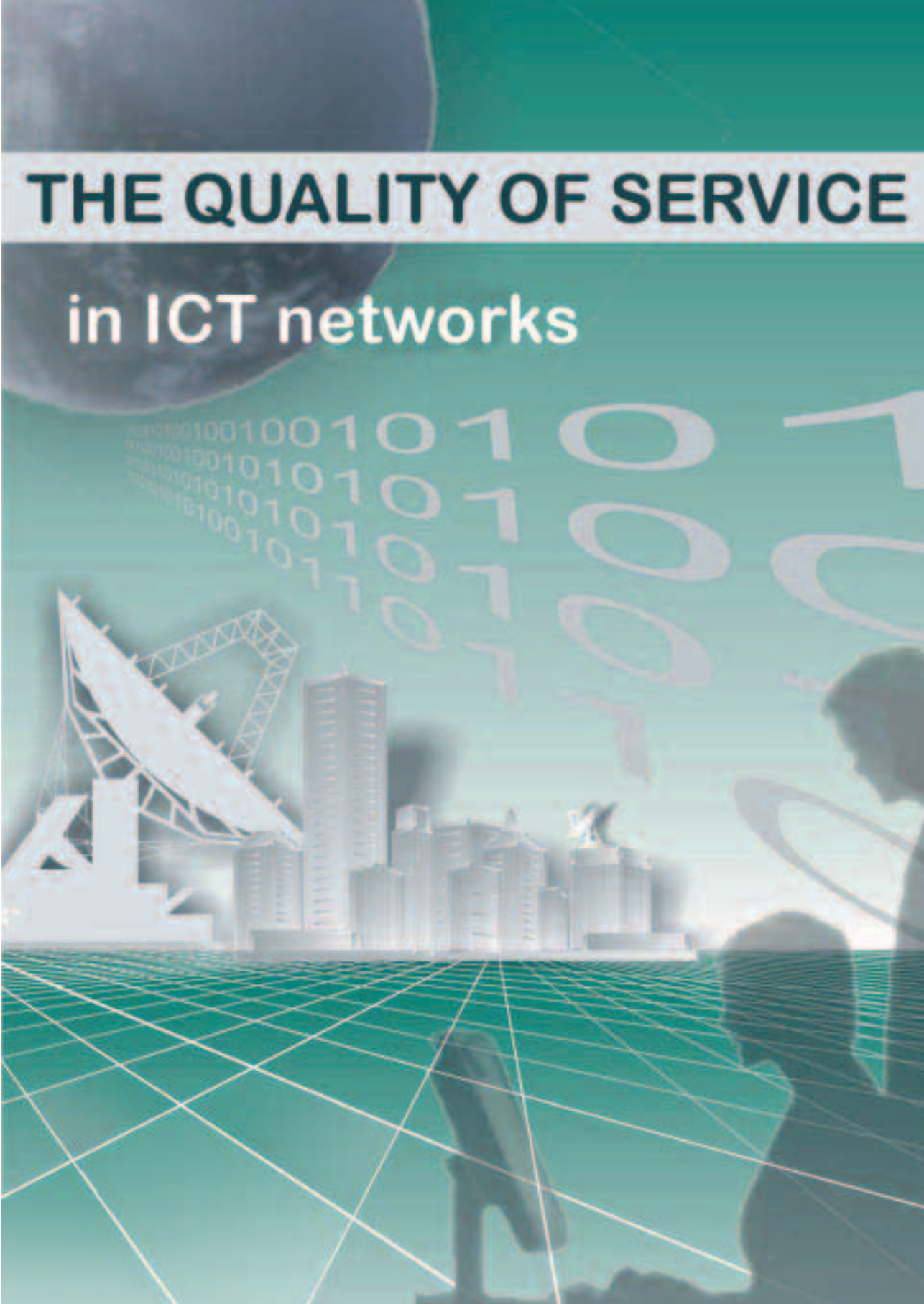
THE QUALITY OF SERVICE

in ICT networks



Istituto Superiore delle Comunicazioni
e delle Tecnologie dell'Informazione
Ministero delle Comunicazioni

The Quality of Service in ICT networks

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The contents of the present volume are to be considered merely as a technical/scientific study orientating to the problems inherent to the Quality of Service in ICT networks.
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1 - Preface

The present volume arises from an initiative by the Istituto Superiore delle Comunicazioni e delle Tecnologie dell'Informazione, with the collaboration of authors that belong to various public and private bodies.

The Istituto Superiore delle Comunicazioni e delle Tecnologie dell'Informazione, constituted in 1907, operates within the Ministry of Communications as a technical-scientific body. Its activities, which are specifically aimed at companies that operate in the ICT sector, to public administrations and users, mainly relates to the regulation, experimentation and basic and applied research, and to specialist training and instruction in the field of telecommunications.

The national and international technical regulations bear an important role to ensure greater transparency and access to services, in favour of users, producers and network providers, and within which the Institute is active and propositional.

In this field the Institute has a double action: through CONCIT (Coordinating committee with European recognition, and made up by CEI (Italian electronic committee), UNI (Italian national unification body and by the same Institute) conducts the transposition into the national regulations of European norms and, at the same time, represents the Administration in addressing and supporting national groups within the various technical commissions and study groups of the ITU (International Communications Union), of the CEPT (Conférence Européenne des Postes et des Télécommunications) and of ETSI (European Telecommunications Standard Institute).

The Institute manages the Scuola Superiore di Specializzazione in Telecomunicazioni (active since 1923), which manages the post-graduate specialisation in the field of electronic communication and information technologies, and releases the related diploma. In agreement with the faculty of Engineering of the Rome

Sapienza University, the School organises yearly courses the curricula of which include laboratory work, seminars and stages.

The Institute also provides upgrade training for Ministry and other public administration personnel in the field of electronic communication and information technologies, security, multimedia and Quality of Service, by planning and realising training aimed at acquiring specialist know-how. In this view the Institute has set up a Test Centre, credited with AICA for the issuing of European Computer Driving Licence – ECDL.

Moreover, the Centre for the training of PA personnel in the field of ICT security is currently being constituted.

The training Centre will implement large scale training and sensitisation activities for PA employees on matters concerning ICT security, through the centralised and coordinated preparation of a Training and Sensitisation Plan that will spread the principles and methods of security throughout the Public Administration.

Moreover, the Institute promotes divulging activities through external communication events and publicises the activities and research conducted.

The Institute's research activities are oriented to the development and improvement of telecommunication services and of those connected to information technologies. In pursuing these aims, activities cover all the areas in the sector, from telephone to television, from signal processing and computation, from network architecture to services implementation.

In view of the know-how and instrumental resources it has available, the role of the Institute is relevant in taking part in European projects for technological development for a more diffuse employment of European funding. These activities are both directly conducted and through agreements with other Research Bodies, Universities and International Study Centres.

Within the Information Society context, the actions being

conducted in collaboration with the Fondazione Ugo Bordoni (FUB) in the fields of telework, informatics security, remote-teaching and access to communication services for the aged and disabled.

Thanks to the Institute's support, in the last years, the Ministry has also been able to support a series of initiatives for the introduction, on communication networks, of new technologies and new systems. Among these, we should highlight the feasibility studies for the application of techniques and new television and multimedia services, the feasibility study for the macro-regional provisioning of digital satellite television services, the study for a European satellite system for the provisioning of broadband multimedia and interactive services, and the participation in the IST (Information Society Technologies) research and technological development project of the European Community called ATLAS.

Considering its role as an impartial public body, the added value of the Institute, in terms of guarantee and competence, is the aspect that distinguishes the technical support and counselling services provided to companies and subjects involved in the telecommunications sector. These services are made substantial not only by the traditional certification activities, realised thanks to the competence and instruments of the Institute's laboratories that allow to verify the compliance of all telematic systems to the various norms and reference recommendations, but also with specialist measurement campaigns for verifying the Quality of Service (QoS), of network security and for assessing the specific techniques of inter-operativeness of services within the scope of inter-connection of the networks of various operators.

The Institute manages the data bank relative to the numerical assignment of the national telecommunication network and the portability of numbers in GSM and UMTS technology, moreover, it manages the National Reference Clock (ONR) for the synchronisation of the Italian Numerical Telecommunications Network and provides an institutional support to those taking part in tender bids for the E-TEN (Trans European Network for TLC). The Institute collaborates with Certification Bodies for activities of verification and control of

Company Quality Systems in compliance with the UNI EN ISO 9000 rules, and is committed in control activities on Credited Laboratories on the basis of the UNI CEI EN ISO/IEC 17025 rules and is a Registered Body for activities conducted on the basis of the Law Decree n° 269 of the 9th May 2001. The Institute has the role of Certification Body for systems and commercial informatics products security (OCSI) and is an evaluation centre (Ce.Va.) of ICT systems and products that process classified data. Moreover, it is a Registered Body in compliance with the Directive concerning radio devices and terminal equipment for telecommunications and is Competent Body and Registered Body relatively to electromagnetic compatibility. In 2002 it became international Certification Body on behalf of TETRA MoU.

The present volume falls within the scope of activities conducted by the Communications Ministry during 2004 related to the realisation of guidelines for:

- Network security – risk analysis and protection strategies
- Network security in critical infrastructures
- Quality of Service in ICT networks

The present volume is aimed at operators and end users of communication networks, both home and business. The Quality of Service topic is dealt with starting from the principle that quality is an essential aspect in characterising products and services of any kind.

Users are used to understanding the parameters and evaluation of vehicles rather than washing-machines, though not technicians nor intending to become so. This knowledge is part of their cultural background and is used in making market choices along with an assessment of pricing. In fact, the perception of product and service prices is "naturally" experienced not as an absolute value, but as a cost/performance ratio.

The same mechanism can be featured with electronic communication. However, in this sector users are less used to immediately grasping which quality parameters characterise the products they require and above all, how they can understand their possible measurement.

The volume deals with two networks commonly used (GSM and ADSL) and develops a treatise of the quality of service parameters that characterise them for the end user. We have attempted to apply a scale of "importance" to these parameters (which are essential, and which are "optional") and to identify the measurement procedures according to international standards. It is a first step towards a more ample treatise that in the future may also deal with all the other existing technologies.

We want to thank those who, with enthusiasm and professionalism, have contributed to the writing of the present document: Andrea Alloisio (MARCONI COMMUNICATIONS Spa), Franco Arzano (SIELTE Spa), Daniele Biondini (Istituto Superiore delle Comunicazioni e delle Tecnologie dell'Informazione), Francesco Chirichigno (INFRATEL Italia Spa), Francesco Console (CISCO SYSTEMS ITALY Srl), Giovanni De Guzzis (ERICSSON TELECOMUNICAZIONI Spa), Francesco Giuffrè (ANIE ICT - CE), Marco Morchio (ACCENTURE Spa), Alessandro Pastore (SIEMENS Spa), Gianfranco Pensili (Istituto Superiore delle Comunicazioni e delle Tecnologie dell'Informazione), Pietro Andrea Polese (ALCATEL ITALIA Spa), Francesco Quaglia (SIEMENS Spa), Antonio Sfameli (ERICSSON TELECOMUNICAZIONI Spa), Andrea Tarantini (ITALTEL Spa), Luca Zanetta (SIRTI Spa).

Rome, March 2005

Luisa Franchina, PhD
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2 - Introduction and reading guide

In compliance with the ITU E.800 recommendation, the Quality of Service (QoS) is defined as "The overall effect of service performances that determine the degree of satisfaction expected by the users of the service".

From the viewpoint of telecommunications networks the quality of service represents the ability of the network in ensuring a given level of service.

The purpose of this document is to illustrate how the end users can assess the real quality expected from a certain type of service.

End users should, in fact, be afforded the conditions to assess if the type of service and network infrastructure responds to their quality requirements.

The model developed as follows proposes the tools with which the service providers can offer users objective information related to the performances offered by the network (e.g. real download speed available to end users). In this way, the end users and operators will have the opportunity to assess the technical performances that are present on the market.

The document continues in identifying the main parameters for the definition and detection of the quality of service with special reference to broadband in line with the principles contained in the Code for Electronic Communications (law decree 259/03).

For greater clarity and ease in reading, the text concentrates the more significant information for the end users in the present chapter, in the next chapter 3 and in chapter 8, while the remaining chapters are dedicated to the description and identification of the technical tools required to achieve the objectives that follow.

More precisely the document features the following pattern:

1. Preface

2. Introduction and reading guide

3. Application and use of the quality measurement method

In this chapter we demonstrate how it is possible to determine the indicators of quality that can orient and make users more conscious of the Quality of Service acquired.

4. Logical reference model

This chapter defines a logical reference model to conduct the surveys required to identify the quality perceived by users.

5. Definition of the Quality of Service parameters

This chapter identifies the main parameters that define the quality of service for a network.

6 Classes of services

This chapter defines the classes of services to be considered in the definition and detection of the quality of service to the end users.

7. Access technologies

This chapter defines the value of the parameters as per chapter 5 with reference to ADSL and GSM technologies.

8. Identification of "expected" classes of quality

This chapter defines the algorithm for the detection of the quality of a network with reference to the service offered.

9. Guidelines for the parameters measurement

This chapter defines the methods and tools with which to measure the quantitative and/or qualitative values of some of the technological parameters to be measured (for the various classes of services and for the ADSL and GSM technologies) in order to assess the quality of a network.

10. Final considerations

11. Acronyms and abbreviations

12. References

3 - Application and use of the quality measurement method

The end users are, nowadays, confronted with an offer of a growing number of services (that result from the convergence of the communications, contents, and applications).

What follows demonstrates that it is possible to determine quality indicators that can orient and make users more conscious of the Quality of Service acquired.

3.1 How to achieve the determination of quality parameter

In order to achieve the determination of an indicator that synthesises the assessment of the quality of a service and that can be fully used as reference for the users, four main points have been identified.

- In the first point the users associate the service, which they intend using, to one of the following four categories (see table 6.1):

  1. Real-time services
  2. Time-Deferred Broadcast services
  3. Interactive services
  4. Other Time-Deferred services.

The definition of these four service categories allows to univocally classifying all types of services, current and future, and is not linked to the technological platform that supports the service.

- In the second point the users choose the technology they are referring to (in this first edition we have analysed the ADSL and GSM technologies).

- In the third point the users identify the importance of the parameters for the type of service, as per point 1, according to the classifications shown in tables 6.2 and 6.3 (the classifications shown in the present volume are purely reference examples).
- In the fourth point, the users proceed to identify the values of the technical parameters of quality of service on the basis of table 7.1 and 7.2 (excellent, good, acceptable) and conduct the measurements of the same or else employs measurements made by third parties. On the basis of these measurements, or of the offers received, they conduct a comparison with the expected values as per tables 7.1 and 7.2 (in this publication the values shown are purely a reference example) and, hence, determine the overall quality index of the product examined on the basis of table 8.1.

The following paragraphs illustrate some examples of the use of this method.

3.2 Use of the abovementioned method: e.g. on-line games

Mr. Giovanni has bought a console with a built-in ADSL modem that allows to interactively playing games, without the need of other real-time services (no video-communication functions) with other on-line competitors.

Mr. Giovanni must now proceed by buying a broadband connection for his home. Following information gathered he has offers for four types of ADSL connection.

Mr. Giovanni knows that interactive and non real time on-line gaming is among the classes of interactive services offered. For this kind of service, the manufacturer of the console has defined an optimal user mask (see chapter 8) that requires at least:

Real time services: 3 points

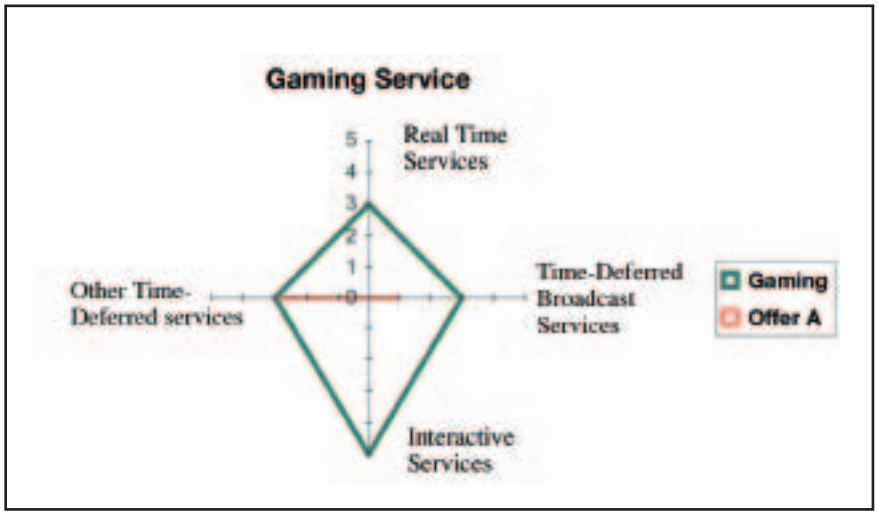
Time-Deferred Broadcast services: 3 points

Interactive services: 5 points

Other Time-Deferred services: 3 points

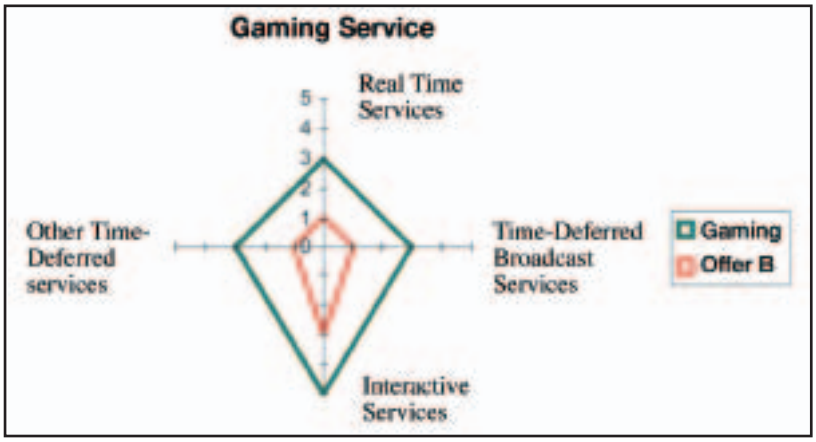
In order to make Mr. Giovanni's choice easier, we have a diagram that compares the technical quality required by the service (green) and the quality of the ADSL connection (red) shown in the offers he has received.

offer A: *k* euro/month Real time services: 0 points; Time-Deferred Broadcast services: 1 point; Interactive services: 0 points; Other Time-Deferred services: 3 points.

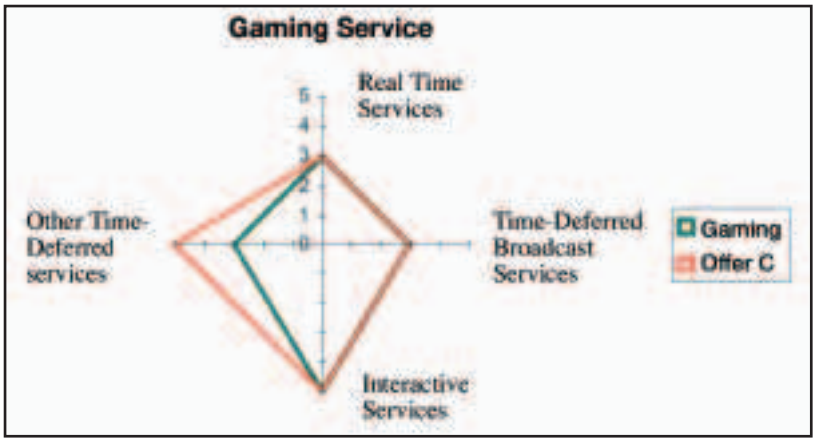


offer B: *w* euro/month Real time services: 1 point; Time-Deferred Broadcast services: 1 point; Interactive services: 3 points; Other Time-Deferred services: 1 point

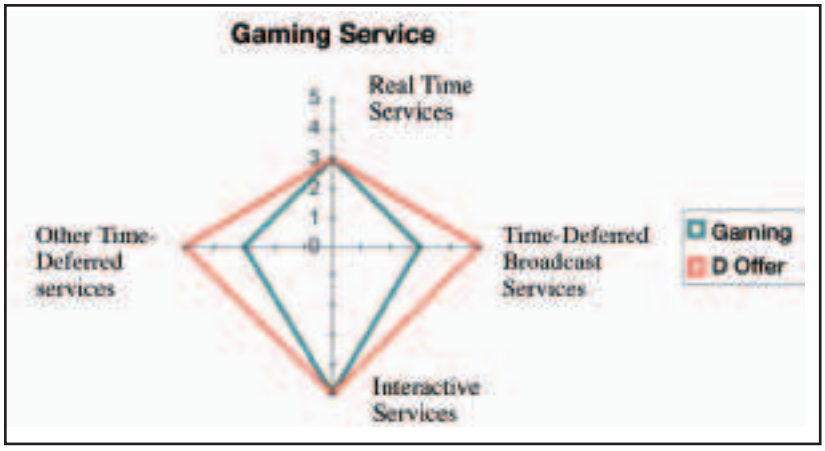
offer C: *y* euro/month Real time services: 3 points; Differed time



diffusion services: 3 points; Interactive services: 5 points; Other differed time services: 5 points



offer D: *x* euro/month Real time services: 3 points; Time-Deferred Broadcast services: 5 points; Interactive services: 5 points; Other Time-Deferred services: 5

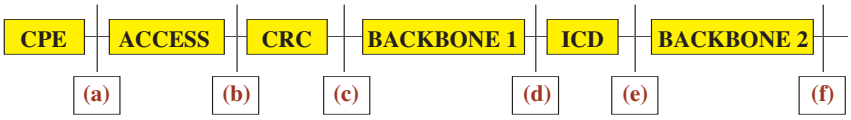


Applying the above method, because Mr. Giovanni will mainly be using the gaming on-line service – that falls under the interactive non real-time services (with no video-communication functions) – he will focus on offers C and D which should satisfy his requirements.

4 - Logical reference model

This chapter defines a logic reference model in order to conduct the necessary surveys to identify the quality perceived by users.

The Logic Reference Model shown in Fig. 4.1 has been defined so as to perform the measurements that determine the quality of services, as perceived by users.



ADSL Case:

CPE: user terminal (modem/router)
Access: includes metropolitan and backbone access sections
CRC: Control and Routing Centre (includes BRAS)
Backbone 1: includes the backbone link from CRC to IDC (national level)
IDC: Inter-Domain Centre
Backbone 2: includes the backbone link from IDC and the corresponding foreign Centre

GSM Case :

CPE: mobile terminals
Access: includes radio access and BTS
CRC: MSC
Backbone 1: includes the backbone link from CRC to IDC (national level)
IDC: Transit Exchange Centre (TEX)
Backbone 2: includes the backbone link from IDC and the corresponding foreign Centre

Figure 4.1 - Logic reference model

This model allows the mapping of the telecommunications network functions implemented by different subjects (e.g. network operators, service providers, content providers) identifying measurement points and the necessary parameters for the Quality of Service definition.

This Logical Reference Model identifies the logic function blocks that make up the telecommunications infrastructure through

which Service Providers (SP) supply the services; the logic function blocks are separated by reference points (RP).

The users of services are connected to the infrastructure by the RPs (A) and possess terminals and user devices (CPE: Customer Premises Equipment) that implement the local functions required for receiving, local distribution, processing and use of the services.

Services Providers can provide the services as per Reference Point (C) or (E).

The RP (C) is downstream of the function block Control and Routing Centre (CRC) at which the service access ends.

In order to be able to consistently measure the quality of service for users at a national level (beyond the SPs considered) one must identify the RP (E) downstream from the function logic block of Inter-Domain Centre (IDC), at which the national interconnectivity ends and international connectivity is possible.

The Access Block Function includes all the functions required to connect the Service Providers with the Users, including the concentration multiplication functions, routing and transmission (e.g. metropolitan and possible long distance backbones).

The Quality of Service supplied by the Service Provider in question can be measured, in principle, between points (A) and (C) and between points (A) and (E). In the first case the measurement of the Quality of Service supplied by the SP is made directly from their service centres connected at RP level (C); in the second case the measurement is made on the access to services directly or indirectly offered by other national or international SPs through the first SP. In the case of SPs with various service centres or with diverse architectures, more than one RP may be identified (C) or (E) to be considered.

5 - Definition of Quality Service parameters

This chapter identifies the main parameters with which it is possible to measure the quality of a network in supplying one or more services.

The Quality of Service supplied by the providers of a telecommunications network is perceived by users as the composition of parameters that may be broken down into the following four macro-areas:

- Support: the ability of an organisation to assist users in employing a service.
- Availability: the possibility of a service to be employed on request and for its entire duration.
- Operativeness: use of the user interfaces and the ease of activation and use of the service and related applications.
- Security: the overall problems related to authentication, reliability and confidentiality of the information transmitted.

5.1 Support

The ability of an organisation in assisting a customer in the use of one or more services is assessed by measuring three processes:

- customer relationship management
- service management and provisioning
- taxation & invoicing.

The following paragraphs list and define the parameters to be measured for each of these processes.

5.1.1 Customer Relationship Management

The quality of Customer Relationship Management (CRM) can be measured with the following parameters.

Service time

The schedule of the CRM availability.

Response time

The time between the request for support service and the activation of the support service.

Waiting time

The time between the request for support service and the assumption of the problem.

Action time

The time between the opening of the ticket and the first diagnosis with forecast of recovery.

Recovery time

The time between the opening of the ticket and the recovery of service.

Service Availability

Percentage of availability versus the service schedule

Management of priorities

Acceptance of management queues with response times according to priorities

Tracking of user requests

Possibility of maintaining user requests history

5.1.2 Service Management and provisioning

The quality of the Management and Provisioning process is measured through the following parameters:

Error ratio in gathering user data

Probability of errors in acquiring user data

Transparency and tracking of contract and fee profiles

Ability of the service to recognise the chosen fee profile

Change of contract, user and fee profiles

Ability of the service in allowing the user to choose and apply new fee profiles

Error ratio in fee profiles

Probability of errors by user with reference to the fee and service plans subscribed.

5.1.3 Taxation & Invoicing

The quality of the taxation & invoicing process is measured through the following parameters.

Over-taxation ratio

The probability of taxing attempts to use the service or of taxing it wrongly

Under-taxation ratio

The probability of not taxing the use of the service in time (with the risk of later compensation)

Invoicing correctness ratio

Probability that the information in the invoice are correct with reference to the users data and to the services used and/or subscribed.

5.1.4 Availability

The ability to provide a service for its entire duration is assessed by measuring two processes:

- Access services
- Connection and service integrity

The following paragraphs list and define the parameters to be measured for each of these areas.

5.2 Access services

The quality of the process is measured by the following parameters:

Ratio of access to the service
Probability of access to the service when required by the users.

Delay in access to service
The time between the request for access to services (e.g. access to the Internet, to e-mail or to a video-on-demand portal) and the actual possibility of access.

Coverage Ratio
Probability of being covered by a network signal.

Upstream/Downstream average speed
Average speed (bit/s) provided by the network in order to use the service (relevant both for network access and service usage).

Average access delay
Delay time between the first attempt to call and the moment when the service is available to the user.

5.2.1 Connection and service integrity

The quality of the connection and service integrity is measured by the following parameters.

Call drop
The probability that a call/connection is interrupted against the users' intentions.

Session drop

The probability that a service, once obtained, can be interrupted against the users' intentions.

Continuity of the network connection and service (Jitter)

Maximum variation in the average delay of packages.

Transmission delay

The time that passes between the sending and receival of packages (half the round-trip delay).

5.3 Operativeness

The quality of the user interfaces are assessed through the measurement of two parameters:

- Service implementation
- User interface availability

The following paragraphs list and define the parameters for each of these processes.

5.3.1 Service implementation

The quality of service implementation is measured through the following parameters:

Implementation time

The time between the subscription of the contract and the availability of the service

Multilingual support

Availability of multilingual support

5.3.2 User interface availability

The quality of the user interface availability is measured through the following parameters.

Ratio of ambiguity of the required service
Probability of misunderstandings in invoking a service

Ratio of ambiguity in perception
Probability of misunderstanding in attempting to use the service

Ratio of abandonment of the service
Probability of involuntary interruption in attempting to use the service

5.4 Security

This is measured through two processes.

- Network security
- Service security

The following paragraphs list and define the parameters to be measured for each of these processes.

5.4.1 Network security

The quality of network security is measured through the following parameters.

Network authentication
Reliability offered by the network in univocally identifying the network provider

Access point vulnerability
Ability of the service provider in recognising external attacks, of any kind, to the network access equipment.

Integrity and confidentiality of information
Guarantees relative to the alteration and interception of sensitive data in accessing the network.

Ratio of non-rejection (at network level)

Probability of errors in the univocal tracking of the transaction in accessing the network

Routing Ratio

Probability of mistaken routing of the service

5.4.2 Service Security

The quality of service security is measured through the following parameters.

Service Authentication

Level of reliability offered by the organisation in univocally identifying the service provider.

Integrity and confidentiality of the information (service level)

Guarantee related to the alteration and interception of sensitive data in accessing the service.

Ratio of non-rejection (service level)

Probability of errors in the univocal tracking of the transaction in accessing the service

6 - Classes of service

This chapter defines the classes of service to be considered in the definition and detection of the quality of service for users. Further, four classes of service have been identified:

- Real time services
- Time-Deferred Broadcast services
- Interactive services
- Other Time-Deferred services

Any other current or future service, through the appropriate telecommunications network, may be associated, univocally, to these four classes of service. Table 6.1 shows the four classes of service with a list of the possible associated services:

Real time services	Diffusion services in differed time	Interactive services	Other differed time services
• Voice • Videophone • Interactive gaming with real time services • Bi-directional telemetry • Telnet	• Audio streaming • Video on demand • File transfer • Still imaging • Telemetry	• Voice messaging • Data • Internet browsing • On-line transactions (e-commerce) • E-mail with network servers • Interactive gaming with no real time services	- Fax - Low priority services (e.g. SMS) - E-mail - (server to server)

Table 6.1 - Examples of classes of service

Table 6.2 shows the degree of importance of the support parameters and their operativeness, as described in chapter 5. The numerical values of these parameters are independent from technologies and not a subject of the present publication.

			Real time services	Time-Deferred Broadcast services	Interactive services	Other Time-Deferred services
Support	CRM	Coverage time	★★★	★★★	★★★	★★★
		Response time	★★★	★★★	★★★	★★★
		Latency time	★★★	★★★	★★★	*
		Action time	★★★	★★★	★★★	★★
		Restore time	★★★	★★	★★★	★★
		Availability of the service	★★	★★	★★	★★
		Action ticket priority management	★★★	★★	★★★	★
		User requests tracking	★★★	★★★	★★★	★★★
	Provisioning	Error ratio in user data recording	★★★	★★	★★★	★
		Tracking and Transparency of the contract and of the fee profile	★	★	★	★
		Change of contract, of user data, and of fee profile	★★	★★	★★	★★
		Error ratio in fee profiling	★★★	★★★	★★★	★
	Charging & Biling	Over-taxation	★★★	★★★	★★★	★
		Under-taxation	★★★	★★★	★★★	★
		Integrity of billing data	★★	★★	★★	★★
Operativeness	Service Implementation	Activation times	★★★	★★	★★★	★★
		Multilingual support	★★★	★★	★★★	★
	User Interface Availability	Ambiguity of requested service	★★★	★★	★★★	★
		Ambiguity of perception	★★★	★★	★★★	★
		Abandonment of service	★★★	★★★	★★★	★

★ Scarcely important ★★★ Very important ★★ Important

Table 6.2 - Importance of parameters related to support and operativeness

Table 6.3 shows the degree of importance of availability and security parameters, as described in chapter 5. The numerical values associated to these parameters depend on the type of technology considered: examples of the values in the present publication are described in chapter 7 relatively to ADSL and GSM technologies.

		Real time services	Time-Deferred Broadcast services	Interactive services	Other Time-Deferred services
Availability	Access probability	★★★	★★★	★★★	★★★
	Delay time in service access	★★★	★★	★★	★
	Coverage	★★★	★★★	★★★	★★★
	Average speed (kbps)	★★★	★★	★★	★
	Average access delay (ms)	★★★	★★	★★	★
	Call drop	★★★	**n.a.**	**n.a.**	**n.a.**
	Session drop	★★★	★★★	★★	★★
	Jitter (ms)	★★★	★★★	★★★	★
	Transmission delay (ms)	★★★	★★	★	★
Security	Authentication	★★★	★★★	★★★	★★★
	Vulnerability of the access point	★★★	★★★	★★★	★★★
	Integrity and confidentiality of information	★★★	★★★	★★★	★★★
	Non rejection	★★★	★★★	★★★	★★★
	Routing	★★★	★★★	★★★	★★★

★ Less important ★★★ Very important
★★ Important n.a.: Not applicable

Table 6.3 - Importance of parameters relative to availability and security

7 - Access technologies

This chapter defines the quantitative threshold values, with reference to ADSL and GSM technologies, of the availability and security parameters to be quantified and measured for the assessment of the quality of a service included in a given class. In the further editions of the present publication we shall be considering other technologies available for access to fixed and mobile networks (e.g. FR/ATM; SDH, etc., UMTS, Wi-Max, etc.).

For each class of service, each parameter is associated to values, and, where possible, **three** values: the first identifies a judgement of "excellent", the second is "good", and the third is "satisfactory".

7. 1 ADSL technology

Table 7.1 shows the threshold values that the parameters measured must be higher than to be considered excellent (first lines), good (second lines) or satisfactory (third lines) with reference to ADSL technology.7.2 GSM technology

		Real time services	Time-Deferred Broadcast services	Interactive services	Other Time-Deferred services
Availability	Access probability	>99% >95% >80%	>99% >95% >80%	>99% >95% >80%	>99% >95% >80%
	Delay time in service access	<10s <30s <60s	<10s <30s <60s	<10s <30s <60s	<10s <30s <60s
	Coverage	n.a.	n.a.	n.a.	n.a.
	Average speed upstream/ downstream (Mbps)	10/10 2/2 1.2/1.2	2/10 1.2/10 0.64/1.2	2/10 0.64/2 0.056/0.64	2/10 0.64/2 0.056/0.64
	Average access delay (ms)	<= 30ms	<= 150ms	n.a	n.a
	Call drop	1/100000 1/10000 1/1000	1/10000 1/100 1/80	1/100000 1/10000 1/1000	1/10000 1/100 1/80
	Session drop	1/100000	1/100000 1/100 1/80	1/100000 1/100 1/80	1/100000 1/100 1/80
	Jitter (ms)	<50ms <100ms <150ms	<500ms <1s <10s	<50ms <100ms <150ms	<500ms <1s <10s
	Transmission delay (ms)	<100 ms <250 ms <400 ms	<500ms <1s <10s	< 1s	n.a
Security	Authentication	Username and password	Username and password	Username and password	Username and password
	Access point vulnerability	not acceptable	not acceptable	not acceptable	not acceptable
	Integrity and confidentiality of information	Encryption	Encryption	Encryption	Encryption
	Non rejection	1/100000 1/100 1/95	1/100000 1/100 1/95	1/100000 1/100 1/95	1/100000 1/100 1/95
	Routing	1/100000 1/100 1/95	1/100000 1/100 1/95	1/100000 1/100 1/95	1/100000 1/100 1/95

Table 7.1 - Values of the technical parameters for ADSL technology – n.a. = not applicable

7.2 GSM technology

Table 7.2 shows the threshold values that the parameters measured must be higher than to be considered excellent (first lines), good (second lines) or satisfactory (third lines) with reference to GSM technology.

		Real time services	Time-Deferred Broadcast services	Interactive services	Other Time-Deferred services
Availability	Access probability	0.98	n.a	n.a.	0.98
	Delay time in service access	2-10 s	n.a	n.a	5-20 s
	Coverage	98%	n.a.	n.a.	98%
	Average speed (kbps)	8-16 Kb/s	n.a.	n.a.	0-10Kb/s
	Average voice access delay (ms)	50 - 250 voce	n.a	n.a	1000-10000
	Call drop	2-3%	n.a	n.a	2-3%
	Session drop	2-5%	n.a.	n.a.	2-5%
	Jitter (ms)	< 50 ms < 100 ms < 150 ms	n.a.	n.a.	<500ms <1s <10s
	Transmission delay (ms)	< 400 ms	< 10 s	< 1s	n.a.
Security	Authentication	Si	n.a.	n.a.	Si
	Vulnerability of the access point	99%	n.a.	n.a.	99%
	Integrity and confidentiality of information	Encryption	n.a.	n.a.	Encryption
	Non rejection	1/100	n.a.	n.a.	1/100
	Routing	1/100	n.a.	n.a.	1/100

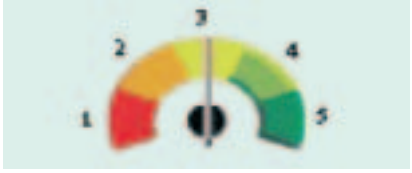
n.a = not applicable

Table 7.2 - Values of the technical parameters for GSM technology in peak traffic hours

8 - Identification of "expected" classes of quality

The present chapter identifies a method suited to provide a numerical and synthetic objective assessment of the quality of a service offered. The procedure takes into account the classes of service introduced in chapter 6 and the degree of importance (very important technical parameter identified with ***, important technical parameter identified with **, and scarcely important technical parameter identified with *). Moreover, the threshold values for the quality parameters introduced in chapter 7 (excellent, good, and satisfactory) are taken into account.

For each class of service an index between one point (satisfactory quality) and five points (excellent quality) is determined



according to the following table:

	Very important parameters	**Important parameters**	Less important parameters
Quality index 5	95% excellent 5% good	100% good	
Quality index 4	70% excellent 30% good	70% good 30% satisfactory	
Quality index 3	50% excellent 50% good	70% good 30% satisfactory	
Quality index 2	95% good 5% satisfactory	100% satisfactory	
Quality index 1	80% good 20% satisfactory	100% satisfactory	

Table 8.1 - Product quality indexes

Therefore, for example, an operator's offer will be assigned an index 5 (top) when 95% of the parameters considered very important, for the reference service chosen by the end user, have an "excellent" value according to table 7.1; 5% of the same parameters are at least "good, while 100% of the parameters considered important for that type of service are also "good".

9 - Guidelines for the parameters measurement

In performing measurements, one considers the network infrastructure described in chapter 4 structured as follows:

- Access network (fixed or mobile)
- Metropolitan network
- Backbone network

9.1 Monitoring tools of the service as perceived by ADSL network users

The quality of a network that employs ADSL technology may be monitored through appropriate investigation tools of the parameters shown in Tables 6.3 and 7.1.

With reference to the model in Figure 4.1, in order to perform the measurements, monitoring systems appropriately connected to the reference points (a), (b), (c), (d) and (e) and appropriate tools and procedures have to be defined as described in this paragraph.

Among the possible measurement architectures considered, it was decided to proceed with non-intrusive monitoring tools as follows.

Among the indicators it is important to measure in order to establish the quality of a service with ADSL connection (see table 6.3), at the present state, the following parameters: Up/Down average speed (Mbps); Jitter (ms); Transmission delay (ms).

These indicators have to be measured across each section, that is, between the user connection and the DSL terminal, between the DSL terminal and ISP the end user has subscribed, and between this ISP and third party ISPs, that is, content providers.

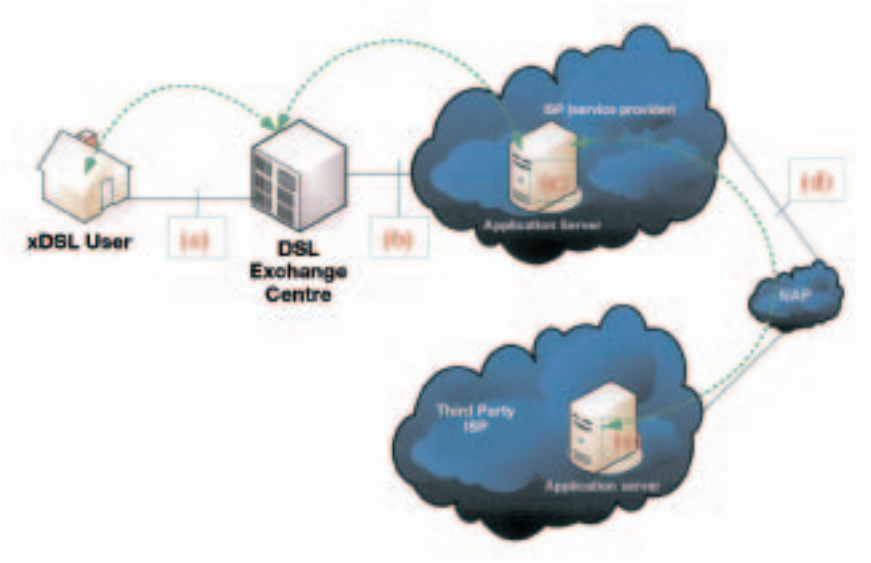


Figure 9.1 - xDSL network logical reference model

It may be necessary to obtain this information both in aggregate form and separately for each section.

In order to measure these indicators it is possible to use a distributed architecture of software agents and a central console for the configuration of the agents and data collection.

These agents should be installed on:

- the end users PCs who have subscribed and ADSL account with an Internet Service Provider (ISP)
- one or more PCs/servers installed within the DSL terminal
- one or more PCs/servers of the ISP subscribed by the user
- one or more PCs/servers of other ISPs.

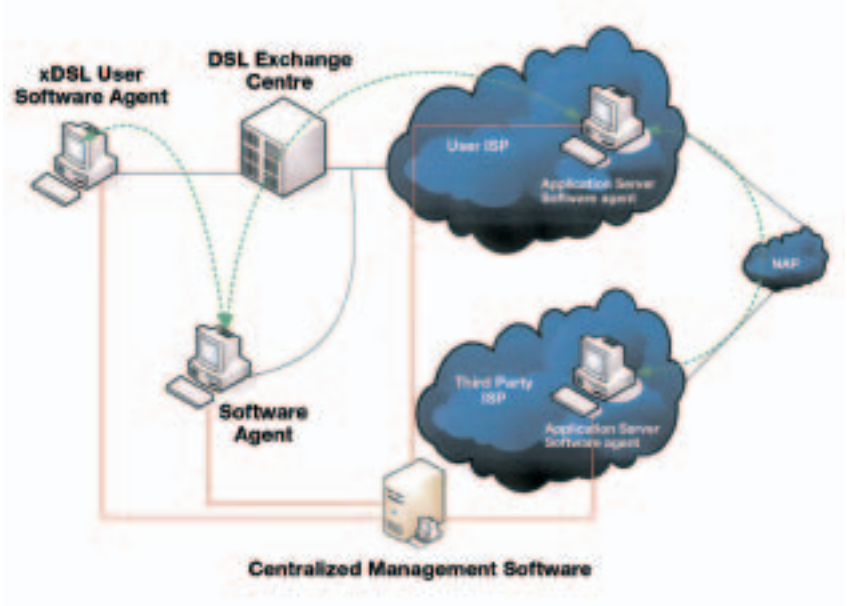


Figure 9.2 - SW agents logical reference model

All agents must communicate among themselves via IP protocols and all must communicate, again via IP protocols, with the central console for the configuration and collection of statistics.

From the central console it must be possible to configure a series of functional tests that allow assessing the band actually provided to the end user, the response times of the various types of applications and the jitter. Appropriately configured, the agents will actively generate a series of transactions in various modes:

- point-to-point: a software agent acts as a client and generates transactions towards another agent that acts as an application server;
- point-to-multi-point: a software agent acts as a client and

generates transactions towards a series of agents acting as application servers;

- multi-point-to-point: a number of agents, that act as clients, generate a series of transactions towards a single agent that acts as an application server;
- multi-point-to-multi-point: a number of agents communicates with a number of agents.

These transactions will not involve real servers and will exclusively serve the purpose of supplying information regarding the quality of the links provided to the customers and of the single paths between the clients and the ISPs.

These tests will have a limited duration and will be employed exclusively as such. For this reason it will be possible to create various measurement profiles that it will be possible to recall and launch whenever required.

The management software will configure the agents so as to simulate the various types of protocols associated to the various classes of service (as defined in chapter 6) according to the following table:

Real time services	Time-deferred Broadcast services	Interactive services	Other Time-deferred services
- Telnet - NetMeeting Audio Stream - NetMeeting Video Stream - Different VoIP codecs	- MPEG Video Stream - NetShow - RealAudio - RealMedia	- Dns - ftp	- http - https - pop3 - smtp

Table 9.1

With such architecture it must be possible to perform basic Throughput and Response time measurements.

9.1.1 Measurements

Measurement of the available bandwidth

The agents must be configured so as to generate traffic among them and measure the throughput, that is the bandwidth, for each path and for full client-server paths. The measurements must be performed both in upload and download, or contemporarily.

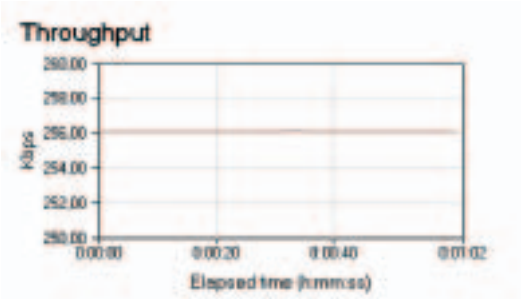


Table 9.1.1.a

Measurement of the Response Time

The agents must be configured so as to be able to simulate different kind of transactions, that is applications and measure the corresponding response time. The measurements must be performed both in upload and download, or contemporarily.

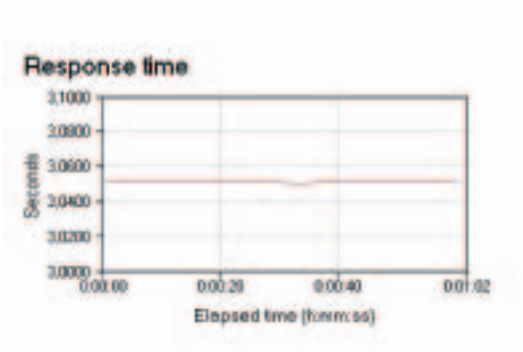


Table 9.1.1.b

9.1.2 Data collection procedure

It will be possible to configure the agents in order to simulate phone calls with various types of Codec and Service Quality. The agents will detect a series of information such as:

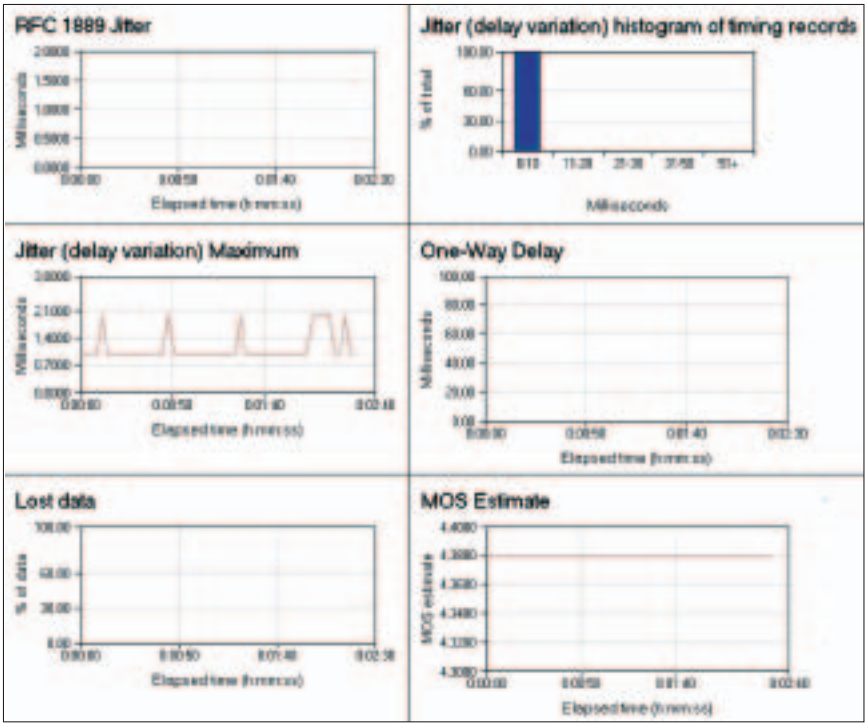


Table 9.1.2

The software is made up of a central console and by various software agents that can be installed on PCs or servers that do not interact with the end user, but may transparently communicate with the console.

The agents are installed as a service and therefore it will be possible to enable or disable these agents whenever required.

The tests can involve any number of these agents. It is possible to install them and employ them when and if necessary.

N.B. The measurement SW must be installed on all servers that provide services. Alternatively, the tests may be conducted by sample installations in the network.

9.2 Monitoring tools of the service as perceived by GSM network users

The quality of a GSM network may be monitored by means of appropriate investigation tools of the parameters shown in tables 6.3 and 7.2.

With reference to the model at figure 4.1, in order to perform the end-to-end quality of service measurements, we need to define the properly connected monitoring systems and the tools and procedures described in the present paragraph.

Among the possible measurement architectures considered, it has been decided to proceed with methods that are non intrusive for the operators.

In order to identify the correct setting of the required tools for the detection of the QoS parameters, a GSM network has been outlined in principle.

It is made up of a user terminal, also called User Mobile Station (MSU), and a cell, that is the area covered by the radio base station, also called Base Transceiver Station (BTS).

The Base Station Controller (BSC) is the system dedicated to the control of a certain number of Base Transceiver Stations. The traffic

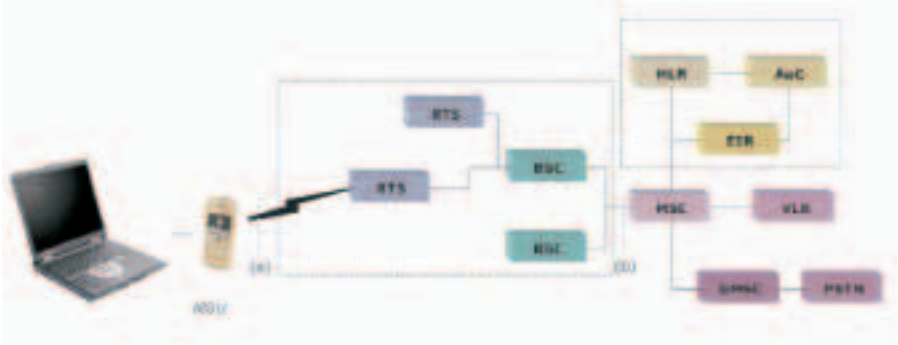


Figure 9.3 - GSM logical reference model

generated by the terminals within the cells is therefore routed through a switching centre of mobile calls, called Mobile Switching Centre (MSC), while the calls generated by fixed networks or directed towards them are managed by a dedicated centre, the Gateway Mobile Switching Centre (GMSC).

The network management and call control is realised using various databases:

- the Home Location Register (HLR) contains permanent data of registered users of the mobile network provider, such as user profiles and some temporary information, such as current position
- the Visited Location Register (VLR), instead, includes information related to users located in its covered area
- the Authentication Centre (AUC) is, instead, a network element that, among others, generates and stores the keys for user authentication, stores information for the communications encryption and checks the validity of data that identify the mobile users, stored in the Equipment Identity Register (EIR).

By setting the measurement tools downstream from the MSU (as shown in fig. 9.3), it is possible to detect the performance of the services provided at the users' terminals, as actually perceived by the mobile terminal, in a non intrusive manner for the operators.

Because we cannot forget the different characteristics of the MSUs, the peculiarity of which significantly affect the quality of the service provided, the measurement of data must be performed with systems that allow the comparison of parameters collected from different user terminals. For this reason, the management software, especially the data collection agent, must be configured so as to support various types of user terminals.

The software agent, who must be exclusively connected to the user terminals, must measure the parameters related to voice and data (SMS) services.

9.2.1 Measurements

In order to establish the quality of service of a GSM connection, a measurement of the indicators listed in table 7.2 is meaningful. Moreover, it may be appropriate to assess aggregate indicators such as: Carrier to Interference Ratio (C/I), and Speech Quality Index (SQI).

The parameter monitoring agents must be able to measure the comparison between the signal supplied by the radio cell and the undesired signal (interference) in terms of service provided (C/I). Such measurements, moreover, must be performed for all the frequencies available to the MSUs for voice calls.

The tool must, through the mobile terminal, be able to measure the quality of voice (SQI) not only through RxQual parameters, but also through more sophisticated approximation and comparison algorithms based on PESQ (ITU-T-P.862.1) standards.

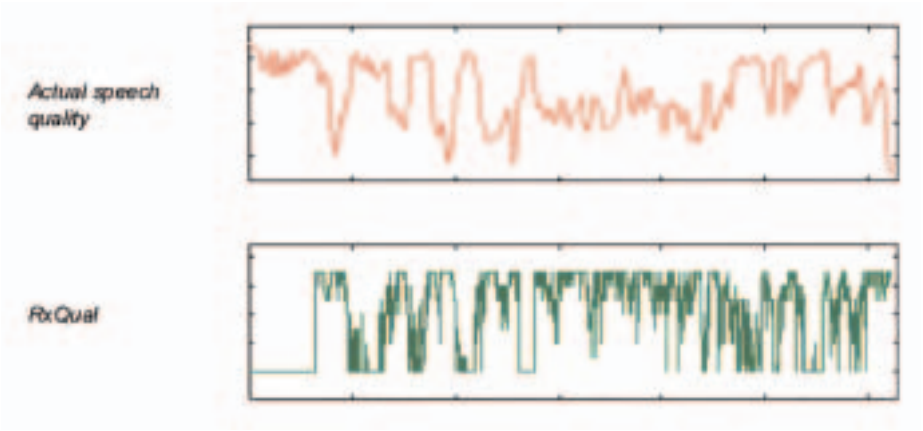


Figure 9.4 SQI assessment diagrams

In addition, the software agent must be able to assess the SQI also for different audio codes, such as, for example, AMR (Adaptive Multi Rate) or others among which EFR (Enhanced Full Rate), FR (Full Rate) and HR (Half Rate).

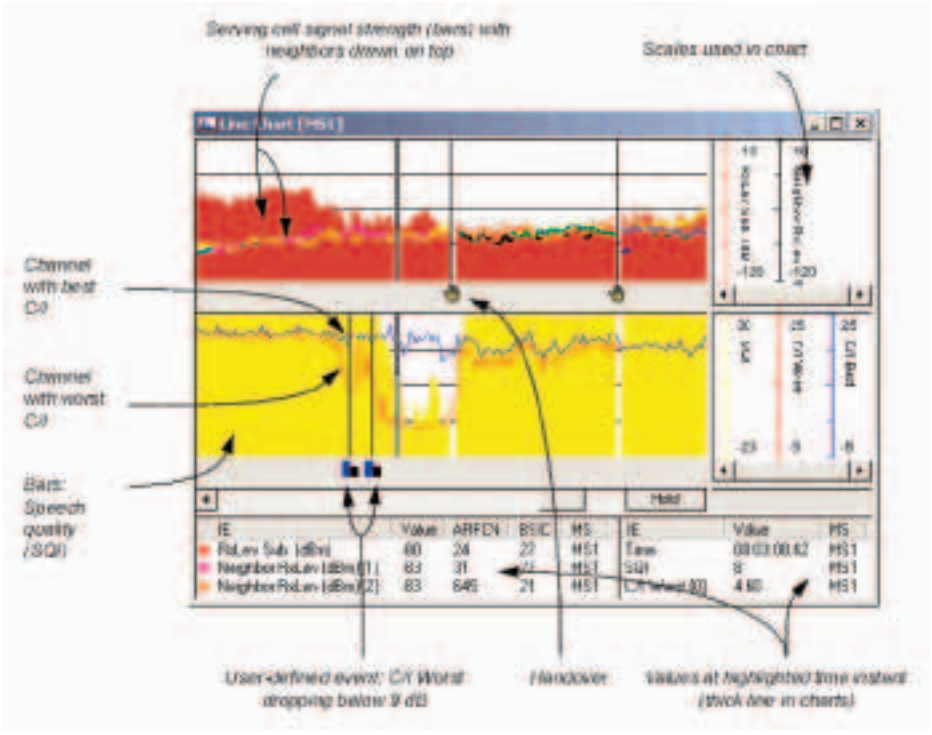


Figure 9.5 – SQI and C/I assessment diagrams relative to data coding

9.2.2 Data collection procedures

The monitoring system must be made up by a user terminal and by a software agent installed on a mobile station.

The user terminal must be identified by a serial International Mobile station Equipment Identity (IMEI) number generated by the constructor and memorised by the operator in the EIR.

The management software can be made up of a central mobile console and the software agent that, through a radio interface (the User Terminal to which it is connected), collects the data.

Diagnostics must be represented in real time with the possibility of storing drive test sessions in order to process differed time data.

The system must be able to monitor the quality of service parameters during different daily or weekly periods and automatically provide statistical reports of the measurements performed.

In order to detect the signal MTUs (Mobile Test Units) must be

Figure 9.6 - Data collection and monitoring

used that, installed on service vehicles, are able to move within the network coverage areas of outdoor providers. Furthermore, the tools must be able to monitor and represent the KPI also in indoor areas.

Moreover, the data collection tests must be represented by means of a geo-reference mapping, that associates the area surveyed to the data collected.

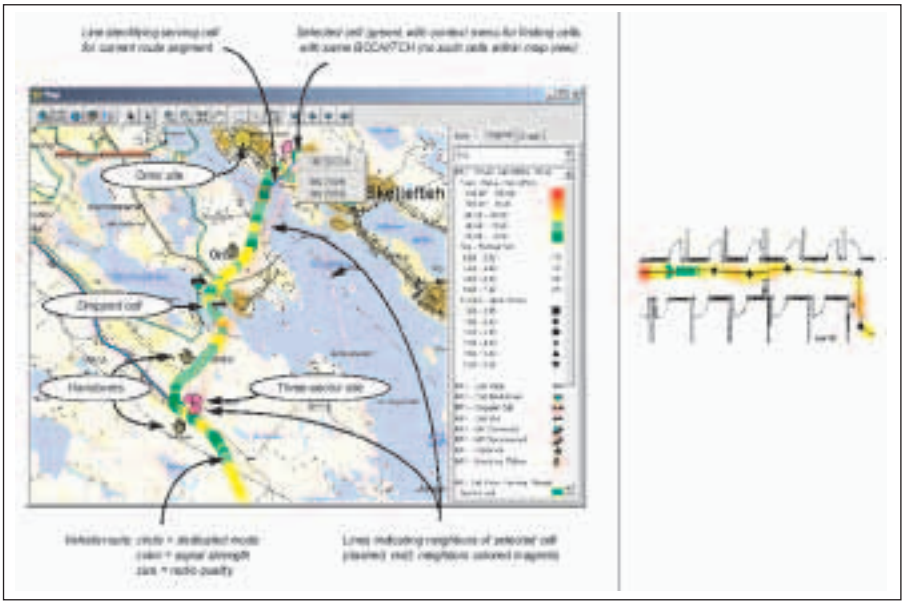


Figure 9.7 - Geo-reference reporting

Final considerations

During the past three years there has been a significant growth in broad-band connections and a confirmation of the widespread mobile phenomenon.

The development of infrastructures may be stimulated by requirements arising from research in the quality of services, especially by activating appropriate synergies between the mobile and fixed communications.

From this viewpoint, the benefits of the liberalisation of the telecommunications markets has enhanced and will improve, thanks to greater competition, the technological and commercial progress, through an incentive the formation of increasingly well aimed services able to satisfy user demands at the most competitive prices possible.

In order to protect such principle a definition of the tools used to measure the quality of the services provided is necessary.

The formation of a method – which is the subject of the present volume – is aimed at ensuring that the objectives of the deregulation do produce the expected improvement in terms of quality, providing customers, before they buy, a key to the interpretation of the quality of the services offered by providers.

We believe that this volume supplies useful food for thought in this sense and, at the same time, identifies the tools to be used to achieve the objective, that is, quality as an index and tool available to the end user.

11 - Acronyms and abbreviations

Abbreviation	Description
ADSL	Asymmetric Digital Subscriber Line
ATM	Asynchronous Transfer Mode
AUC	Authentication Center
BRAS	Broadband Remote Access Server
BSC	Base Station Controller
BTS	Base Transceiver System
C/I	Carrier to Interference Ratio
CP	Content Provider
CCI	Centro di Controllo e Instradamento
CID	Centro Interdominio
CPE	Customer Premises Equipment
CRM	Customer Relationship Management
DNS	Domain Name System/Service
DSL	Digital Subscriber Line
EIR	Equipment Identity Register
FdS	Fornitore di Servizio
FTP	File Transfer Protocol
FR	Frame Relay
FR	Full Rate
GMSC	Gateway Mobile Switching Center
GSM	Global System for Mobile communications
HLR	Home Location Register
HTTP	HyperText Transport Protocol
HTTPS	HyperText Transport Secure Protocol
IMEI	International Mobile Station Equipment Identity
ISP	Internet Service Provider
ITU	International Telecommunication Union
KPI	Key Performance Indicators
MOS	Mean Opinion Score
MSC	Mobile Switching Center
MSU	Mobile Station User
MTU	Mobile Test Unit
MPEG	Moving Pictures Experts Group
MTU	Maximum Transmission [/Transfer] Unit
PC	Personal Computer
PdR	Punti di Riferimento
PESQ	Perceptual Evaluation of Speech Quality
QOS	Quality of Service
SDH	Synchronous Digital Hierarchy
SMTP	Simple Mail Transfer Protocol
SMS	Service Management System
SQI	Speech Quality Index
SW	Software
TE	Telecom Equipment
UMTS	Universal Mobile Telecommunication System
VLR	Visited Location Register
VOIP	Voice Over IP
xDSL	All the different DSL technologies
Wi-Max	Worldwide Interoperability for Microwave Access

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