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| Grifo UA preto | **Universidade de Aveiro**  **Ano 2017** | Departamento de Eletrónica,  Telecomunicações e Informática | |
| **Tomás Marques Rodrigues** | **End-user quality of service and experience in mobile networks**  Qualidade de serviço e experiência em redes móveis na ótica do utilizador final | | |
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|  | Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia de Computadores e Telemática, realizada sob a orientação científica do Doutor João Paulo Silva Barraca, Professor assistente convidado do Departamento de Eletrónica, Telecomunicações e Informática da Universidade de Aveiro. | | |
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| palavras-chave | Qualidade de serviço, qualidade de experiência, redes móveis, aplicação móvel, android SDK, 4G, LTE |
| resumo | Os operadores de redes móveis recorrem a equipamentos dedicados (sondas) para obtenção de métricas relativas ao desempenho, QoS e QoE das suas redes e serviços. Pretende-se desenvolver uma App Android com funcionalidades de probing, não só complementando os equipamentos dedicados na recolha de informação relativa ao desempenho, QoS e QoE, como também detetando problemas ao nível da rede e dos seus serviços automaticamente no próprio terminal do cliente final, como também disponibilizando ferramentas de teste ao cliente e ao suporte para uma maior celeridade na resolução de problemas. |
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| keywords | Quality of service, quality of experience, mobile networks, mobile app, android SDK, 4G, LTE |
| abstract | Mobile network operators use dedicated equipment (probes) to obtain performance, QoS and QoE metrics for their networks and services. It is intended to develop an Android App with probing features, not only complementing the dedicated equipment in the collection of information regarding performance, QoS and QoE, but also detecting problems at the network and its services automatically in the final client terminal and providing customer test tools and support for faster troubleshooting. |

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# List of acronyms

3

**3GPP –** 3rd Generation Partnership Project

4

**4G –** Fourth generation of [wireless](https://en.wikipedia.org/wiki/Wireless) [mobile telecommunications](https://en.wikipedia.org/wiki/Mobile_telephony) technology

A

**APN –** Access Point Name

B

**BSSID –** Basic Service Set Identifier

C

**CDMA –** Code Division Multiple Access

D

**DMTF –** Dual Tone – Multi Frequency

E

**EDGE –** Enhanced Data rate for GSM Evolution

G

**GPRS –** General Packet Radio Service

H

**HSDPA** – High Speed Downlink Packet Access

**HSPA+ –** Evolved High Speed Packet Access

**HSUPA –** High Speed Uplink Packet Access

I

**ICMP** **–** Internet Control Message Protocol

**IEEE –** Institute of Electrical and Electronics Engineers

**IPv4** **–** Internet Protocol version 4

**ISP** **–** Internet Service Provide

L

**LTE –** Long Term Evolution

M

**MMS –** Multimedia Messaging Service

Q

**QoE –** Quality of experience

**QoS –** Quality of service

S

**SSID –** Service Set Identifier

U

**UMTS –** Universal Mobile Telecommunications System

W

**WAP –** Wireless Application Protocol

**WCDMA –** Wideband Code Division Multiple Access

**Wi-Fi –** Wireless Fidelity

**WLAN –** Wireless Local Area Network

**WMAN –** Wireless Metropolitan Area Network

**WPAN –** Wireless Personal Area Network

Chapter **1**

# **I**ntroduction

Human relationships are based on communication and the technology is linguee changing to improve the way we interact with each other. In telecommunications we evolved from analogical services to the digital, including not only voice, but also data services to 4G with better debits and capacity and lower latency. The requirement for higher data speed on smartphones is increasing rapidly, much due to the usage of social networks and other entertainment data in these small devices. Constant improvement in wireless data rate is already happening and different network technologies are integrated to provide seamless connectivity and are transparent to user, making the network appear heterogeneous despite the complexity involved.

User’s expectations are always growing with new services appearing constantly the quality of service needs to be in a constant improvement in order to follow this technological evolution. Although the internet was designed to provide services without quality guarantees in case of operators they are contractually obliged to guarantee certain quality in some services provided by them and working for clients that more and more want to be always connected with mobility at same time leads to a lot of work to be done to grant the same quality and a good user experience.

## Motivation

Technology is, more and more, part of the daily life of the human being. Nowadays the humanity communicates on a global scale thanks to the increasing development of mobile devices technology. Computing and communication had led to a notorious evolution of mobile devices, which have become not only a mean of communication, but also a way of accessing extensive functionalities, becoming the communication and entertainment tool of today’s election.

The rapid growth of wireless communications allowed the rising number of small devices, like smart phones and tablets, connected together in the network. Evaluate the network and what is happening is extremely important to the operator to assurance good quality of service to his clients and maintains them.

Given the importance of this, operators have fixed and mobile probes to try give the best user experience and grant network availability and performance. The current dissertation, with the increasing functionalities and technology on the small devices fits by adding a more flexible, transparent and dynamic solution to improve network service quality.

## Objectives

The key objective of this dissertation is to propose a solution that retrieves QoS and QoE metrics in the network and useful radio parameters dependent of the access technology being used in the moment with an android smart phone. With this application we still intend to run tests in the network (e.g. check the internet speed) to get more information and troubleshoot possible problems with it and observe the data gathered over time in a simple and attractive interface for the final user.

This solution will be connected to a backend sending all data to a unified platform called ArQoS, a centralized and convergent product built on Altice Labs that evaluates the customer perceived quality in service usage (Voice, IPTV, SMS, MMS, email, Internet, …), multi-technology and in multi-vendor environments in order to increase customer satisfaction and optimize resources in case of the operator. [2]

Taking in to account these points this solution can be used in a vast case of scenarios like in drive tests through the city, since it’s only needed a regular smart phone and can be used by operator’s technicians to identify concerning locations that needs better coverage, to know how the network is working in real time with real metrics or used by a regular user to check internet connectivity or the downlink speed in that moment.

## Contributions

## Project Structure

This document is split into 6 chapters of which, chapter 1, Introduction, was already presented. The remaining chapters are:

* **Chapter 2:** presentation of the state of art. The core concepts of quality of service, cellular networks and XXXxxxxXXX will be presented in this chapter. Additionally, it also gives an objective analysis of some solutions proposals relevant to the area;
* **Chapter 3:** brief introduction to Android. An overview of fixed probes and what can they do in comparison to a smart phone. …

…

* **Chapter 4:** description of the implemented solution, the proposed architecture along with the technologies used and a detailed explanation of the followed approach during implementation;
* **Chapter 5:** presentation and analysis of results obtained, as well of insights about those. …
* **Chapter 6:** final conclusions about the chosen path and obtained results, also addressing potential improvements for possible future work.

Chapter **2**

# State of Art

## Cellular Networks Technologies

Long Term Evolution-Advanced (LTE-A) is known as 4G and it is the solution for heterogeneous networks and wireless broadband services. International Mobile Telecommunication-Advanced (IMT-Advanced) represents a family of mobile wireless technologies, known as 4G.

Network evolution is occurring throughout the globe and we are shifting toward an all-IP communication. The core of 4G network is IP and the signaling is done through advanced IPv6 itself. Internet Protocol (IP) describes the format as well as the switching technology of what is popularly called Evolved Packet Core (EPC). Basically, IP was termed as a general-purpose data transport protocol in the network layer, but now extended as a carrier for voice and video communications over 4G networks. [1…ver]

Wireless networks in the future will be heterogeneous. Different access networks such as Institute of Electrical and Electronics Engineers (IEEE) 802.15 Wireless Personal Area Network (WPAN), IEEE 802.11 Wireless Local Area Network (WLAN), IEEE 802.16 Wireless Metropolitan Area Network (WMAN), General Packet Radio Service (GPRS), Enhanced Data rate for GSM Evolution (EDGE), Wideband Code Division Multiple Access (WCDMA), Code Division Multiple Access (CDMA2000), satellite network etc are integrated. [1…ver]

## Quality of Service

From the QoS point of view, the protocol stack is composed of upper layer protocols (transport and above), on top of IP. Applications can, in this context, be classified according to the data flows they exchange as elastic or real-time. The network layer includes IP traffic control that implements datagram policing and classification, flow shaping, and scheduling. The data link layer may also provide QoS support, by means of transmission priorities or virtual channels. QoS provision in 4G networks is challenging as they support varying bit rates from multiple users and variety of applications, hostile channel characteristics, bandwidth allocation, fault-tolerance levels, and frequent handoff among heterogeneous wireless networks.

QoS support can occur at the transport, application, network, user and switching levels. To meet QoS, we should address the following issues like latencies, encryption protocols, security and “trust of information”, error profiles, burstiness, different rates, dynamic optimization of scarce resources and fast handoff control [1].

QoS requirements have become a significant topic in the usage of all those access networks and priority is to maximize the QoS experienced by the user. QoS is the ability of a network to provide premier service to some fraction of total network traffic over specific underlying technologies.

QoS can be achieved by resource reservation (integrated services), prioritization (differentiated services). We can apply QoS according to per flow (individual, unidirectional streams) or per aggregate (two or more flows having something in common) basis. To evaluate QoS there are some metrics we can use to indicate performance like delay, jitter (delay variation), service availability, bandwidth, throughput, packet loss rate.

## Study of Market

## VoIP

### VoLTE

### VoWifi

## Parameters

### Radio Parameters

### Device Parameters

## Android

### Which varies with the Api’s

### Permissions

### Root/Jailbreak

Reversivel – “Root Checker Pro” App to verify

Tb é possivel guarder apps, contactos, sms instaladas

<http://www.droidgator.com/install-official-jelly-bean-412-xxuamf1-firmware-galaxy-s2-i9210-lte/>

<http://www.droidgator.com/how-to-perform-a-nandroid-backup-without-restarting-into-recovery-mode/>

<http://downloadstockrom.com/how-to-backup-complete-nandroid-using-cwm.html>

<https://www.quora.com/Is-it-illegal-to-root-my-Android-phone>

<http://forum.techtudo.com.br/perguntas/57562/para-que-serve-um-root-de-aparelho-android-danifica-o-aparelho>

<http://www.androidpit.com.br/5-motivos-nao-rootear-smartphone>

<http://www.tudocelular.com/android/noticias/n37359/5-motivo-para-nao-fazer-root-em-seu-android.html>

<http://www.smartzone.com.br/android-root-o-que-e-para-que-serve/>

# **Explaining the behavior of an Android application: System apps vs Non-System apps**

by [Sergio](https://www.ricston.com/blog/author/sergio/) | Apr 10, 2013 | [Android](https://www.ricston.com/blog/category/open-source/android/) | [13 comments](https://www.ricston.com/blog/explaining-behavior-android-application-system-apps-nonsystem-apps/#respond)

There exists a lot of contrariety on the web when it comes to the description of an Android System application. I will therefore explain the correct methodology here, which will hopefully enlighten you on whether you should place your Android application as a System application or not.

A System application is NOT an application which is signed by the OS’s platform signatures. This is a common mistake believed by many and we shall come to this later on. A System application is merely an application which is placed under **/system/app** folder in an Android device. An application can only be installed in that folder if we have access to the OS’s ROM (system.img). The application is placed under**/app** folder after the ROM has been extracted. A device which loads the custom ROM will have the new System application added. The benefit of a System application is that the application cannot be removed from the device (cannot be uninstalled by the user). This is only because**/system/app** is a read-only folder.

A non-System application is an ordinary application, which will be installed under **/data/app** folder, and which is read-write. A user can uninstall such applications normally from the Settings application. One can check if an application is a System application or not using “ApplicationInfo.FLAG\_SYSTEM”. If the constant returns true, then the application in question is a System application.

Finally we shall explain the benefits of an application being signed by a particular ROM’s platform signatures. Certain permissions are protected under the “signatureOrSystem” protection level. Such permissions are not available to every application because they will grant risky privileges such as control over other applications, background installation and un-installation, among others. Such permissions can be utilized for malicious purposes, therefore Android will only grant them for System applications or Ordinary applications signed by platform signatures. System applications do not require signing by a platform signature to access these permissions. However, it is necessary for Ordinary applications to be signed before they can utilise these permissions.

Ver -> <https://www.ricston.com/blog/explaining-behavior-android-application-system-apps-nonsystem-apps/>

## <http://www.addictivetips.com/mobile/how-to-install-any-app-as-system-app-on-android/>

<https://www.cnet.com/how-to/hack-your-android-like-a-pro-rooting-and-roms-explained/>

<https://blogs.uni-paderborn.de/sse/2013/05/17/privacy-threatened-by-logging/>

<http://www.androidpolice.com/2014/09/04/stop-log-can-disable-all-android-logs-on-your-device-for-enhanced-privacy-and-performance-root-only/>

Logfiiles -> <https://www.escolaandroid.com/android-dalvik/>

Chapter **3**

# ArQoS Pocket solution

This chapter presents a solution to complement the ArQoS system referred on the previous chapter. It is an android app solution that works as a mobile probe collecting multiple data and indicators of the network.

Supporting multiple technologies on mobile networks (GSM, GPRS, UMTS, HSDPA, HSUPA, HSPA+, etc) and Wi-Fi this solution allows continuous tests to check the connectivity and availability of the network, as well as help in troubleshooting and monitor the quality of service with more intrusive tests.

The key features of ArQoS Pocket solution are:

* **Integration** with ArQoS management system;
* **Scheduling** personalizedtests;
* An alarm **failure** **notification;**
* Tests and anomalies are **saved** and can be seen in a **history tab** with all the information and data associated to the test/anomaly. [3]

## Architecture

Chapter **4**

# Developed Work

## Tests

There was been developed several tests in the building of this applications not only to grant quality of service to the user, but to help troubleshoot possible problems in the network too. We can divide the tests in two categories: intrusive tests and passive tests, the intrusive ones introduce packets in the network in order to evaluate what is happening in the moment. Passive tests are tests there are running since the app starts, don’t need to introduce data in the network and are note noticed by the user. Both this tests can retrieve important information about the environment around.

ArQoS Pocket app test Voice and Data. In Voice we can simulate answering a voice call, hang up or record the in call audio to analyze its quality after. In the data part, web browsing, PING, speed test, portal logins and many more useful tests are done. We will talk about these tests in detail now.

### Intrusive Tests

…

### Passive Tests

… ….

* **Scan Wi-Fi Networks:** We have a few networks around us almost every time, in big city’s more than a few. Know which network as the best signal level in the user place, network’s name or which network have or not a security password to allow connectivity is very important to user. Android does this scan natively periodically but we perform this scan in the app because we can retrieve valuable parameters from here that android don’t give us in his main interface.

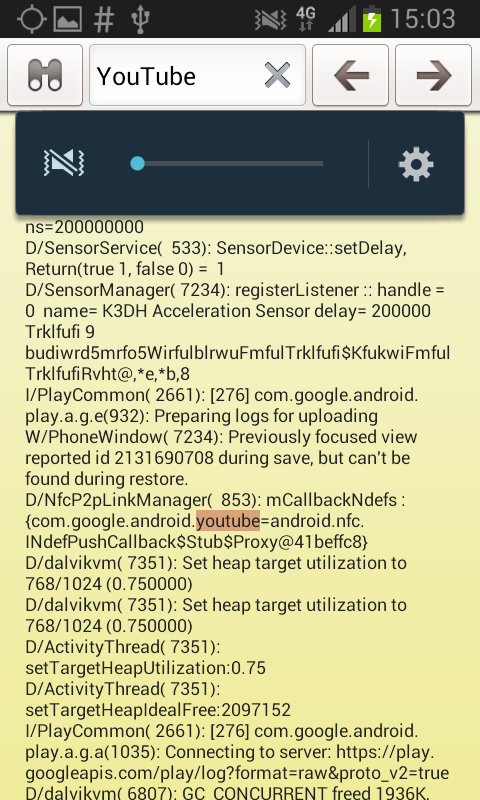
In this test, it is obviously required that the device’s Wi-Fi is turned on, so it is turned on in the beginning of the test, if it is not already. After that is performed the scan and the parameters we retrieve from this test are: ssid, bssid, signal level, management key protocol, security capabilities, frequency, timestamp, distance, passpoint, channel bandwidth, center freq and some more.

* **Write LogCat to a file:** Android has several files where he dumps information and what is happening in the system in that moment. The location of this files are not standardized (i.e. some can be ROM-specific):
  + */data/anr*: Some trace files seem to get here (Dalvik writes stack traces here on ANR, i.e. "Application Not Responding" aka "Force-Close";)
  + */data/dontpanic* seems to be a standard location (AOSP), and contains some crash logs including traces.
  + */data/kernelpanics* is another location but not having any "kernel panic" on the android device yet means no content there yet too.
  + */data/panic/panic\_daemon.config*may point to other locations configured like /sdcard/panic\_data/ mentioned Droid 2 also has a /data/panicreports directory.
  + */data/tombstones* may hold several tombstone\_nn files (with nn being a serial, increased with every new file). As tombstones are placed for the dead, it is done here for "processes died by accident" (i.e. crashed) -- and it is what is referred to as "core dumps" on Linux/Unix systems. However, not all apps create tombstones; this must be explicitly enabled by the developer.

Most of logging is done on *tmpfs* but with reboot these data is lost. Most developers usually use these logs to help troubleshoot problems or crashes in applications but there is a lot more information there divided in 5 levels – verbose, debug, error, info and warning. So there have been concerns about privacy because despite we can write messages to logfile to use as debug also SMS/MMS, contacts information, e-mails, etc can be written. Bellow we can see some examples of relevant private information that can be used by hackers like GPS information: [4]



Figure 1 - Navigation information

 And many more examples can be given, accessing a Wi-Fi network can write the SSID of the network or the associated MAC address, after enabling Bluetooth was founded the Bluetooth address written in clear text or when a user opens a specific app, the logfile contains the package name of the selected app:



Although all this examples founded in clear text, there are also information that can be sanitized. If we call toSafeString() method URI’s are sanitized before they are written into the “log file”. So URI’s started by “tel:”, “smsto:”, “mailto:”, etc are written as “xxxxxxx”

Figure 2 - Open a specific app



Figure - Sanitized information

Is this a problem nowadays? Yes, if you have a rooted phone. No if you have not. Since android version 4.1 Google don’t allow to read log entries from other applications anymore, so if you dump the “LogCat” to a file in an unrooted device ( > v. 4.1.x) you will only see log entries from your own app.

All of this information has been tested and for reading logs in rooted devices I had to grant permissions not only in the “Manifest.xml” but some in real time via shell commands, like this:



Figure 4 - Grant access to READ\_LOGS via shell command

And after, call LogCat in a background process and send its content to a .txt file.



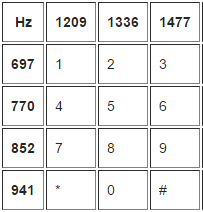
Figure - Call logcat in runtime

* **Start call with a custom APN:** An APN is a gateway between a computer network, normally the public internet and the network used by the device technology (GSM, GPRS, 3G, 4G). In 3GPP data access networks APN is used to identify the packet data network that user wants to communicate with or to define the type of service (e.g MMS, WAP). It contains a mandatory *network identifier* that defines the external network to which the GGSN is connected and a optional *operator identifier* that defines the operator’s packet domain (e.g. Internet-v4.mnc111.mcc222.gprs, mmsc.tmn.pt).

In the development of this test was founded a list with 1370 APN’s and its configurations, in further investigations we confirmed that Google has a .xml file in android devices that keeps this information, normally under the /etc folder and the correct settings are defined by the SIM card inserted in the device.

Changing the preferred APN requires the application to be a system application. As explained in chapter 2 these applications are located under the *system/app* folder and have some permissions that user apps don’t have, allowing change and insert new APN’s on device’s configurations.

* **Send DTMF tones:** On the first telephones the dialing was done through a "disk" that generated a sequence of pulses, dual-tone multi-frequency signaling is a substitute for that on keypad phones. When an user presses a key is generated a high frequency and a low frequency based on the key pressed and the sum of the sinusoids of the two frequencies is then sent to the central that analyses the signal, knowing that the key was pressed.



Tabel - DTMF table

In the app are being sent a sequence of a DTMF tones interacting with voicemail service automatically (e.g. “200,3,,4,,1”). Unfortunately in android is not possible to send this tones on the voice’s uplink during an active call as an app developer, but we can do it when initiate the call. There are a few contributions at the moment with new implementations of CallManager class waiting for Google developers to review and accept in “Android open source project” about the subject at the moment.

Chapter **5**

# Results and Discussion

Chapter **6**

# Conclusions and Future Work

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**Appendix**