ANACOM AUTORIDADE NACIONAL DE COMUNICAÇÕES

GSM/UMTS/LTE

Mobile Communication Systems

Assessment of Quality of Service

Methodology for Assessing the Performance of Mobile Services and GSM, UMTS and LTE Coverage

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ANACOM

Contents

ABBREVIATIONS AND ACRONYMS

APN	Access Point Name.
CEPT	European Conference of Postal and Telecommunications Administrations.
CoDec	Coder/Decoder.
CPICH RSCP	Common Pilot Channel, Received Signal Code Power – level of radio signal received by a mobile terminal (UMTS).
CS	Circuit Switched.
CSFB	Circuit Switched Fallback.
ECC	Electronic Communications Committee.
EPS	Evolved Packet System – optimised 4G network packet-switched system, resulting from the evolution of 3G/UMTS systems, characterized by high data speed, low latency and for allowing multiple radio access network technologies.
ETSI	European Telecommunications Standards Institute.
FCT	*Fundação para a Ciência e a Tecnologia*, I.P. - the Foundation for Science and Technology, Public Institute.
FTP	File Transfer Protocol.
GigaPIX	Portuguese Internet Exchange Point.
GSM	Global System for Mobile communications (2G).
HTTP	Hyper Text Transfer Protocol.
ITU	International Telecommunications Union.
LTE	Long Term Evolution – 4G Mobile Communication System.
MIMO	Multiple Input Multiple Output – technology that uses multiple transmitters and receivers (antennas) to improve the performance of radio communications.
MMS	Multimedia Messaging Service.
MMSC	Multimedia Messaging Service Centre.
MOS	Mean Opinion Score – Quality index that quantifies the effort required to perceive an end-to-end type communication. 0 (zero) is the lowest limit, where no communication is established, and 5 (five) is the highest limit, where communication is perfect.
PDP	Packet Data Protocol.
POLQA	Perceptual Objective Listening Quality Assessment – algorithm used to analyse the audio quality of a voice communication (recommended by ITU: ITU-T Recommendation P.863 (01/2011)).
PS	Packet Switched.
ISDN	Integrated Services Digital Networks – technology used in the fixed access network.
RF	Radio Frequency.
RSRP	Reference Signal Received Power – level of radio signal received by a mobile terminal (LTE).
RxLev	Received signal level – level of radio signal received by a mobile terminal (GSM).
Scanner RF	Measuring equipment that draws radio signal levels for each frequency band channel.
SIM	Subscriber Identity Module – SIM card.
SMS	Short Message Service.
SMSC	Short Message Service Centre.
SQuad-LQ	SwissQual's speech quality algorithm for Listening Quality.
TCP/IP	Transmission Control Protocol / Internet Protocol.
UMTS	Universal Mobile Telecommunications System – 3G Mobile Communication System.
USIM	UMTS Subscriber Identity Module – USIM card.
VQuad	Objective Model for Video Quality Assessment – algorithm developed by SwissQual.
WCDMA	Wideband Code Division Multiple Access – technology used in the radio component of UMTS communication systems.

1 INTRODUCTION

The majority of individual consumers and companies use electronic communications services supported on GSM/UMTS/LTE mobile communication systems to meet their everyday communication needs, in particular as far as telephony, messages and data are concerned, including emergency and security communications, reason for which these systems play a very relevant in the context of national electronic communications.

In the scope of GSM/UMTS/LTE mobile communication systems, quality of service from the user's perspective is of the utmost importance, especially on account of the radio nature of access, for the mobility they allow and the take-up rate they show.

On the other hand, National Regulatory Authorities throughout the European Union must also monitor and ensure access to open Internet and promote the continuous availability of non-discriminatory Internet access services, with levels of quality that reflect technological progress.

ANACOM, in the scope of its assignments and using the powers provided for in its Statutes, is entitled to arrange for independent studies of assessment of quality of service from the user's perspective to be conducted, so as to provide the market, especially the most vulnerable consumers - individuals and micro and small companies -, with fair information on the performance of electronic communications services supported on mobile communication systems available on the market.

The monitoring of the performance of mobile networks and services, carried out with commercial terminal equipment and from a common user's perspective, is an inclusive, extremely accurate and reliable process, that provides information on the geographic coverage and quality of service made available by GSM/UMTS/LTE operators. The intrusive approach of this method is acknowledged to be the best possible commitment between the feasibility of its technical implementation, the guarantee of user privacy and the accurateness and reliability of information achieved. As such, field-testing, using teams of technical experts and automatic testing systems, in particular motion-based approaches - drive tests and walk tests - allows for objective measuring and accurate definition of analysed geographic areas. It also allows services to be analysed independently of the operation of telecommunication networks themselves. For example, areas with poor or even no radio coverage may also be considered in the analysis, the results of the study thus becoming a good indicator of the overall network behaviour from the user's perspective. This is also the best method to conduct operator performance benchmarks, as it guarantees that tests are made under equal and simultaneous conditions for all.

This document presents a set of indicators for assessing the performance of the most relevant services, in the current context of mobile networks, and for checking coverage of each radio technology used by operators. Measurement profiles are also shown, defining a set of commitments and conditions which must be ensured to correctly assess the quality of service and to guarantee the reliability of tests. These profiles also cover the standardization of procedures and the definition of testing and measuring parameters, to allow the feasibility of analyses and the comparability of results obtained.

2 OBJECTIVES

This document aims to define a methodology that makes it possible:

A. To analyse, from the user's perspective, the performance of electronic communications services supported on Portuguese GSM/UMTS/LTE mobile communication systems, by conducting automatic end-to-end tests;

B. To check GSM/UMTS/LTE coverage of Portuguese mobile communication systems.

3 SCOPE

3.1 MOBILE SERVICES

The assessment of quality of service, from the user's perspective, must take into account services that, in each technology, are of high relevance for end-users and that are made available by all operators on the market.

Bearing in mind this guiding principle, and in the light of the current reality [ANACOM] the following services require analysis:

1. Telephony Services:
    a. **Voice Service**;
2. Message Service:
    b. **SMS – Short Message Service**;
3. Data Service:
    c. **File Transfer Service** (HTTP upload/download);
    d. **Internet browsing Service** (HTTP web browsing);
    e. **YouTube Video Streaming Service**.

3.2 RADIO COVERAGE

The key distinguishing feature of services provided by mobile communication systems is mobility, which is achieved via wireless access networks with radio interfaces.

Mobile communication systems are distinguished for their radio interfaces and for the services provided. GSM - the first generation of such systems - was initially designed for the provision of telephony and messaging services. Later, this system evolved to allow the provision of data services (GPRS, EDGE). 3G and 4G systems - UMTS and LTE - were developed for the provision of high performance data transmission services, such as Internet access and multimedia services. From the user's perspective, the difference between UMTS and LTE is the maximum transmission speed provided, which in the LTE context is much higher.

As such, when assessing the performance of mobile communication systems, it is fundamental to check the availability of all radio interfaces used in access networks. At present, the most prominent analyses are as follows:

a. **Availability of the GSM Radio Network;**

b. **Availability of the UMTS Radio Network**;

c. **Availability of the LTE Radio Network**.

4 FRAMEWORK

4.1 QUALITY OF SERVICE FROM THE USER'S PERSPECTIVE

ITU (International Telecommunications Union) defines Quality of Service as the collective effect of performance which determines the degree of satisfaction of a user of the service; and Network Performance is defined as the ability of a network or network portion to provide the functions related to communications between users [ITU-T E.800].

The quality of service is characterized by a combination of the performance of different factors, such as customer care, user-friendliness of the service, service accessibility, retention/maintenance of the service, service integrity, service security and other specific factors of each service.

In the context of this document, the following concepts are used:

- ***Network Performance*** - ability of a network or network portion to provide a service with a specific degree of quality. This covers the functions, mechanisms and procedures, implemented by the cellular network and by the terminal equipment, that ensure the provision of quality of service negotiated between the terminal equipment and the core network.
- ***Quality of Service from the User's Perspective*** - corresponds to the quality perceived by a user when he/she uses the service. Indicates the degree of satisfaction of the user in terms, for example, of accessibility, integrity and maintainability of the service.

The *Quality of Service from the User's Perspective* is usually expressed in terms of human perceptions, such as "Excellent", "Good", "Acceptable", "Poor" and "Bad", whereas *Network Performance* is a purely technical concept that is measured, expressed and understood in the perspective of the network or of its elements, and of very little significance to the user. However, these aspects are interlinked: a better network performance typically entails a better quality perceived by the user. However, good performance parameters do not ensure the satisfaction of the user. For example, high audio quality of the voice service in a given location is of not much use to the user if right next to it the network provides no radio coverage. Consequently, the need to guarantee user satisfaction is what really counts, thus the performance objective of a cellular infrastructure must be the provision of high Quality of Service from the User's Perspective (*Figure 1*).

This document focuses on the *Quality of Service from the User's Perspective*, only addressing technical aspects that contribute to user satisfaction.

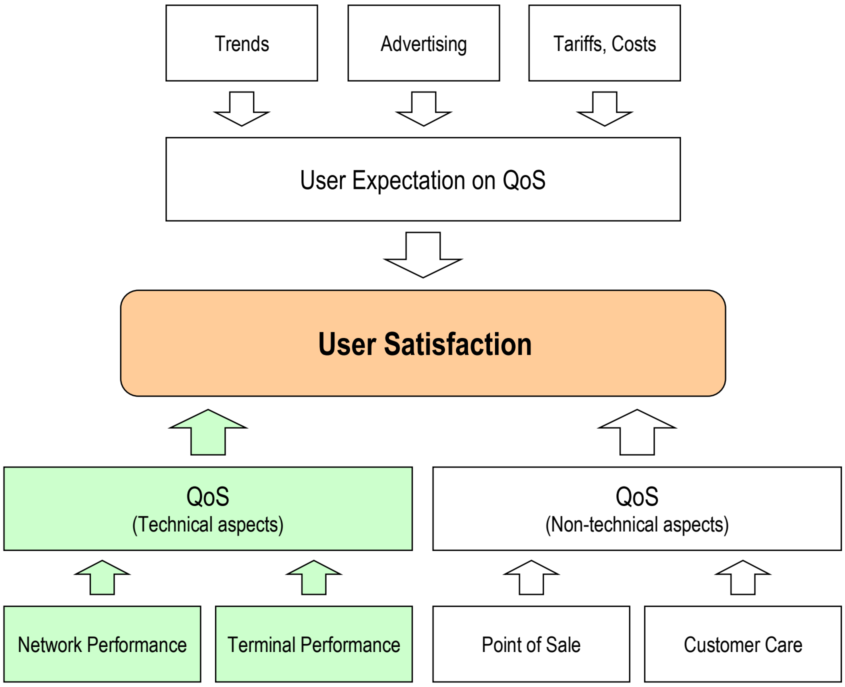

Figure 1 – Relationship between User Satisfaction, QoS and Network Performance [ETSI TS 102 250-1].

From a user's perspective, the usage of services supported on mobile communication systems can also be separated in consecutive phases. The figure below shows the different phases of network access, service access and service usage and the according QoS aspects.

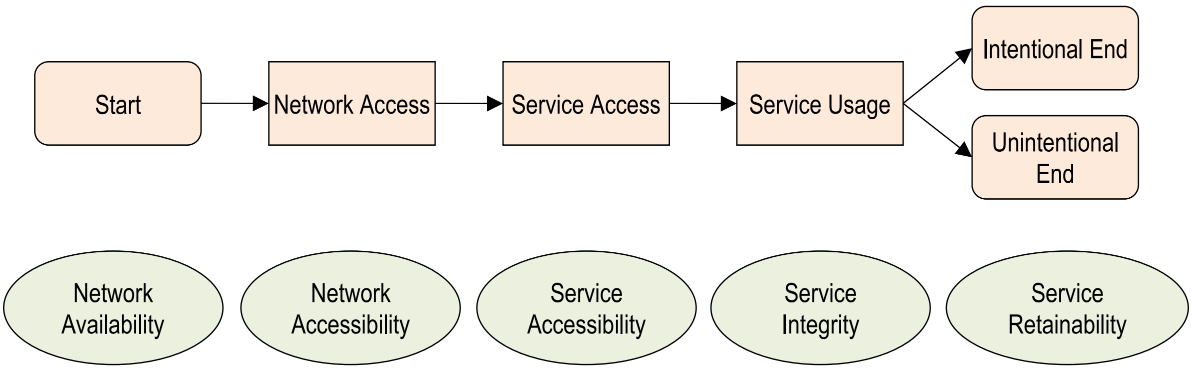

Figure 2 – Phases of service usage and related QoS aspects [ETSI TS 102 250-1].

QoS aspects, related to different phases of service usage, have the following meaning [ETSI TS 102 250-1]:

a. **Network Availability** - Probability that the services are available via an infrastructure of the mobile network.

b. **Network Accessibility** - Probability that the user (its terminal equipment) performs a successful registration on the mobile network which delivers the intended service. The mobile network can only be accessed if it is available to the user.

c. **Service Accessibility** - Probability that the user can access the intended service, insofar as the mobile network is accessible.

d. **Service Integrity** - This describes the service performance during use, after access to that service has been guaranteed, through elements of the transmitted content (such as speech quality, video quality, number of bit errors in a transmitted file, etc.)

e. **Service Retainability** - Describes the completion of the service (in accordance with or against the will of the user), after access to that service has been guaranteed.

QoS indicators/parameters must achieve relevant information on each of the phases/aspects identified above, so as to allow, among others:

a. Benchmarking of the performance levels made available by different operators;

b. The study of performance evolution over time;

c. The identification of the causes of problems and assessment of the impact of implemented solutions.

Nevertheless, special care must be taken in using QoS parameters due to effect of radio coverage, which is able to misrepresent absolute values of these parameters and make the performance of networks impossible to compare. Some factors must be taken into account:

- Networks may not have been designed with the same coverage priorities. Operators may focus their network's radio coverage on specific geographic areas (such as urban, rural, littoral, interior areas, etc.) or on specific types of users (such as residential or business customers, etc.), especially during the first years of operation;
- The absolute average level of mobile network performance may be of very little interest for users, who may only take interest in the performance of networks in a specific geographic area, and there may be situations where a given network has better coverage in a given area while another

network provides better coverage in another area;

- The capacity and coverage of a mobile network change frequently, especially during the first years of operation, thus performance improves as operators develop their networks. As such, QoS analyses made in a given location and at a given time may not be indicative of the average network performance over a long period of time;
- Network performance indicators obtained through drive-tests only apply to targeted moments and sites, except in situations where the sample collected is representative of the use of mobile services.

4.2 Methodological Options

Mobile communication systems are distinguished for their radio interfaces and for the services provided. GSM - the first generation of such systems - was initially designed for the provision of telephony and messaging services. Later, this system evolved to allow the provision of data services (GPRS, EDGE). 3G and 4G systems - UMTS and LTE - were developed for the provision of high performance data transmission services, such as Internet access and multimedia services. From the user's perspective, the difference between UMTS and LTE is the maximum transmission speed provided, which in the LTE context is much higher.

The key distinguishing feature of services provided by mobile communication systems is mobility, which is achieved though wireless access networks with radio interfaces. As such, when assessing the performance of mobile communication systems, it is fundamental to check the availability of all radio interfaces used in access networks (GSM, UMTS and LTE).

In any study, it is impossible to reflect accurately the reality intended to be studied, and this is even more evident where that reality involves complex systems with human interaction.

When assessing the performance of mobile networks and services, against the rate of penetration of mobile services, the diversity of terminal equipment used and services provided and the inherently subjective nature of each user, it is impossible to rigorously depict the conditions of interaction of each consumer with networks. As such, a quality analysis is only possible through compromises and approaches, although within the limits that allow results obtained to be considered as reliable indicators of the overall behaviour of mobile communication systems, namely as regards the geographic coverage and signal levels of access radio networks, as well as the accessibility, integrity and retainability of services.

In the scope of these analyses, it would be ideal if measurements could be made in all sites where electronic communications services may be provided; ultimately, all geographic areas under study should be taken into consideration, including inside buildings and transport vehicles. However, this is quite impractical, so a commitment that involves the performance of tests in public locations and in motion (the so-called drive-tests) is the chosen approach. This has been the approach used worldwide by sector regulators and mobile operators in general, to very good effect.

It would also be ideal if all types of terminal equipment on the market were used, in the different versions of operative systems and software applications. All services made available by operators, taking into account the different usage profiles, should also be studied. It is easy to understand that conducting tests that take all these variables into account would be also impractical. As such, these analyses usually focus on main services, that are provided homogeneously by all operators on the market, so that all technologies with which operators are provided are analysed, and commercial terminal equipment with the same characteristics and settings are used.

The use of commercial mobile terminals, with similar characteristics to terminal equipment used by consumers in general and with no additional external antennas, in tests conducted in in-car contexts, either static or in motion (drive tests), allows testing conditions that are identical to those of a common use in these environments. The attenuation of radio signals caused by the structure of the car, also enables testing conditions that are close to those experienced by common users of mobile services in indoor environments, when compared to those that would be obtained by tests performed in outdoor environments or with terminal equipment in cars provided with exterior antennas.

On the other hand, the way how services are tested follows a methodology that reflects the reality of a common user, with the best possible approximation, given that, among other aspects, commercial terminal equipment and software applications are used; talks are simulated (for the purpose of assessment of the voice service audio quality); files are transferred, web pages and YouTube videos are downloaded (for the purpose of assessment of data services); and the presence and signal levels of radio networks in several locations are checked. This type of approach is usually known as *end-to-end measurements from the user's perspective.*

Voice and SMS traffic is at present overwhelmingly of a Mobile-to-Mobile nature and mostly intra-network, so these settings must be considered in the testing methodology. However, to minimize the uncertainty that is always a part of measurement procedures, in tests to the voice service, one of the communication ends must present good levels and great stability of performance. The impact of this end on indicators must be minimum, thus static mobile user equipment must be used in sites with appropriate (good) radio coverage, minimum interference and high probability of access to the voice service. As far as the SMS message service is concerned, messages are sent and received at different times, thus tests to this service may take place with both terminals in motion.

File transfer, Internet browsing (reference web page) and transmission latency tests must be conducted using Internet servers located at a “neutral” site for all operators under analysis. As such, the best option in Portugal is to host test servers at an FCT (*Fundação para a Ciência e a Tecnologia*, I.P. - Foundation for Science and Technology) datacentre, linked to the Internet through a neutral traffic exchange point, namely GigaPIX (Portuguese IP network traffic exchange point) [GigaPIX]. Servers must operate just like servers available on the Internet and must be exclusively dedicated to testing, with no limitations in terms of capacity for processing or storing information, access availability and bandwidth.

These tests with dedicated servers, hosted in a “neutral” location that is “equidistant” from the various operators, make it possible to know the intrinsic performance of infrastructures of each operator and its impact on the performance of services provided to customers.

In addition, tests with public servers must also be performed, hosting the contents most searched by Portuguese internet users (web pages and YouTube video clips), as they provide information on the impact of each operator’s infrastructures on the access by the respective customers to these contents.

In the light of the current situation, methodological options that safeguard commitments adopted are described and justified in the table below.

Table 1 – Substantiation of main methodological options

Decision	Rationale
End-to-end analysis, from the user's perspective, using commercial terminal equipment	▪ This methodology for testing mobile networks and services reflects the reality of a common user, with the best possible approximation, given that, among other aspects, commercial terminal equipment and software applications are used; talks are simulated (for the purpose of assessment of the voice service audio quality); files are transferred, web pages and YouTube videos are downloaded (for the purpose of assessment of data services); and the presence and signal levels of radio networks in several locations are checked [ITU-T E.800, ETSI TS 102 250-x]; ▪ This type of analysis is able to provide reliable indicators of the overall behaviour of mobile communication systems, namely as regards the geographic coverage and signal levels of access radio networks, as well as the accessibility, integrity and retainability of services.
Level playing field for all operators under study	▪ Mobile networks and services are analysed at the same time, at the same locations, with the same equipment and settings for all operators under study; ▪ USIM are rotated among terminal equipment, so that all operators are subject to equal average testing conditions, namely as regards the position within the test car and intrinsic characteristics of equipment; ▪ Operator performance benchmarking is enabled.
Automatic testing systems	▪ Objectivity of measurements carried out given that human intervention or decision is eliminated; ▪ Operators are submitted to identical testing conditions, which allows for performance benchmarking; ▪ Very good repeatability and reproducibility of all measurement procedures, leading to highly robust and reliable results.
Outdoor drive tests	▪ It is possible to fully explore outdoors the main distinguishing factor of services provided by mobile communication systems: mobility; ▪ It is possible to analyse larger geographic areas in a shorter period of time; ▪ It is possible to use more robust and reliable testing platforms; ▪ Ease of deployment; ▪ Good ratio between implementation costs and results obtained.
Testing mobile terminal equipment is located in-car, roughly in the middle of the passenger compartment, with no additional external antennas	▪ Allows testing conditions to the same as those of a common use of services in car environments; ▪ The attenuation of radio signals caused by the structure of the vehicle, also enables testing conditions to be close to those experienced by common users of mobile services in indoor environments, when compared to those that would be obtained by conducting tests in outdoor environments or with terminal equipment in cars provided with exterior antennas [ETSI TR 102 581]; ▪ The use of antennas of mobile terminal equipment allows radio transmission techniques (such as MIMO), under test conditions, to be conducted in exactly the same way as when networks are commonly used, with the same impact on radio transmission.
Commercial smartphones with Android operative system	▪ Smartphones are the type of mobile terminal most used today in Portugal by consumers (69% of terminals, with an upward trend) [ANACOM, Marktest_BTC, GfK_TEMAX]; ▪ The Android operative system currently presents the largest smartphone market share (around 88%) [IDC, Strategy_Analytics].

Decision	Rationale
Smartphones set to automatically select GSM, UMTS and LTE radio interfaces	▪ Bearing in mind the high penetration rate of smartphones [ANACOM, Marktest_BTC, GfK_TEMAX] – which for the most part are able to use and select these technologies automatically - as well as commercial offers made available by Portuguese operators [MEO, NOS, Vodafone] – which make no distinction between access radio technologies - this is the option that comes closest to the reality of mobile network users in general.
Voice and SMS testing in Intra-Network Mobile-to-Mobile setting	▪ Mobile-to-Mobile voice traffic exceeds 90% of all voice traffic originated in mobile networks [ANACOM]; ▪ Intra-network voice traffic represents 56.2% of all voice traffic originated in mobile networks [ANACOM]; ▪ SMS traffic is overwhelmingly of a Mobile-to-Mobile nature and mostly intra-network (68,1%) [ANACOM]; ▪ Uses to good effect all functions and possibilities implemented by mobile networks (such as HD Voice, VoLTE, etc.)
One of the communication ends remains static during voice service tests	▪ To minimize the uncertainty that is always a part of measurement procedures, one of the communication ends must present good levels and great stability of performance. The impact of this end on indicators must be minimum, thus static mobile user equipment (UE) must be used in sites with appropriate (good) radio coverage, minimum interference and high probability of access to the voice service.
Duration of test (voice) calls: 150 seconds	▪ Approximate duration of voice calls originated in Portuguese mobile networks [ANACOM].
Alternating start of test (voice) calls	▪ Allows the start and completion abilities of calls in motion by mobile communication systems to be assessed, in locations under study.
Both communication ends in motion in the same location (SMS)	▪ Allows the SMS sending and receiving abilities in motion to be assessed - a factor with relevant impact on this service - and testing costs to be minimized (as tests may be conducted with only two mobile terminals per operator); ▪ It is not critical, from the mobile network perspective, given that the service operates at different times, thus the sending and receiving of test SMS messages in the same location is not a network congestion factor (when compared to a situation where SMS were only originated or terminated in a specific location), and it is possible to distinguish, unequivocally, the impact of the message originator and receiver in the service performance.
YouTube portal (YouTube video streaming)	▪ Video services (namely video streaming) are currently responsible for more than 50% of data traffic over mobile networks [Ericsson_MR, Cisco_VNI]; ▪ The YouTube portal is currently responsible for 40% to 70% of all video traffic over mobile networks [Ericsson_MR, Cisco_VNI].
Test contents in dedicated servers and in public servers (data services)	▪ Tests with dedicated servers, hosted in a "neutral" location that is "equidistant" from the various operators, make it possible to know the intrinsic performance of infrastructures of each operator and its impact on the performance of services provided to customers. They allow the use of stable reference contents, such as binary files and the Kepler web page developed by ETSI [ETSI TR 102 505]; ▪ Tests with public servers, that host the contents most searched by Portuguese internet users (web pages and YouTube video clips), provide information on the impact of each operator's infrastructures on the access by the respective customers to these contents.

Decision	Rationale
GigaPIX Dedicated Servers	▪ Dedicated Servers hosted in a "neutral" location that is "equidistant" from the various operators under analysis; ▪ The best option in Portugal is to host Test Servers at an FCT (*Fundação para a Ciência e a Tecnologia*, I.P. - Foundation for Science and Technology) datacentre, linked to the Internet through a neutral traffic exchange point, namely GigaPIX (Portuguese IP network traffic exchange point) [GigaPIX]; ▪ These servers operate just like servers available on the Internet and must be exclusively dedicated to testing, with no limitations in terms of capacity for processing or storing information, access availability and bandwidth, access availability and bandwidth.
HTTP protocol in tests to data services	▪ This protocol carries most data traffic, received or sent by users of mobile networks when the Internet is accessed, namely when a webpage is downloaded, files are transferred or multimedia content is downloaded from the YouTube portal. It is stressed that video traffic represents more than half the weight of data traffic over mobile networks and that the YouTube portal is currently responsible for 40% to 70% of all video traffic over mobile networks [Ericsson_MR, Cisco_VNI].
File transfer (HTTP upload/download) carried out according to the concept of fixed data transfer time instead of full file transfer of a fixed size	▪ Allows a specific amount of measurements for a defined time period, which can lead to saving of time and effort needed to monitor the performance of a mobile network; ▪ Appropriate where a large variance of measured parameters is expected (such as download and upload speeds) [ETSI TR 102 678]; ▪ Method particularly recommended in case of drive tests for benchmarking several operators as it allows a correct and fair comparative analysis [ETSI TR 102 678].
GSM, UMTS and LTE radio interfaces	▪ Radio technologies used in access networks of mobile communication systems provided by Portuguese operators; ▪ Determining the coverage levels of each radio interface in order to define locations most likely to be successful when services are used.

All the above-mentioned options, as well as the definition of measurement profiles and indicators of quality of service from the user's perspective, are based on technical specifications defined by leading international organisations, such as ITU, ETSI (European Telecommunications Standards Institute) and CEPT-ECC (European Conference of Postal and Telecommunications Administrations – Electronic Communications Committee), namely the following: ETSI TS 102 250, ETSI TR 101 578, ETSI TR 102 678, ETSI EG 202 057, ETSI ES 202 057, ETSI TR 102 505, ETSI TR 102 581, ETSI TS 100 910, ETSI TS 143 022, ETSI TS 145 008, ETSI TS 125 304, ETSI TS 136 304, ETSI TS 136 133, ITU-T P.863, ITU-T P.863.1, ITU-T J.343, ITU-T J.343.1, ITU-T P.910, ITU-T E.800, ITU-T Q.3960, ECC Report 256 and ECC Report 103 [ETSI TS 102 250-x, ETSI TR 101 578, ETSI TR 102 678, ETSI EG 202 057-x, ETSI ES 202 057-1, ETSI TR 102 505, ETSI TR 102 581, ETSI TS 100 910, ETSI TS 143 022, ETSI TS 145 008, ETSI TS 125 304, ETSI TS 136 304, ETSI TS 136 133, ITU-T P.863, ITU-T P.863.1, ITU-T J.343, ITU-T J.343.1, ITU-T P.910, ITU-T E.800, ITU-T Q.3960, ECC Report 256 and ECC Report 103].

The proposed methodology is thus based on field tests, carried out from the user's perspective, using an automatic measurement system, reflecting the various aspects that affect the quality of services (end-to-end measurements). Measurements are performed objectively (with no human intervention or decision), a level playing field being guaranteed for all operators, as measurements take place at the same time, in the same locations, with the same equipment and settings, to allow cellular systems of targeted operators to be benchmarked.

5 MEASUREMENT PROFILES

Measurement profiles define a set of conditions that must be ensured to correctly assess the quality of service and to guarantee the reliability of tests. They also cover the standardization of procedures and the definition of test and measurement parameters, so as to allow the feasibility of analyses and the comparability of results obtained[1].

5.1 GENERAL MATTERS

The assessment of mobile network performance is carried out in an objective manner using an automatic testing platform, ensuring that there is no human intervention or decision while the test is conducted. The same commercial mobile terminals are used (smartphones with Android operative system) for all operators under examination.

Measurements take place in public outdoor locations and in motion (drive tests), using cars. All collected parameters are geo-referenced.

While tests are conducted, mobile terminals remain inside the vehicles, located roughly in the middle of the passenger compartment, use their own antennas and automatically select the service supporting radio infrastructure (GSM, UMTS or LTE). USIM are rotated among terminal equipment is implemented in order to grant all operators with the same average testing conditions, namely as regards the position inside the testing car and intrinsic characteristics of equipment itself.

Mobile services are analysed end-to-end and under equal conditions for all operators, namely at the same time, in the same places, with the same equipment and with the same settings.

Tests to voice, SMS and data services take place in parallel, using however independent mobile terminal equipment for each test and operator. Notwithstanding, in a given location, no more than two services will be analysed at the same time.

Levels of radio coverage are checked in a passive mode, in parallel with tests to services, using specific

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[1] These measurements profiles and parameters are based on the following technical specifications ETSI TS 102 250, namely part 5, ETSI TR 101 578, ETSI TR 102 678, ETSI TR 102 505, ETSI TR 102 581, ETSI EG 202 057, namely parts 3 and 4, ETSI TS 100 910, ETSI TS 143 022, ETSI TS 145 008, ETSI TS 125 304, ETSI TS 136 304, ETSI TS 136 133; on the following recommendations ITU-T P.863, ITU-T P.863.1, ITU-T J.343, ITU-T J.343.1, ITU-T P.910 and ITU-T Q.3960; and on the following reports ECC Report 256 and ECC Report 103 [ETSI TS 102 250-5, ETSI TR 101 578, ETSI TR 102 678, ETSI TR 102 505, ETSI TR 102 581, ETSI EG 202 057-3, ETSI EG 202 057-4, ETSI TS 100 910, ETSI TS 143 022, ETSI TS 145 008, ETSI TS 125 304, ETSI TS 136 304, ETSI TS 136 133, ITU-T P.863, ITU-T P.863.1, ITU-T J.343, ITU-T J.343.1, ITU-T P.910, ITU-T Q.3960, ECC Report 256, ECC Report 103].

equipment (RF scanner).

5.2 RADIO COVERAGE

Network coverage assessment is made by measuring the downlink signal levels, RxLev (Received signal Level) for GSM and CPICH RSCP (Common Pilot Channel Received Signal Code Power) for UMTS and RSRP (*Reference Signal Received Power*) LTE, along each analysed route.

Measurements are performed with an RF Scanner device adapted and exclusively dedicated to this task, so that the measured signal levels correspond to the effective levels. Consistently with the assessment mobile services performance, equipment antennas are placed inside the test car, located roughly in the middle of the passenger compartment, thus measurements are affected by the attenuation caused by the structure of the vehicle. The measurement equipment collects signal samples from all GSM, UMTS and LTE radio channels used by the operators under analysis. These samples are later analysed and only the best signal level results obtained for each point, technology and operator are considered.

Each measurement point is geo-referenced so that signal levels can be later represented on digital cartography, thus making it easier to visualise coverage levels of mobile networks along the routes under study and to identify the locations with poor or no coverage.

This approach for checking radio coverage, especially UMTS and LTE coverage, does not take into consideration the load of networks as regards the number of users at the same time and the type of services used. An indication of good level of coverage, in a given location and at a given moment, must be perceived as the presence of radio network at levels that enable access and use of all services, although the quality levels of the service provision may differ among users. For example, it is likely that maximum data transfer speed for each connection (user) decreases with the increase of simultaneous connections (users) in a radio cell or as users draw closer to the fringes of that cell.

5.3 VOICE SERVICE

The analysis of the voice service, at a given location, includes the abilities to make and to end calls, as well as the integrity of the communication. The end-to-end performance is assessed, in Intra-Network Mobile-To-Mobile setting, the “call” being the basic testing unit.

Test calls are made between mobile terminal equipment (User Equipment - UE). One of the UE moves along the studied route/location and the other UE remains static in a location with proper (good) radio coverage, minimum interference and high probability of access to the service[2].

To allow the alternating start of test calls, which takes place automatically between the two involved terminal, test sessions use a fixed time frame for making each call. In case of a call failure, either at the call making phase or during the conversation phase, the next call starts only at the next time frame.

The time frame covers, in addition to the call duration itself, also the time periods to make and end the call, as well as a pause of not less than 30 seconds between consecutive calls, to prevent any network constraints related to signalling or mobility management.

After the test call is started, a conversation is simulated for about 150 seconds to analyse the integrity of the communication. The audio quality is alternatively analysed in each direction, regardless of the end that started the call, using the POLQA algorithm [ITU-T P.863, ITU-T P.863.1].

Test parameters used to analyse the voice service present the following values:

- Relationship for starting calls between UE: 1/1
- Test call duration: 150 s
- Test call time frame: 200 s
- Maximum call set up time: 20 s

5.4 SMS – SHORT MESSAGE SERVICE

The end-to-end performance of the service is assessed, the message transfer being the basic testing unit.

Tests are carried out in Intra-Network Mobile-To-Mobile setting, messages being originated and terminated in separate equipment. That is, each test uses two terminal equipment: the originator and the receiver devices. Both these devices are in motion in the same location.

Another important aspect that guarantees the reliability of tests is to prevent the mobile terminal from being disrupted by a message while the former is received. As such, an appropriate interval must take place between consecutive message sending.

[2] The static UE is placed in ANACOM's premises at Barcarena.

For feasibility purposes, a time frame for the delivery of messages is defined. Messages delivered outside the time frame are considered to be failed attempts. Corrupted messages (at least one-bit error) are also considered to be failed attempts. Duplicate received messages is not accounted for delivery ratio purposes.

Each test message is associated to a unique identifier to make its identification easier at reception and to avoid ambiguity concerning the co-relation between sent and received messages. Received messages deemed to be invalid (which have not been sent by the originator terminal or which are not part of the test session) are discarded.

Mobile terminal equipment that is used shows no limitations in terms of capacity for processing or storing information that could affect message sending or reception.

The test message used to analyse the SMS service is 120 characters long and uses different symbols to better check content integrity.

Taking into account conditions defined above, test parameters for the SMS message service present the following values:

- Test message size: 120 characters
- Test message character sequence: `The quick brown fox jumps over the lazy dog. 1234567890 aeiou QUICK BROWN FOX`
- Maximum time for SMS delivery: 20 s
- Pause time between consecutive SMS sending: 60 s
- SMS delivery time frame: 30 s

5.5 DATA SERVICES

5.5.1 TEST SEQUENCE

To assess the performance of these services, data sessions are established, in packet-switched operation mode, between user equipment - *Smartphones* - and Internet *Content Servers*. These sessions are always started by *Smartphones*.

Tests are carried out according to the following sequence:

1. File transfer (HTTP download);
2. Checking data transfer latency (Ping);
3. File transfer (HTTP upload);
4. Internet browsing – reference webpage (HTTP web browsing);
5. Internet browsing – public webpage (HTTP web browsing);
6. Video streaming (YouTube).

Login and server authentication procedures are not considered to be part of service tests. Appropriate access privileges are ensured; it is also guaranteed that files, webpages and videos are available at the respective servers.

After a test sequence, and even in situations where an irrecoverable cycle completion occurred, all connections to the test server are shut down, the cache memory is cleared and a pause is made before a new sequence of tests is performed.

The test platform shows no storage space limitation and all hardware and software elements are common in the various tests to the different operators, namely:

- Operating system (type and version) and respective settings;
- Size of MTU (Maximum Transmission Unit);
- Location of test-dedicated servers;
- Type and version of the browser users, and respective settings (HTTP Web browsing tests);
- Size and type of files and reference webpage used for test purposes.

Dedicated Servers are hosted in a “neutral” location that is “equidistant” from the various operators under analysis. The best option in Portugal is to host Test Servers at an FCT (Fundação para a Ciência e a Tecnologia, I.P. - Foundation for Science and Technology) datacentre, connected to the Internet through a neutral traffic exchange point, namely GigaPIX (Portuguese IP network traffic exchange point) [GigaPIX]. These servers operate just like servers available on the Internet and are exclusively dedicated to testing, with no limitations in terms of capacity for processing or storing information, access availability and bandwidth.

These tests with dedicated servers, hosted in a “neutral” location that is “equidistant” from the various operators, make it possible to know the intrinsic performance of infrastructures of each operator and its impact on the performance of services provided to customers.

In addition, tests with public servers, that host the contents most searched by Portuguese internet users (web pages and YouTube video clips), provide information on the impact of each operator's infrastructures on the access by the respective customers to these contents.

Taking into account the preceding considerations, general and specific parameters for each type of service, that allow the feasibility of tests and the comparability of results, were defined. General test parameters are as follows:

- Pause time between test sequences: 20 s
- Pause time between tests in the same sequence: 10 s

5.5.2 FILE TRANSFER (HTTP)

File transfer tests (HTTP upload/download) are carried out according to the concept of *fixed data transfer time*, that is, data is transferred during a predefined period of time instead of the full file transfer of a fixed size.

A *Dedicated Server* and stable contents are used, that is, there is no quantitative and qualitative variations. Test files are of a binary type, made up of random bit sequences, which cannot be thus compressed, and have a (virtually) infinite size.

Specific parameters for the analysis of the file transfer service (HTTP upload/download) are as follows:

- Dedicated Server location: GigaPIX
- Data transfer period of time: 30 s
- Maximum session set up time: 30 s

5.5.3 INTERNET BROWSING (*HTTP WEB BROWSING*)

To assess this service, two webpages from two servers with different contents are downloaded:

i. ***Kepler*** – reference webpage developed by ETSI [ETSI TR 102 505], hosted at the *Dedicated Server*;

ii. ***Public webpage*** – most accessed webpage[3] (webpage with the most views) by Portuguese-speaking Internet users, according to the Marktest's Ranking Netscope [Netscope], hosted at a *Public Server*.

The reference webpage is made up of a mix of text and images, and does not include dynamic content.

Parameters for the analysis of the Internet browsing service (HTTP web browsing) are as follows:

- Reference webpage used: *Kepler*
- Reference webpage size*:* 800.000 Bytes
- Dedicated Server location: GigaPIX
- Public webpage: *to be determined*
- Maximum webpage transfer time: 30 s
- Maximum session set up time: 30 s

5.5.4 *YOUTUBE VIDEO STREAMING*

The performance analysis of the YouTube Video Streaming service, in a given location, includes the abilities to set up and complete sessions, as well as the integrity of the communication.

Videos of the YouTube portal with a 30 second duration are downloaded, using Smartphones.

One of the public videos most viewed[4] by Portuguese internet users, according to the YouTube portal[5], is used.

The visual quality of received contents is estimated through the algorithm defined by ITU in its Recommendation J.343 [ITU-T J.343, ITU-T J.343.1].

Test parameters used to analyse this video streaming service present the following values:

- Contents: *to be defined*
- Content duration: 30 s
- Application for content reproduction: *player* installed on the Smartphone

[3] At the start date of a study.

[4] At the start date of a study.

[5] https://www.youtube.com/feed/trending

- Minimum threshold for an interruption: 120 ms
- Maximum session set up time: 30 s
- Maximum session duration: 45 s

5.5.5 DATA TRANSFER LATENCY

Tests to Data Transfer Latency are carried out using the ping (ICMP echo) tool.

A *Dedicated Server* is used and a sequence of 12 tests is conducted, end results (maximum and minimum) obtained for the purpose of calculation of this indicator being disregarded.

Specific test parameters are as follows:

- Data packet size: 32 Bytes
- Number of requests: 12
- Pause time between requests: 10 ms
- ICMP echo timeout: 2 s
- Dedicated Server location: GigaPIX

In order to bring results obtained with this test even closer to the reality faced by users of mobile services, the use of a service is simulated immediately before the test itself is conducted. For this purpose, a sequence of 10 ping is sent, with the following settings:

- Data packet size: 800 Bytes
- Number of requests: 10
- Pause time between requests: 50 ms
- ICMP echo timeout: 2 s
- Dedicated Server location: GigaPIX

Results obtained with this sequence are not considered in the calculation of latency.

6 INDICATORS OF QUALITY OF SERVICE

This section defines quality indicators that characterize the performance of services supported on mobile communication systems in their various phases of access and use[6].

6.1 RADIO COVERAGE

6.1.1 RADIO NETWORK AVAILABILITY

Network availability is the probability that mobile services are available to a user, via a radio infrastructure (network radio coverage).

$$Radio\ Network\ Availability\ [\%] = \frac{\sum Measurements\ with\ Available\ Mobile\ Services}{\sum Measurements\ Conducted} \times 100$$

(6.1.1)

Mobile services are considered to be available when radio signal levels show values above the minimum thresholds that allow their use. These thresholds may be adjusted by mobile operators and usually present different values for GSM, UMTS and LTE.

As appropriate measurement equipment - RF Scanner -, combined with a geo-referencing system makes it possible to obtain coverage levels of mobile networks on the routes under study.

Table 2 –GSM, UMTS and LTE Coverage Levels

Coverage	GSM	UMTS	LTE
Very good	$-75\ \text{dBm} \leq$ RxLev	$-85\ \text{dBm} \leq$ CPICH RSCP	$-95\ \text{dBm} \leq$ RSRP
Good	$-85\ \text{dBm} \leq$ RxLev $< -75\ \text{dBm}$	$-95\ \text{dBm} \leq$ CPICH RSCP $< -85\ \text{dBm}$	$-105\ \text{dBm} \leq$ RSRP $< -95\ \text{dBm}$
Acceptable	$-95\ \text{dBm} \leq$ RxLev $< -85\ \text{dBm}$	$-105\ \text{dBm} \leq$ CPICH RSCP $< -95\ \text{dBm}$	$-115\ \text{dBm} \leq$ RSRP $< -105\ \text{dBm}$
Poor	$-105\ \text{dBm} \leq$ RxLev $< -95\ \text{dBm}$	$-115\ \text{dBm} \leq$ CPICH RSCP $< -105\ \text{dBm}$	$-125\ \text{dBm} \leq$ RSRP $< -115\ \text{dBm}$
Non-existent	RxLev $< -105\ \text{dBm}$	CPICH RSCP $< -115\ \text{dBm}$	RSRP $< -125\ \text{dBm}$

[6] These *Service Quality Indicators* are based on the following technical specifications: ETSI TS 102 250, namely part 2, ETSI TR 101 578, ETSI TR 102 678, ETSI TR 102 505, ETSI TR 102 581, ETSI EG 202 057, namely parts 3 and 4, ETSI TS 100 910, ETSI TS 143 022, ETSI TS 145 008, ETSI TS 125 304, ETSI TS 136 304, ETSI TS 136 133; on the following recommendations ITU-T P.863, ITU-T P.863.1, ITU-T J.343, ITU-T J.343.1, ITU-T P.910 and ITU-T Q.3960; and on the following reports ECC Report 256 and ECC Report 103 [ETSI TS 102 250-2, ETSI TR 101 578, ETSI TR 102 678, ETSI TR 102 505, ETSI TR 102 581, ETSI EG 202 057-3, ETSI EG 202 057-4, ETSI TS 100 910, ETSI TS 143 022, ETSI TS 145 008, ETSI TS 125 304, ETSI TS 136 304, ETSI TS 136 133, ITU-T P.863, ITU-T P.863.1, ITU-T J.343, ITU-T J.343.1, ITU-T P.910, ITU-T Q.3960, ECC Report 256, ECC Report 103].

6.2 VOICE SERVICE

6.2.1 ACCESSIBILITY OF THE VOICE SERVICE

Service accessibility is the probability that the end-user can access the voice service, that is, the probability of being successful when making calls.

A call is considered to be "Set Up with Success" if it reaches the called terminal (a "call signal" is heard on the caller terminal).

$$Service\ accessibility\ [\%] = \frac{\sum Sucessfully\ Set\ Up\ Calls}{\sum Attempts\ to\ Set\ Up\ Calls} \times 100$$

(6.2.1)

6.2.2 VOICE CALL SET UP TIME

Call set up time is the period of time elapsing from the sending of a complete destination address (target telephone number) to the setting up of a call.

$$Call\ Set\ up\ time\ [s] = t_{calling\ signal} - t_{address\ sending}$$

$t_{address\ sending}$ – moment when the user presses the send button.
$t_{calling\ signal}$ – moment when the call is successfully set up (one hears the "call signal" on the caller terminal).

(6.2.2)

6.2.3 VOICE CALL COMPLETION RATE

The voice call completion rate is the probability that a call has, after being successfully set up, to be maintained during a period of time, ending normally, that is, according to the user's will.

$$Call\ Completion\ Rate\ [\%] = \frac{\sum Normally\ ended\ calls}{\sum Sucessfully\ Set\ Up\ Calls} \times 100$$

(6.2.3)

6.2.4 VOICE CALL AUDIO QUALITY

This indicator quantifies the perceptibility of the conversation during a voice call. Both communication directions are assessed and only calls ending normally are considered.

The assessment of this QoS indicator consists in the comparison between the original audio sample that is sent, *X(t),* and the corresponding received degraded sample, *Y(t)*, on the other end of the call, by applying the POLQA algorithm[7]. The objective audio quality index obtained through this algorithm is close to what would be obtained if sample *Y(t)* were submitted to the subjective appreciation of a panel of service users.

$$Call\ Audio\ Quality_{side\ A}\ [MOS_{LQO}] = f\{X_B(t)\ ;\ Y_A(t)\}$$

$$Call\ Audio\ Quality_{side\ B}\ [MOS_{LQO}] = f\{X_A(t)\ ;\ Y_B(t)\}$$

side A; side B – designation of both ends of a voice call.
MOS_{LQO} – scale that measures the perceived audio quality (Mean Opinion Score – Listening-only Quality Objective).
f – function corresponding to the application of a calculation algorithm and conversion function of results in MOS_{LQO} values.
$X_A(t); X_B(t)$ – original audio sample sent by side A (B).
$Y_A(t); Y_B(t)$ – – degraded audio sample received by side A (B), resulting from the transmission of the original sample $X_B(t)$ $(X_A(t))$.

(6.2.4)

Results obtained by the application of the algorithm are shown on a MOS (Mean Opinion Score) type scale ranging from 1 to 5 called MOS_LQO (Mean Opinion Score – Listening-only Quality Objective), such as shown on *Table 3*. The MOS scale quantifies the effort that it takes to perceive a communication.

Table 3 - MOS_{LQO} Scale

MOS	Quality
5	Excellent
4	Good
3	Acceptable
2	Poor
1	Bad

In situations where each direction of the same call sends and receives several ("*n*") audio samples $\{X_1(t), X_2(t), \ldots, X_n(t); Y_1(t), Y_2(t), \ldots, Y_n(t)\}$, the Call Audio Quality indicator is calculated through the arithmetic average of values obtained by applying the formula shown above to each pair of audio samples, that is:

[7] POLQA – *Perceptual Objective Listening Quality Assessment* [ITU-T P.863, ITU-T P.863.1].

$$Call\ Audio\ Quality_{side\ A}\ [MOS_{LQO}] = \frac{\sum_{i=1}^{n} f\{X_{i_B}(t)\ ;\ Y_{i_A}(t)\}}{n}$$

$$Call\ Audio\ Quality_{side\ B}\ [MOS_{LQO}] = \frac{\sum_{i=1}^{n} f\{X_{i_A}(t)\ ;\ Y_{i_B}(t)\}}{n}$$

(6.2.5)

6.3 SMS – Short Message Service

6.3.1 Accessibility of the SMS Service

Service accessibility is the probability that the user can access the Short Message Service, that is, the probability of being successful when sending SMS.

$$Accessibilityof\ the\ SMS\ Service\ [\%] = \frac{\sum Successfully\ Sent\ SMS}{\sum Attempts\ to\ Send\ SMS} \times 100$$

(6.3.1)

6.3.2 SMS Delivery Time

The SMS delivery time corresponds to the time between the beginning of the sending of the message to a Short Message Centre (SMSC) and the end of its reception at the destination terminal equipment.

$$SMS\ Delivery\ Time\ [s] = t_{end\_reception} - t_{start\_sending}$$

$t_{start\_sending}$ – moment when the user starts sending the SMS.

$t_{end\_reception}$ – moment when the destination terminal equipment ends reception of the SMS sent by the origination terminal equipment

(6.3.2)

Corrupted messages, messages delivered outside the predefined time frame and duplicate received messages are not taken into consideration in the calculation of this indicator. An SMS is considered to be corrupted where there is at least one-bit error.

6.3.3 SMS Delivery Rate

The SMS delivery rate is the probability that the message is delivered successfully to the destination, that is, the ratio between the number of SMS received successfully by the destination terminal equipment and the number of SMS sent by the origination terminal equipment.

$$SMS\ delivery\ rate\ [\%] = \frac{\sum Successfully\ Received\ SMS}{\sum Attempts\ to\ Send\ SMS} \times 100$$

(6.3.3)

Corrupted messages or messages delivered outside the predefined time frame are considered to have failed for the purpose of the calculation of this indicator. An SMS is considered to be corrupted where there is at least one-bit error.

Duplicate received messages are not accounted for in this indicator.

6.4 DATA SERVICES

6.4.1 COMPLETED DATA SESSION RATE (*HTTP, HTTP WEB BROWSING AND YOUTUBE VIDEO STREAMING*)

Probability that a data session (File Transfer - HTTP upload/download –, Internet browsing – HTTP web browsing – or YouTube Video Streaming) is set up and takes place successfully, that is, where it remains active during the full period of time predefined for the file transfer (HTTP upload/download), where it allows the full transfer of the webpage (HTTP web browsing) or where it allows the transfer and full playout of multimedia content (YouTube Video Streaming).

$$Completed\ Data\ Session\ Ratio\ [\%] = \frac{\sum Successfully\ Completed\ Sessions}{\sum Attempts\ to\ Set\ Up\ Sessions} \times 100$$

(6.4.1)

6.4.2 DATA TRANSFER RATE (*HTTP*)

This indicator quantifies the average data transfer rate during a File Transfer session (HTTP upload/download).

This indicator only takes account of successfully completed sessions (sessions that remained active during the full period of time predefined to transfer the file).

$$Data\ Transfer\ Rate\ [kbps] = \frac{Volume\ of\ Data\ Sent\ or\ Received\ [kbit]}{Sending\ or\ Reception\ Time\ [s]}$$

$Sending\ or\ Reception\ Time$ – Predefined period of time required to send or receive the information. Does not include the period of time required to set up data sessions (phases of packet switched network registration, PDP context activation (for GSM/UMTS) or Dedicated EPS Bearer Setup (for LTE) and remote server authentication).

(6.4.2)

6.4.3 WEBPAGE TRANSFER TIME (HTTP WEB BROWSING)

This indicator quantifies the average time required for the transfer of a webpage (reference page or another).

This indicator only takes account of successfully completed sessions (sessions that allowed the full transfer of the webpage).

$$Webpage\ Transfer\ Time\ [s] = t_{end\_reception} - t_{webpage\_request}$$

$T_{webpage\_request}$ – moment when the user equipment makes the webpage reception request.
$T_{end\_reception}$ – moment when the full webpage is received by the user equipment.

(6.4.3)

6.4.4 CONTENT DISPLAY DELAY (YOUTUBE VIDEO STREAMING)

The Content Display Delay within a YouTube Video Streaming session is the period of time between the request for multimedia contents (the user presses “play”) and the start of video playout (display of the first frame) in the terminal equipment of the user.

$$Content\ Display\ Delay\ [s] = t_{start\ of\ playout} - t_{content\ request}$$

$T_{content\ request}$ – moment when the user makes the request for contents.
$T_{start\ of\ playout}$ – moment when the playout of contents requested start in the user equipment.

(6.4.4)

6.4.5 FREEZE DURATION (YOUTUBE VIDEO STREAMING)

This indicator aggregates all interruptions or freezing events during a YouTube Video Streaming session that ends normally. Freezes are only considered where they are recognized by the user (where they exceed 120 ms [ETSI TR 101 578]).

$$Freeze\ Duration\ [s] = \sum_{i=0}^{n} (Freeze\ Duration)_i\ [s]$$

n – total number of freezes during a session

(6.4.5)

6.4.6 VIDEO QUALITY (YOUTUBE VIDEO STREAMING)

This indicator quantifies the visual quality of the communication during the YouTube Video Streaming session. Only sessions that are normally completed are considered.

The video quality is estimated through the algorithm defined by ITU in its Recommendation J.343.1 [ITU-T J.343.1]. This algorithm is based on a no-reference[8] model (Hybrid-NRe – hybrid no-reference encrypted), that is, the video quality is estimated via analysis of the received video, the video originally transmitted not being known.

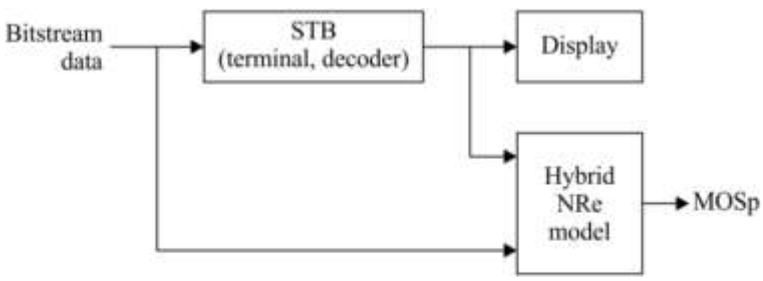

Figure 3 – Block-diagram of the Hybrid-NRe model [ITU-T J.343.1].

The Hybrid-NRe model measures the visual effect of spatial and temporal degradations as a result of video coding, erroneous transmission or video rescaling.

The visual quality estimated by this model is presented on a MOS (Mean Opinion Score) scale, ranging from 1 to 5, derived from the ACR (absolute category rating) scale defined by ITU in Recommendation

[8] The use of a “no-reference” model allows for tests with any public content available on YouTube to be conducted.

P.910 [ITU-T P910], presented in Table 4.

Table 4 - MOS Scale [ITU-T P.910]

MOS	Quality
5	Excellent
4	Good
3	Acceptable
2	Poor
1	Bad

6.4.7 VIDEO STREAMING RESOLUTION (YOUTUBE VIDEO STREAMING)

In a YouTube Video Streaming session, the YouTube allows the dynamic adjustment of the video resolution of transmitted contents, optimizing it to the available bandwidth and characteristics of the mobile terminal, and improving the viewing experience. Only sessions that are normally completed are considered.

$$Video\ streaming\ resolution\ [p] = \frac{\sum_{i=1}^{n}(Video\ clip\ resolution)_i\ [p]}{n}$$

n – total number of video clips that make up the contents received in the mobile terminal equipment

(6.4.6)

6.4.8 DATA TRANSFER LATENCY

This indicator quantifies the time required for an information packet to be delivered from the user equipment to the *Dedicated Server* or *vice-versa*. This delay corresponds to half the Round Trip Time (RTT) obtained by the Ping tool (ICMP echo).

$$Data\ Transfer\ Latency\ [ms] = \frac{Ping_{RTT}[ms]}{2}$$

(6.4.7)

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