describes a family of measures used in evaluating the quality of telecommunications services used over the years as a basis for understanding and assessing possible differences between competing services. To service providers, it's a means of determining what improvements in service performance are needed to assure customer satisfaction. In evaluating telecommunications services in ways that are operationally meaningful, useful to decision-makers and which can be achieved with a minimum investment in time and money, QoS is measured via a set of metrics known as Key Performance Indicators (KPIs) that relates to the subscriber's satisfaction in accessing network services. KPI help define the performance metrics used to measure the QoS of the network. KPIs are calculated from measurements of various network parameters, using equations based upon simple counters that are used to give a more meaningful measurement of performance [Hardy, 2001].

The KPIs used as standards in the assessment of QoS provided by MNOs include:

- a. Call Set-Up Success Rate (CSSR): is the fraction of the attempts to make a call that result in a connection to the dialed number. A call attempt invokes a call setup procedure, which, if successful, results in a connected call. If a call is connected successfully but the dialed number is busy, the call is counted as successful. The main reasons for unsuccessful call setups are lack of radio coverage (either in the downlink or the uplink), radio interference between different subscribers, imperfections in the functioning of the network (such as failed call setup redirect procedures), overload of the different elements of the network (such as cells) etc. The call setup success rate is usually included, together with other technical parameters of the network, in a key performance indicator for service accessibility. It is calculated as $CSSR = \frac{\text{number of successful seizure of SDCCH channel}}{\text{total number of request for seizure of SDCCH channel}}$. The recommended benchmark by NCC is 90%.
- b. Received Signal (Rx) Quality and Strength: is a measure of the strength and quality of the power present in a received radio signal by the MS antenna: the higher the number, the stronger the signal. It is measured as mW or dBm. Low Rx Strength means that the user will find it difficult in accessing the network.
- c. Dropped Call Rate (DCR): is the fraction of the telephone calls which, due to technical reasons, were cut off before the speaking parties had finished their conversation and before one of them had hung up (i.e. after a channel has been allocated). It is usually measured as a percentage of all calls. If an already connected call is terminated (disconnected) due to a technical reason before the parties making the call would wish to do so (in ordinary phone calls this would mean before either of the parties has hung up), such calls are classified as dropped calls. The main reasons for dropped calls in

mobile networks are lack of radio coverage (either in the downlink or the uplink), radio interference between different subscribers, imperfections in the functioning of the network (such as failed handover or cell-reselection attempts), overload of the different elements of the network (such as cells), etc. The dropped-call rate is usually included, together with other technical parameters of the network, in a key performance indicator for call retainability. It is calculated as $DCR = (\text{number TCH drops after assignment} / \text{total number of TCH assignment}) * 100 \%$. The recommended benchmark by NCC is 2%.

- d. Traffic Channel Congestion (TCH-CONG): is failure in connecting to the service needed by the user after an SDCCH has been assigned. It is the rate of blocked calls due to resource unavailability. Congestion on TCH makes it impossible to set up a call and makes handover from another cell impossible to perform. It is calculated as $TCCCH-CONG = (\text{Number of calls blocked due to resource unavailable} / \text{total number of request}) * 100\%$. The recommended benchmark by NCC is 10% at peak traffic hours.
- e. Stand Alone Dedicated Control Channel Congestion (SDCCH-CONG): is failure in assigning a channel to request for a service. It is defined as the probability of failure of accessing a stand-alone dedicated control channel during call set up. Congestion on SDCCH makes it impossible to set up a call. It is calculated as $SDDCH-CONG = (\text{number of connect fail due to Immediate Assignment failure} / \text{MOC call attempts}) * 100\%$.
- f. Handover Success Rate (HSR): The ease with which a mobile device can move seamlessly from one cell-area to another. It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel. Handoff is divided into two broad categories; hard and soft handoffs. In hard handoffs, current resources are released before new resources are used; in soft handoffs, both existing and new resources are used during the handoff process Rate of successful handovers might be affected and degraded due to following issues: (a) Interference (either external or internal) being observed over air interface, which might affect on-going call switching in case of handover (b) Missing adjacencies (c) Hardware faults (such as BTS transceiver) (d) Location area code (LAC) boundaries wrongly planned and/or defined (where Location area represents a cluster of cells) (e) Coverage limitation. It is calculated as $HOS-Rate = (\text{number of intracell and intercell handover attempts} / \text{total number of handover request}) * 100\%$. The recommended benchmark by NCC is 90% [Qing-An and Dharma, 2001; Nigerian University Commission].

Importance of KPIs and QoS

It is important to differentiate network traffic based on priority level. Some traffic classes should be given higher priority over other classes. Priority is given for voice services as they are considered as the primary service. They are very delay sensitive and require real – time service. Data services are less delay sensitive but expect better throughput and less or no loss rate.

It should be noted that more preference has to be given to customers who pay more to get better service, without affecting the remaining customers who pay normal amount. QoS monitoring and measurements can be used for many purposes by network administrators, operators, end users, and researchers for, such includes;

1. improving the existing network coverage and capacity
2. improving the offered service quality for fulfillment of customer demands.
3. maintaining the KPIs by monitoring networking performance, easing handover triggering and congestion control management.
4. Testing network equipment manufacturers (testing) and QoS aware application developers (e.g. adapting video traffic flow) (Jarmo, 2007).

MEASUREMENT METHODS

Each KPI has a minimum acceptable value set by the NCC. Measurement of these KPIs is carried out by the MNOs, collated and submitted to the NCC every quarter of a year. The established techniques for measuring these KPIs include:

- a. Drive Testing: a hardware-based technique in which the special equipment is slowly driven through a preselected route in an area spanning several kilometers. The equipment steadily measures key parameters of the network signal received. This is the most commonly used method.
- b. Special Hardware: special Hardware can also be attached to the equipment used in transmitting radio signals covering an area. This hardware monitors the operations involved in service provision, record logs and help calculate KPIs.
- c. Software methods: software applications installed on mobile devices, this is a relatively new technique in which the device platform (phones, tablets, modems etc.) used by customers in accessing networking services also serves as a measuring tool for the KPIs i.e. those experiencing the network should be the source of measurements. This emerging technique proposed for improving service quality through improved measurement methods which will give a true state of services provided to users. This is not limited by the location of users either rural or urban and it offers a larger database based on real time experience by individual users.

Given the widespread use, continuing penetration of smart phones, their usage characteristics and unique features; smart phones offer an unparalleled platform for collecting KPIs of the network. Smart phones have multi-sensing capabilities and can sense and measure geo-location, light, movement, network parameters, audio and visual sensors amongst others.

In determining how well a particular MNO is performing, the NCC sets benchmarks for each KPI. However, the data used in calculating these parameters are samples i.e a representative of the service offered to the user over a given period. The dataset is gathered via drive testing on pre-selected routes or from a few MSCs. These methods result in averages that do a poor job of giving a full perspective on actual moment-by-moment QoS as experienced by the user. The research is therefore motivated by the urgent need to:-

1. Measure real-time QoS experienced by subscribers
2. Provide an impartial comparison of KPI between MNOs, since the data is obtained via Crowd sourcing
3. Enhance response time by flagging network problems before users make official complaints and gather necessary data without the need for drive testing.
4. Provide day-to-day statistics that can be used by MNOs in planning, roll-out and upgrade of services.

Drive Testing

In practice, one major way in which QoS is measured is through drive testing, this method is used by MNO and monitoring bodies. Drive testing is also used to measure and assess coverage and capacity of a network. This technique consists of using a motor vehicle containing mobile radio network air interface measurement equipment that can detect and record a wide variety of the physical and virtual parameters of mobile cellular service in a given geographical area. The aim is to measure what a wireless network subscriber would experience in any specific area so that MNO can improve coverage and service to their customers.

Drive testing requires a mobile vehicle outfitted with highly specialized electronic devices that interface to OEM (Original Equipment Manufacturer) mobile handsets. This ensures measurements are realistic and comparable to actual user experiences. Equipment typically includes one measurement device for each network operator and two SIM cards for each equipment set. One of the SIM cards, is used for voice services (SC) and the other for data services (PS). A scanner is connected to the system to scan relevant bands for detecting active frequency channels along the route. A Global Positioning System (GPS) is also connected to the system to get geographical positional information [Kadioglu, Dalveren, and Kara, 2012].

Some shortcomings of drive testing are;

1. It is largely reactive, therefore customers have to complain of poor service, often continuously before the MNO deploys a drive testing team.
2. The measurements taken on a drive test are only a snapshot, a sample that may not be representative enough to paint the actual picture of services provided for an area.
3. In a bid to get more relevant sample measurements, rural areas, less accessible areas, places with low customer count are not often included in the drive test route
4. Customers with fluctuating service suffer from average readings
5. Readings and analysis are not usually made available to end users

Data Gathering From Centers

Academic institutions use this method to gather QoS metrics and it is attached to a measuring device that stores counters of the necessary parameters to a server in a network center. The measurements are collected at intervals over a period of time, typically 6-8 months. The data is usually analyzed, graphs plotted and simulations run in order to infer trends and carry out statistical analysis.

Measurements are collated and sampled from the Network Operating Centers (NOCs) specifically the Network Management System (NMS). The sample measurements are generated from the NMS (a server running NMS software which is connected to other network elements such as BSC, BTS, MSC, HLR) configured to retrieve BTS measurements of remote MSCs and its BSCs. It provides CSSR, CDR and TCH Congestion Ratio measurements [Idigo, Azubogu, Ohaneme, and Akpado, 2012].

Data is collected at the Operation and Maintenance Centre (OMC) where a measuring device has been deployed. The collected traffic data are generated for the OMC from other network elements measurements (MSC and BSS) by using some predefined algorithms that increment certain counters. The traffic data is stored in a data file. The data files are then sent to the OMC as raw data via a pre-defined interface at regular interval. At the OMC, special software converts the collected data in the file, into raw statistics values and stored in a database [Osahenvemwen and Emagbetere, 2012; Madhusmita and Saraju, 2011].

The data collated is then used for propagation simulations to predict the performance of the wireless network. These simulations are useful in that they can be used to analyze all areas of the network. However, the complex nature of these propagation paths means that the simulations are always only approximations of the real situation.

Shortcomings of this technique are;

1. It is often costly (extra traffic generated, power, load on the center's servers) to continue running this technique.
2. The measuring device can pose a security risk to the network.
3. Readings are not usually made available to end users.

4. It is not usually used to correct simple performance issue.
5. Though this technique takes a larger sample over a longer period of time, it still excludes rural areas, inaccessible places and cell areas with low number of subscribers.

Emerging Technique: Mobile Crowdsourcing

An emerging trend that is taking advantage of the large number of network users is mobile crowdsourcing. It enlists the help of subscribers with mobile phones that can accept third party applications.

Crowdsourcing is a relatively new concept that was coined together by Jeff Howe, an editor at Wired Magazine, in 2006. It denotes the process by which tasks are thrown open to a large community of connected people, with a goal to achieve [Howe, 2008]. These tasks are conventionally done by a delegated person or a set of assigned people, but this time around, they are thrown open to like-minded and interested individuals, within a large community. It employs the knowledge and availability of a large group of people scattered around a geographical area, usually to complete a task within a specified period of time. However, the adaptable ability of crowdsourcing makes it to be a very effective tool, but makes it a little difficult to categorize and give a precise definition. Various researchers have classified different services as crowdsourcing, while others argued the opposite, based on the different approaches used in classification [Enrique and Fernando, 2012].

Crowd sourcing, comprehensively defined by [Enrique and Fernando, 2012] as a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task. Crowdsourcing has been used in varying problem-solving and data-gathering paradigm on the World-Wide Web. Well-known examples of crowdsourcing include Wikipedia, Linux, Yahoo! Answers, YouTube, Mechanical Turk-based applications. Crowdsourcing is also been applied to different field from mutual fund management to traffic systems all the way to fund raising and fashion. And still more effort is being directed toward developing many more [Chatzimilioudis, Konstantinidis, Laoudias, and Zeinalipour-Yazti, 2011].

The prospects of a mobile workforce, which is still partially obscured, will eventually unfold the full potential of this new problem-solving model. A pragmatic approach to crowdsourcing reveals that it saves cost. The people are able to communicate with each other and pass messages across to each other, thereby eliminating the existence of a 'middle man' [Nedkov and Zlatanova, 2012].

Comparative Analysis of KPIs Measurement Methods

The improved battery life and processing power of smart phones allow subscribers to perform certain operations that would otherwise require a desktop computer. A comparative analysis of how the proposed crowdsourcing application performs in relation to other existing methods according to some performance characteristics as presented in this section. Table 1 shows a summary of the comparative analysis based on some important metrics considered.

1. **Required Equipment:** the basic hardware and software needed for carrying out other existing measurement require the use of sophisticated telecommunication equipment. It also includes extra resources needed such as cars, cooling units etc.
2. **Cost and Availability:** describes how expensive and easy to purchase the equipment necessary for carrying out necessary measurements for QoS analysis.

Table 1: Comparative Analysis of the Performance Characteristics of Measurement Methods

Performance Characteristics	Drive Test	Using Data Centers	Crowdsourced Applications
Required equipment	Special test phones, RF scanners	Special hardware and additional server	Smart phones
Cost availability	Expensive and hardware are not readily available	Very expensive and requires permission	App is free
Target users	Team of network specialist	Usually used by academicians	Anyone that installs the application
Measurement level	Radio level measurement, service level measurements	Radio level measurement, service level measurements	Radio level measurement, service level measurements and QoE (Quality of Experience)
Measurement Size	Measurements are only during the test drive	Measurements are only for a certain period	Measurements are continuous
Position accuracy	GPS, current cell	Current cell	GPS, current cell
Traffic Overhead	Little or no overhead traffic	High overhead	No overhead traffic
Requires human intervention	Trained users required (active)	Yes	No (passive)
Scalability	Reduced, more drive test requires more specialized equipment	Difficult, technology dependent	Handles all sizes of traffic/measurements

3. **Target Users:** describes the target users of the measurements, it also specifies who can view the results.
4. **Measurement Level:** is the level of the network that is being measured. This can either be the underlying technology (radio level), how easy it is to access the network with a device (service level) or the quality of network access by users (quality of experience).
5. **Measurement size:** is the total amount of data gathered during the measurements. It is a measure of how representative the measurements are of the quality off experience subscribers actually experience.
6. **Position Accuracy:** this is the degree of accuracy in measuring the location of a given device. It can either be coarse location (i.e. using the local area code (LAC) and cell identification Cell ID) or fine location (via GPS).
7. **Traffic Overhead:** is the additional traffic generated by the measuring device exclusively during measurements.
8. **Human Intervention:** describes if the technique is autonomous i.e. whether it requires constant human control and input.
9. **Scalability:** is a measure of how much the technique can adjust to taking more measurements or covering a wider area.

RELATED WORKS USING MOBILE CROWDSOURCING

Crowdsourcing applications on smart phones can be classified into extensions of web-based applications or as new applications. The former class expands to users that do not have access to a conventional workstation and adds the dimension of real-time location-based information to the service. The latter class includes applications for crowdsourced traffic monitoring (e.g. Waze) [Waze, 2015] and road traffic delay estimation (e.g. VTrack); constructing fine-grained noise maps by letting users upload data captured by their smart phone microphone (e.g. Ear-Phone, NoiseTube); identifying holes in streets by allowing users to share vibration and location data captured by their smart phone (e.g. PotHole); location-based games with a purpose to collect geospatial data (e.g. CityExplorer); leveraging mobile phones for collaborative traffic signal schedule advisory (e.g. SignalGuru); and real-time fine-grained indoor localization services exploiting the Radio Signal Strength (RSS) of WiFi access points (e.g. Airplace) [Chatzimilioudis, Konstantinidis, Laoudias, and Zeinalipour-Yazti, 2011].

An example of such third party application is OpenSignal. Boasting over 2.5 million downloads, Open Signal is an app based on a simple idea: use crowdsourcing to create coverage maps almost as accurate as the carriers, rank carriers and provide a personalized report that applies their coverage map to individuals. It keeps track of how often one is connected to the cell phone network, which network (4G, 3G, 2G) one is on, signal strength and what WiFi networks one is connected to. A colorful and intuitive GUI makes it easy for users to toggle among functionalities and vary level of detail.

Open Signal's product description claims it is lightweight enough to run on most phones. Designed to have negligible impact on battery life, it runs in the background and logs network status, along with frequency of phone usage. Over time, it computes average signal strength and type, information on minutes spent in calls, quantity of text messages sent, data service statistics used. It tracks signal health and help minimize data cap or run up a bill texting. It allows users to specify how much data the app should collect with settings ranging from minimum, medium and maximum.

Network carriers can be compared via a numbered list or a heat map of signal strength. Comparison can be in an area or against other cities in a country or even across the entire globe. This can be viewed in the app itself, or on the Open Signal website.

However, users still report bugs (e.g the screen widget), performance issues and compatibility problems on certain phone models and platforms. Also users are expecting interfacing with other services [White, 2013].

MobiPerf is another third party application deployed in 2009. The app is a handy mobile network measurement tool designed to collect anonymous network measurement information directly from end users. It runs on Android and iOS devices and within few minutes of start-up, users are able to obtain a rich set of basic network information (e.g., the device's IP address as seen by the server and the network type such as HSDPA), network performance information and network policies.

The network measurement results are sent to the central server together with a hashed and anonymized device ID and a timestamp as the ID of a specific run. To protect the users' privacy, the hashed device ID cannot be used to identify any personal information of users, and results sent to the central server do not contain any of user's personal data. It provides simple and convenient UI to users. Users are able to see the progress of the ongoing test and intermediate results. Users may also choose to stop and resume the tests at any time. Results can be viewed in various levels of detail while past records can also be viewed.

MobiPerf is an energy consuming application due to the amount of test it has to run. Bandwidth intensive tests also consume data. Another issue is the distance between MobiPerf's server (MobiPerf uses a single server) and user which can lead to congestions and DNS delays and hence failure in completing test [Junxian, et al., 2011].

[Mankowitz and Paverd, 2011] proposed a new approach to cellular network coverage analysis using crowd sourcing. This approach uses an application running on standard consumer mobile devices to measure various network and device parameters available to the mobile devices. Although similar in architecture to the solution implemented by Root Wireless, this new approach provides additional analysis functionality and worldwide applicability. The prototype system is currently limited to GSM and 3G network, these constitute the majority of cellular networks. Functionality provided includes: high accuracy coverage mapping, improved cell boundary identification, detailed cell performance measurements and dynamic network coverage analysis.

Incorporated into this approach is battery optimization algorithm, store and-forward communication system, data visualization in a location based context and identify patterns and trends in the data. This approach could lead to the spawning of technologies such as planning, diagnostics and analysis of current generation cellular networks and the automated self-optimization and enhancement of future cellular network technologies.

Ciprian-Mihai, 2011 proposed an indoor localization of mobile devices for a wireless monitoring system based on crowdsourcing. The approach uses smart phones due to their high mobility, internet connectivity, wide spread use, network monitoring capabilities, robust operating systems that offers multi-tasking. The data needed is gathered in the background, in a continuous, but infrequent manner. The user also has to provide certain data periodically by asking the user where they are and the user will have to point their location on the map of the building.

A fingerprint of the access points, their signal strengths, as well as the location is stored in a file on the device and then the file is sent back to the server to update the database. The server uses a machine-learning algorithm to predict exact location after getting enough training data. The key advantage of this approach is the fact that crowdsourcing positioning system error decreases with increase in the training data [Ciprian-Mihai, 2011]. The fingerprinting is combined with a second type of localization which relies on the sensors of the phone (accelerometer, compass) for pedestrian dead reckoning, as well as map-matching in order to estimate the position of the device.

[Chatzimilioudis, Konstantinidis, Laoudias, and Zeinalipour-Yazti, 2011] presents the emerging, rapidly evolving field of crowd-sourcing on smart phones in terms of energy consumption, privacy preservation and application performance that might be the building blocks of future applications in this domain. Smart phone networks comprise a new computation system that involves the joint efforts of both computers and humans. The unique data generated by the smart phone sensors and the crowd's constant movement, will enable new challenging applications and the solution of harder problems than crowds can currently accomplish. The focus of future efforts in this area lies in the collection of specialized location-related data and the better task assignment to match the particular expertise and interests of the smart phone users. The paper also provided an overview of the key considerations involved in crowdsourcing with smart phones.

CONCEPTUAL SYSTEM DESIGN

The application is designed to collect, collate and analyze the relevant network data. Most modern mobile

phones chipsets have engineering measurement capabilities built into them which were used during the mobile phone's design process. This can be exploited to provide values of the needed parameters since each mobile device constantly receives information about the network from the serving cell to which it is connected. The model of the overall system is shown in Figure 1.

The client application runs on users' devices (crowd paradigm) recording and collating the QoS as experienced by each individual. The app is composed of the User Interface that the individuals interact with, the Task Managers that work behind the interface getting network parameters, monitoring the QoS of various network services, saving the data to logs, displaying the logs on demand and uploading the compressed logs to the remote server through the internet. Data mining of the data will be carried out on the server and appropriate quality of service and quality of experience analysis.

Appropriate analysis of the crowdsourced data is carried out on the web server and made available to users. The users of the analyzed data can be individuals, community members, organizations, mobile network operators and the government. An administrator is also essential to manage the server.

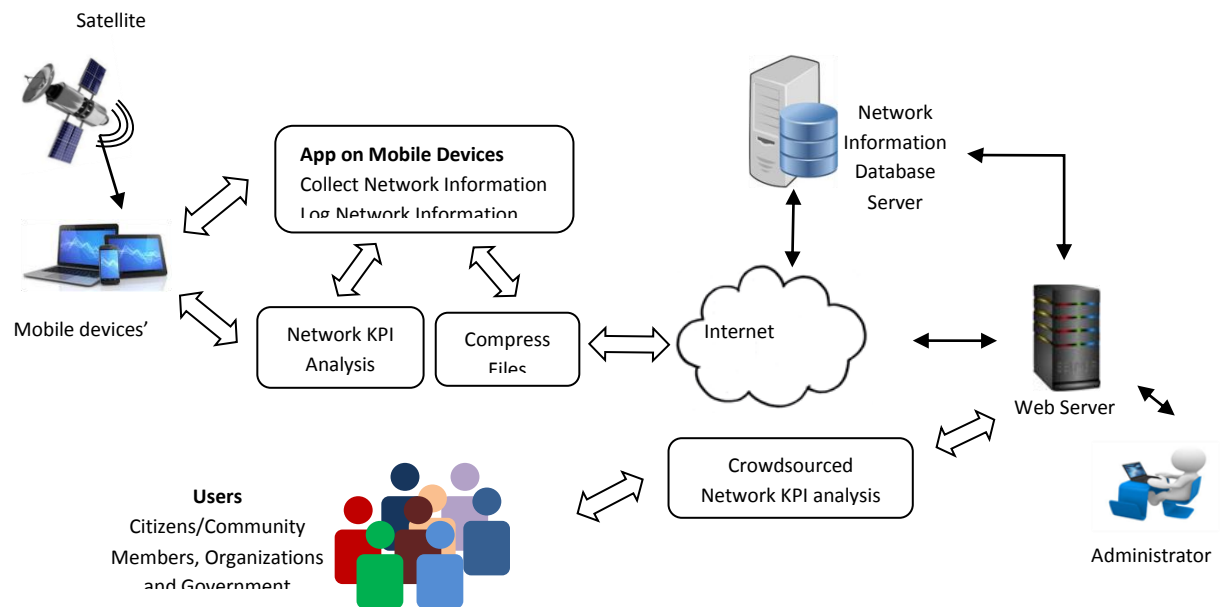


Figure 1: System architecture

User Interfaces (UI)

The UI of the proposed app is composed basically of GUI components that display to the user certain quality of service statistics that might be of interest to the user. Figure 2 shows a summary of these user interfaces.

The UI is classified into four types; firstly, the network statistics interface display to the user current network statistics as measured by the mobile device in an idle state. The logs interface displays to the user the database of data collected on the device. It shows the user the logs of statistics both in idle state, in service state and at periodic intervals. Analysis interface it displays analysis of the QoS as experienced by the user and also the

results of the analysis as experienced by other users on demand from the user. Lastly, the references interface provides a means for users to choose and set preferences on how the application is to operate on their mobile devices.

Task Managers

Task managers define the services offered by the application. They run as background threads/ services that acquire data without user intervention or undue interruptions to the user. They access and manage the resources of the mobile device. These are the statistics, file and connectivity managers

The statistics manager interfaces with the mobile device in-built network radio/antenna to access signals received it sends the data received to the files manager. The files manager handles the logging of data sent by the other managers into the mobile device’s storage space. It manages the creation, appending and reading of data t/from log files maintained by the application. It also saves the user preferences and comments of the user. The connectivity manager manages the accessing, status checking, opening, making use of and closing of sockets needed to send and receive data. It controls all http and ftp protocol related tasks the application needs to perform.

Triggers

Triggers are specified events that initiate managers to start performing predefined tasks according to the type of trigger that initiated the manager. Triggers ensure that the application is not constantly running in the background holding on to device resources not currently in use.

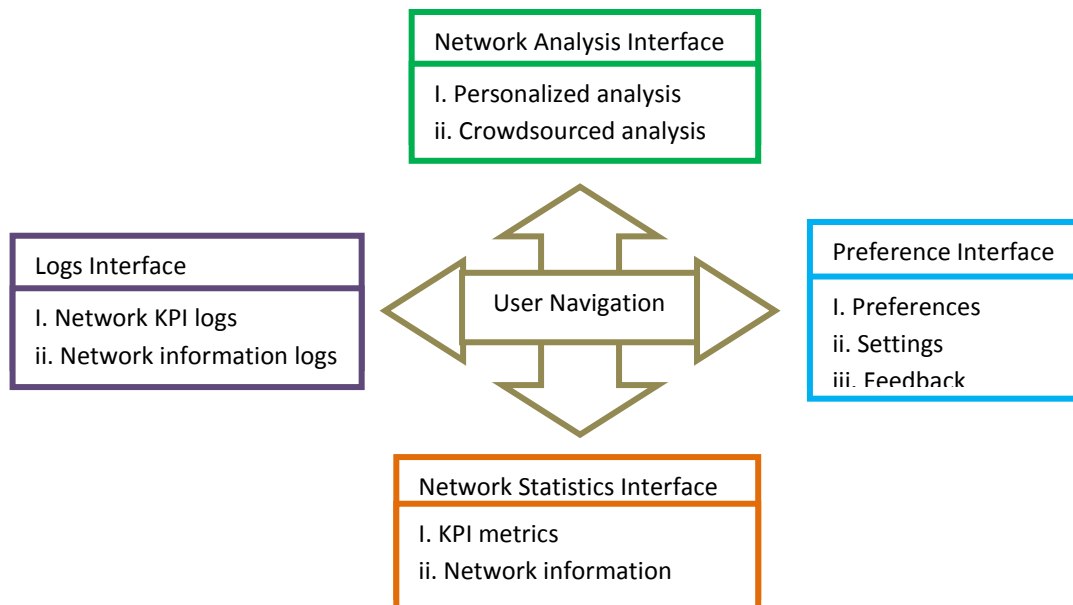


Figure 2: Summary of the user interface

System Requirement

The application was developed for and implemented on the Android platform chosen for its easy-to-use APIs, wide use, GUI capabilities and the functionalities provided by the kind-of hardware it runs on (smart phones). Developing an android application requires knowledge of the following programming languages: JAVA,

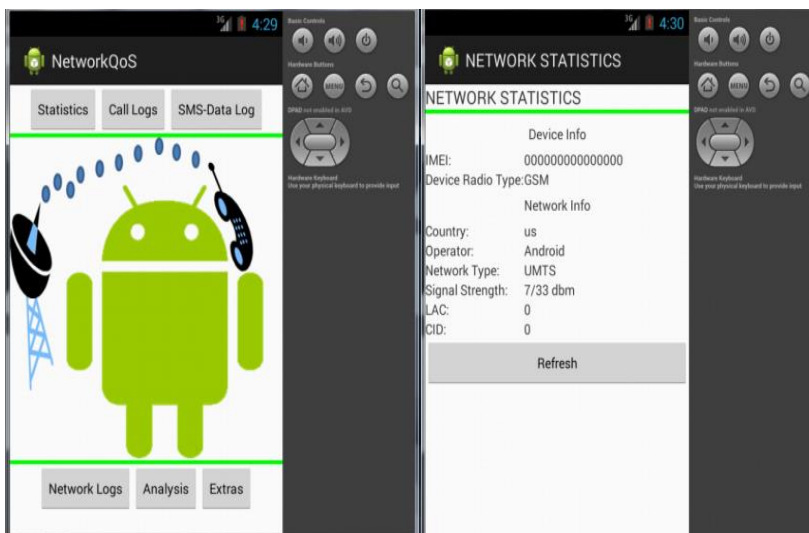
XML, SQLITE, and Android. The software and Integrated Development Environment (IDE) used include the following Eclipse and Android Development Tools (ADT), Emulators, Android smart phone. The app requires a mobile device with SIM card that can install and run android applications with a minimum version of android 2.2.

The proposed mobile application is an energy-saving, data-efficient and storage-minimizing app that runs on the android platform to measure KPIs and log the data on the mobile device. Data collated can be analyzed and graphs viewed on the mobile phones. The logs of the data are then transferred to the remote server through the internet. The collated crowdsourced data is analyzed at the remote server and result made available through the web to interested people.

NETWORKQoS APP PROTOTYPE

The app requires a mobile device with an active SIM card with a minimum version of android 2.2, with capabilities of installing and running mobile applications. In comparing the app to a website, each webpage is equivalent to an activity in android terms. Each activity is actually a screen displayed to the user. The main activity provides navigating access to the user. Figure 2 shows the NETWORKQoS App snapshot.

- a. Network Statistics Page: This activity provides the user with a view of the network signal in phone idle state. It displays the current signal strength received by the phone, the cell ID the phone is connected to, the type of network (EDGE, HSPA etc.) and also the network operator's name.



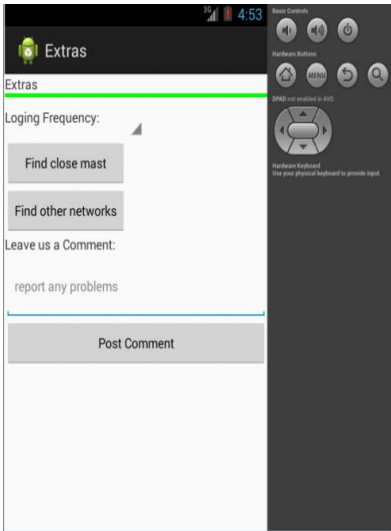


Figure 3: App snapshot

- b. Logs and Logs Page: This displays the logs saved to the device storage, it comprises of list of parameters measured and inferences about each.
- c. Network Analysis Page: This display a simple comparison of location and signal strength received from locations visited. It displays the ID of cell areas with the worst and best reception quality.
- d. Preferences Page: This is the only activity in which the app accepts user input. It comprises a set of selection buttons to help users control the frequency of logging, find nearby networks as well. It also provides a means of receiving any comments the user may have about the app.
- e. Background Services and Notifications: These are not activities and they do not possess a UI the user can view. They are background threads that the run anonymously. The only indication of their operation is android pop-ups that notify the user of various states of the app.

Results

The app was installed on some mobile devices for preliminary analysis and the logs were retrieved after a six (6) day period. The data collected from three mobile operator's network in Nigeria to which the volunteers' mobile devices were subscribed to. Analysis of logs from the first operator's network indicated that the signal strength provided by the operator is averagely okay; a large percentage of the measurements showed the signal strength is between 8 - 28dbm out of the possible 33dbm. The network types experienced by the users were EDGE (46%) and HSPA (53%). Handover success rate was 100% in the observed LAC and CSSR was approximately 93%. Congestion could not be completely decided but from the inferences, there were indications that the network was poor during 9 -10am, 3 - 4pm, and 9 -10pm.

Preliminary analysis of the measurements shows that the second network operator has comparatively stronger signal strength at similar coverage area. A large percentage of the measurements showed the signal strength is between 15 - 31dbm out of possible 33dbm. The network type mostly experienced by user was HSPA (87%) with 100% handover success rate at the observed LACs and the CSSR was approximately 97%. Congestion could not be completely decided but indications that network is poor between 8-10pm.

The third network also had comparatively strong signal strength with a large percentage of the measurements showed the signal strength is between 11 - 30dbm out of possible 33dbm. The network type mostly experienced by users is HSPA with handover success rate of 100% in the observed LACs. The logs for the third network were too small to successfully calculate CSSR.

The app is still underdevelopment and presently, it could not differentiate between a dropped call and a legitimately terminated call. The app could detect and indicate congestion but not its cause.

CONCLUSION AND RECOMMENDATION

This research work focused on measuring KPIs using subscribers' mobile devices through participatory methods. The proposed android app should successfully measure the KPIs which are Call Set-Up Success Rate (CSSR), Radio Signal Quality and Strength (Rx), Dropped Call Rate (DCR), Traffic Channel Congestion (TCH-CONG), Stand-Alone Dedicated Control Channel Congestion (SDCCH-CONG) and Handover Success Rate (HSR).

The developed mobile application is proposed to be energy-saving, data-efficient and storage-minimizing app that runs on the android platform to measure KPIs and log the data on the mobile device. Data collated can be analyzed and graphs viewed on the mobile phones. The logs of the data are then transferred to the remote server through the internet. The collated crowdsourced data is analyzed at the remote server and result made available through the web to interested people.

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