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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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| agradecimentos | Aos meus orientadores, …  A XXX. Obrigada pela forma xxx como me acolheram e me integraram no vosso grupo de trabalho. Foi uma ótima ajuda para que tudo corresse pelo melhor.  Aos meus pais e à minha irmã o maior agradecimento. Para vos agradecer tudo o que já fizeram por mim eu precisava de uma tese inteira e não apenas de uma secção nos agradecimentos, vocês foram o meu pilar ao longo destes anos. Obrigado por terem sempre acreditado em mim e por me ajudarem a conseguir fazer sempre mais e melhor. Obrigada por me mostrarem que não interessam as notas ou os graus que eu consiga, que aquilo que interessa é eu seguir o meu sonho e ser feliz. Obrigada por todos os sacrifícios que já fizeram por mim. Obrigada por não me deixarem sentir mal mesmo quando as coisas correm menos bem. Obrigada por estarem sempre presentes. Muito, muito obrigado, sem vocês isto nunca teria sido possível.  A todos os meus amigos, por toda a disponibilidade e por me apoiarem nas minhas derrotas e por festejarem comigo as minhas vitórias. |

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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. |

Contents

[List of figures ix](#_Toc474241904)

[List of tables x](#_Toc474241905)

[List of acronyms xii](#_Toc474241906)

[**I**ntroduction 14](#_Toc474241907)

[1.1 Motivation 14](#_Toc474241908)

[1.2 Objectives 16](#_Toc474241909)

[1.3 Contributions 17](#_Toc474241910)

[1.4 Project Structure 17](#_Toc474241911)

[State of Art 18](#_Toc474241912)

[2.1 Study of Market 18](#_Toc474241913)

[2.2 Cellular Networks Technologies 18](#_Toc474241914)

[2.3 VoIP 18](#_Toc474241915)

[2.3.1 VoLTE 18](#_Toc474241916)

[2.3.2 VoWifi 18](#_Toc474241917)

[2.4 Parameters 18](#_Toc474241918)

[3.3.1 Radio Parameters 18](#_Toc474241919)

[3.3.2 Device Parameters 18](#_Toc474241920)

[3.1 What is difference between Api’s 19](#_Toc474241921)

[ArQoS Pocket solution 21](#_Toc474241922)

[3.1 Architecture 21](#_Toc474241923)

[Developed Work 23](#_Toc474241924)

[Results and Discussion 25](#_Toc474241925)

[Conclusions and Future Work 27](#_Toc474241926)

[References 28](#_Toc474241927)

[**Appendix** 29](#_Toc474241928)

# List of figures

**Não foi encontrada nenhuma entrada do índice de ilustrações.**

# List of tables

# 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

C

**CDMA –** Code Division Multiple Access

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

Q

**QoE –** Quality of experience

**QoS –** Quality of service

U

**UMTS –** Universal Mobile Telecommunications System

W

**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

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.

## Motivation

Human relationships are based on communication and technology changed the way we interact with each other and the world. 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 the final user, making the network more and more heterogeneous.

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. Selecting the suitable access network to meet the QoS requirements of a specific application has become a significant topic 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 [1]. 🡨

QoS metrics are delay, jitter (delay variation), service availability, bandwidth, throughput, packet loss rate. Metrics are used to indicate performance of particular scheme employed.

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.

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 network, transport, application, user and switching levels. To meet QoS, we should address the following issues like encryption protocols, security and “trust of information”, different rates, error profiles, latencies, burstiness, dynamic optimization of scarce resources and fast handoff control [2].

Over the past several years there have been a considerable amount of research in the field of quality-of-service support for 4G systems as it’s more challenging than previous generations. Regarding this, some research papers have presented their idea of QoS architectures across all protocol layers.

## 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. [3]

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

## 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

## Study of Market

## 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]

## VoIP

### VoLTE

### VoWifi

## Parameters

### Radio Parameters

### Device Parameters

## What is difference between Api’s

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. [4…ver ultimo ]

## Architecture

Chapter **4**

# Developed Work

Chapter **5**

# Results and Discussion

Chapter **6**

# Conclusions and Future Work

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**Appendix**