Settembre 2008 RR-08.73

Campagna E.- De Nitto Personè V.

Quality of Service: definitions and methods in the international standard

Overview

Introduction

Quality is an essential feature in the characterization of products and services.

The definition and measure of quality, that is easy in some specific contexts (for example, when we buy a car or another real product), becomes very difficult when we decide to evaluate the quality of something that is "immaterial", such as the services of computer systems. Therefore, it's necessary to clarify and identify the key aspects of Quality of Service (QoS) for all the entities involved in the service: the system, its infrastructure and the users.

A general definition of quality is the following: *"all the properties and characteristics of an entity which give it the capacity to meet expressed or implicit needs"* [7].

In the international context, according with **ITU** (*International Telecommunication Union*) **Recommendation E.800** [1]**,** the Quality of Service is defined as "*the collective effect of service performance which determines the degree of satisfaction of a user of the service*" and, from the point of view of the system, in particular, "*the QoS is the ability of a network (or of a system) to ensure a certain level of service*".

Starting from these definitions, it's evident the importance of the concept of Quality as a **value** [7] that must be guaranteed to the end-user. For this reason, it's essential that this concept becomes "common", even if it is difficult that a user is really aware of what level of quality should be expected from a product (or rather, from a service), in a dynamic environment such as the Information Technology.

With the increasing use of IP network, QoS control has a raising importance; the main objective of the service providers is to guarantee that each service is delivered with a specific level of quality. Checking the QoS over IP and mobile networks means to guarantee that the information that is carried through a specific service will reach its destination on time and with the characteristics that the service requires.

The transformation of the end-users from passive users of the service to customers with the opportunity to choose their own provider and the growth of demand for high quality yield the Service Providers to measure and manage the QoS to guarantee a specific **Service Level Agreement** (SLA).

A Service Level Agreement [5] is a formal agreement between two or more entities (parties) reached after a negotiation, in order to evaluate service characteristics, responsibility and obligations of each party.

The part of a SLA document which refers to QoS, usually called *QoS Agreement*, provides a formal program established between two parties in order to define, to monitor and to measure QoS parameters.

The objective of a SLA is to achieve the agreed QoS and thus to obtain the "customer satisfaction".

Users, usually, don't care about product technology but they are interested in the benefits that they can obtain from it and in its "ease of use", as explained in [6].

Quality of service perceived by the customer assumes, in this way, a basic role. The point of view of the service provider and the point of view of user are closely related because the quality of the network must be related to the quality perceived by the end user, according to the ITU recommendations.

Considering the user experience means to better understand the needs and the expectations of the end-user of a specific service, focusing mainly on his satisfaction (e.g. a customer wants to use a service that ensures a shorter response times and high reliability).

For all the above mentioned topics, we must also consider **Quality of Experience** (**QoE**), or quality perceived by users rather than Quality of Service.

Different users may consider a service in different ways, depending on their connection to the Internet (dial-up, ADSL etc), the conditions of the network (level of congestion, line speed etc) and, generally, the instruments that they use to access to the system.

The quality perceived by the user is the result of a comparison between his expectations about the product and his perception of the effective performance of the product.

A definition of quality could be the following:

$$Quality = Perceptions - Expectations$$

Expectations of a user may be interpreted as "forecasts" for the service, in other words what he imagines to obtain from the utilization of a specific service.

This is very different from the point of view of service provider, whose vision of quality is based on the service level guaranteed by the network. The assessment of quality is driven by both the requirements and the real time measurements that are made on the network.

An important task of the service provider is to translate user requirements into objective measures.

The problem of defining QoE quantitatively [6] can be managed as follows: we usually measure the QoS of a system but we should measure the QoE as well, and then we should understand what are the factors that must be considered for this purpose.

As mentioned before, the experience is subjective and many factors can affect the judgments of each person about something (historical, economic or social reasons).

On the contrary, the measurement of QoE involves many factors that can be measured only if their values are objective: the QoS considers specifically measurable factors while the subjectivity is very significant for the QoE. It's very difficult to quantify the user preferences and usually this happens in the social sciences or in the market research.

We are thus obliged to develop measures which consider the subjective nature of experience: in systems engineering, efficiency and effectiveness are determined by measures of the performance and these try to reach specific values that can ensure a certain quality. In designing new systems, it's important to consider the users as part of the system and also to establish performance measures that consider the element of subjectivity, which represents the system from the user's point of view.

The quantification of QoE is still a very tricky problem while in the quantification of QoS *system modeling* assumes a crucial role.

A complex system can be reduced in a simplified model to quantify the QoS giving a value to certain characteristics of interest (for example, the *arrival rate*).

The aim is studying the relevant characteristics of the system and monitoring the values that the variables representing the *measures* of quality can assume. Using system modeling, we can describe a system in terms of its attributes of quality and we can then use the model into the design of the system.

The model is useful in the maintenance phase of the system since it is crucial for managing the QoS and for its improvement. By monitoring and "tuning" the values of

the performance indices (such as *throughput*, *response time*, *transmission delay*) we can maintain the QoS of a system at the level that ensure the required quality to the user.
The Quality of Service can be analyzed from two different perspectives: the quality of the network, which involves service providers (or network operators) and the quality perceived by the customer, which involves the users of the service, as shown in Figure 1.

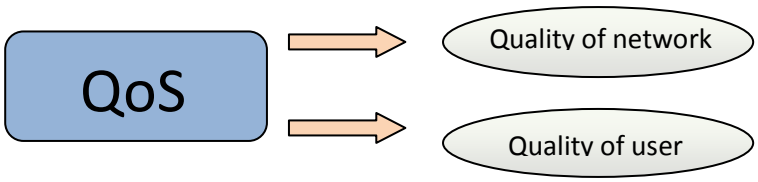

Figure 1 - Different points of views of QoS

In this work we want to analyze documents related to the QoS standards in a very general context, without going into details of a particular service or implementation.
A deep research on ITU and ISO (*International Organization for Standardization*) web sites and an accurate verification of the documentation on QoS, have enabled us to identify five specific documents addressing the issue of networks quality of service in a very general way, that are listed in the following:

- *International Standard ISO/IEC 13236 – Information technology – Quality of service: Framework* (December 1998) [2]
- *Technical Report ISO/IEC TR 13243 – Information technology – Quality of service – Guide to methods and mechanism* (November 1999) [3]
- *ITU-T Recommendation G.1000 - Communications quality of service: a framework and definitions* (November 2001) [4]
- *ITU-T Recommendation E.860 – Framework of a service level agreement* (June 2002) [5]
- *ITU-T Recommendation E.802 - Framework and methodologies for the determination and application of QoS parameters* (February 2007) [8]

The five documents have been analyzed in detail, highlighting terminology and important concepts that have to be acquired when we want to deal with a problem

concerning the QoS. We have emphasized similarities and differences between documents with an in-depth examination.

The performed research shows that after the standard ISO, published in 1998 there wasn't any new publication, related to this standard, issued by ISO but only a Technical Report, dated 1999. We have identified three documents concerning the QoS Framework and the definition of *Service Level Agreement* (SLA) relating to QoS from ITU web site that are most recent than the ISO documents above mentioned.

The document concerning the SLA has a significant importance in the context of the quality because in the activities relating to the QoS, as we will see later, there is a particular stage where the agreements (SLA) on QoS between the parties are to be regulated.

1. INTERNATIONAL STANDARD ISO/IEC 13236 (12/1998) Information Technology – Quality of service : Framework [2]

1.1 Introduction

ISO and IEC (*International Electrotechnical Commission*) have developed an international standard to provide a common basis for the coordinated development and the improving of the wide range of documents that specify the quality of service, requirements and mechanisms for quality in information technology.

The Framework makes available to service providers and users a common vocabulary, concepts, terminology and definitions suitable to various protocols and architectures.

The aim is to provide a means for development and improvement of standards related to QoS and providing the concepts and terminology necessary to maintain consistency of standards related.

The initial motivation for the development of the QoS Framework was the clarification of the description of QoS in ITU document *Basic Reference Model of OSI* (*Open System Interconnection*).

The management of QoS is not important only in OSI communications but also in a broader context, regarding network architectures and distributed processes.

The QoS Framework aims to aid in the design of IT systems, in the definition of communication services and protocols providing a guide to the applicability of QoS systems, resources and services of various kinds. It describes **how QoS can be characterized, how QoS requirements can be specified and how QoS can be managed**.

The Framework describes how QoS requirements can be expressed and identifies the mechanisms for the QoS management.

The document is designed to provide main definitions and terminology for the QoS and describes different concepts many times. In this work, we try to make the description of QoS provided by the standard more organic and less repetitive, emphasizing the significant sections of the document.

First, we will introduce the concepts of QoS and then we investigate each one in detail

and, finally, the analysis of the verification of QoS will be presented, which will be discussed in detail in [5].

1.2 Concepts of QoS Framework

The basic concepts about QoS are:

• the concept of **service** to which QoS applies;

• QoS **characteristics**, that describe the fundamental aspects of QoS that are to be managed;

• QoS **requirements** and QoS **policies**;

• QoS **categories**, representing different areas of application where a particular set of QoS requirements is significant;

• QoS **management functions**, the **phases** of management activities and basic QoS **mechanisms**.

1.2.1 The service to which QoS applies

The term **service** is understood in a very general sense to enable the Framework to be used in many applications. Specifically, it refers to:

- the provision of a process and functions which carry information about entities, objects, applications, processes;

- interactions between entities, objects, applications;

- information maintained by the system;

- communication services.

The services have some important features:

• they are intangibles, we qualify them for their performance rather than for any physical attribute;

• they are heterogeneous, their performances vary from supplier to supplier, from day to day and from user to user;

• the production and use of a service are inseparable: the quality of service is measured when customer use it, not in the planning stage or in workshop;

• they are continuing, performances cannot be assessed immediately but over a period of time and compared to average levels of quality provided;

• the service involves direct contact between the provider and the user unlike the development of a product.

1.2.2 QoS characteristics

The term QoS characteristic is used in the Framework in this sense: *a quantifiable aspect of QoS which is defined independently of the means by which it is represented or controlled*. A QoS characteristic denotes a real aspect of QoS, for example, the current behavior of the system.

For example, defining a QoS characteristic like *throughput*, we want to know what is the throughput and this is different from how it can be measured, controlled or negotiated.

The values that may be taken by QoS characteristic are not only numbers but also vectors, matrices or other.

The characteristics of QoS can be divided according to the characteristics of general importance and also we distinguish *general*, *specialized* or *derived* characteristics.

1.2.2.1 QoS characteristics of general importance

QoS characteristics of general importance to communications and processing, can be grouped as follows:

- characteristics related to time;
- characteristics of consistency (of data);
- characteristics related to capacity (e.g. *throughput*);
- characteristics related to integrity (accuracy of information);
- characteristics related to safety (safe operation of the network or application);
- characteristics related to security (e.g. *authentication*);
- reliability-related characteristics (e.g. functioning of the network in case of partial failures);
- other characteristics.

The definition of a QoS characteristic includes the following information:

- a name for the characteristic (*NAME*);
- a definition that explains its purpose intended area of application (*AS DEFINED*);
- a statement of how the characteristic is quantified and the units of measure in which values are expressed (*QUANTIFIED AS*);

- (if the characteristic has derived characteristic) its *STATISTICAL DERIVATION*;
- (if the characteristic has a specialized characteristic) its *SPECIALIZATIONS*;
- optional or additional information.

The specialized and derived characteristics have this information, too.
The Framework provides definition, quantification, specializations and derivations for each characteristic.
For example, for the characteristic *capacity* the Framework states:

NAME	***capacity***
DEFINED AS	***amount of service that can be provided in a specified period of time.***
QUANTIFIED AS	***since the capacity characteristic can be applied to different types of resources, it is quantified using various units. The quantification of capacity also depends on the time unit used for the measurement.***
SPECIALIZATIONS	***throughput.***

1.2.2.2 General, specialized and derived characteristics

Many QoS characteristics can be applied to a wide variety of circumstances and contexts. It's important to clearly define the characteristic that must be applied to particular circumstances. First, we define a "generic characteristic" (for example, *the delay*) independently of what it will be applied to and then, we define various "specializations" to make the characteristic concrete and usable in practice (for example, *delay transmission*).
This approach achieves consistency in two ways: first, we have consistency between different uses of the same characteristic in different circumstances because it shares a common abstract definition, second the approach can be used to give consistency

between quite different characteristics where the same specialization are applied. Specialization makes an abstract characteristic more concrete.

Some characteristics may be defined as mathematical functions of others: these are referred to as **derived characteristics** (for example, *the number of packets lost*, obtained by the difference between packets sent and received). Another important type of derivation is *statistical*: for example, for the characteristic *throughput* we can define *the average, maximum or minimum throughput*. The statistical derivations can be regarded as orthogonal to the specializations, as shown in Figure 1.1:

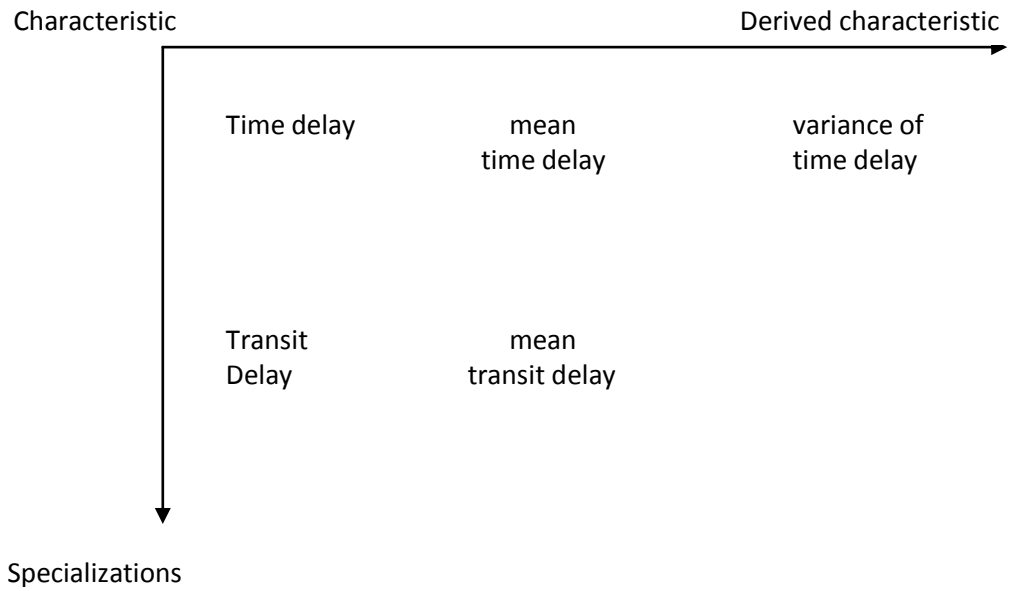

Figure 1.1 - Specialized and derived characteristics

We can define characteristics that are derived mathematical functions of one or more basic or derived characteristics, for example the *availability* is a function of *reliability* and *maintainability*.

1.2.3 Users QoS requirements and QoS policies

QoS management activities are driven by user requirements, the system and communication environment and the policies in use for the activity. User requirements are quantified and expressed in a set of **QoS requirements**. As the user requirements can vary considerably depending on the particular application, QoS characteristics and QoS management functions to be used may be determined by the type of system,

applications, and the type of network technology used.

The systems and communications networks are designed and configured according to one or more **QoS policies**, set of rules that determine the characteristics of QoS and management functions of QoS to use.

1.2.3.1 QoS Parameter and QoS Context

A user requirement originate from a user who wishes to use a service and it is translated into one or more **QoS requirements**. These QoS requirements can be expressed as QoS **parameters** and QoS **contexts**. The definitions of the two concepts introduced by the document are:

- ***QoS context****: QoS information that is retained, interpolated or extrapolated by one or more entities and used in managing QoS.*

- ***QoS parameter****: QoS information that is conveyed between entities as part of a QoS mechanism and may be related to one or more characteristics of QoS*.

Generally, an activity is initiated by a user whose QoS requirements are transmitted to service providers such as QoS parameters or made available to the service provider as a QoS context. The entities that receive these requirements are concerned to analyze them to determine the functions and QoS mechanisms needed to meet these requirements.

Usually, a QoS parameter is a vector or a scalar value that is shared among entities that are in the same system or in different systems. For example, if a QoS requirement predicts that the *transit delay* of data between two points does not exceed a maximum value, the QoS characteristic under consideration is the transit delay while the maximum delay can be expressed as a parameter or in a context of QoS. As the user requirements may change over time, the user might send the new requirements to the provider like QoS parameter, or the provider could control the user requirements made available as QoS context, when it's necessary,.

1.2.4 QoS categories

Different user application types will have different requirements to establish QoS and for monitoring and maintaining the actual QoS achieved: for example, the QoS requirements for *video streams* are typically very different from those for *database* update transactions. The different sets of user requirements or application are called **QoS categories** and they lead to the choice of a particular set of QoS characteristics to manage.

1.2.4.1 Fundamental QoS categories

The systems and network architectures which have be standardized to date have not fully considered requirements for specific quality of service but only the requirements for general services. There is a wide variety of applications where we can apply specific policies during communications and processing activities, leading to the choice of a particular set of QoS characteristics to implement the requirements.

The concept of *QoS category* was developed to enable the identification of what qualities of service best categorize the requirements. The qualities of a service that are identified for each category may be similar but have different emphasis. In addition, the QoS categories are not mutually exclusive. A non-exhaustive list of qualities may include:

- data security system;
- safety critical of network, software and hardware;
- time critical of the system (in some environment, it gives great importance to the characteristics related to time, for example, it wants that some events occurring in a given time window);
- high reliability of the system;
- ease of use of the system;
- extendibility/ flexibility of the system;
- monitoring / testability of system.

1.2.5 QoS management functions, phases of management activities and QoS mechanisms

1.2.5.1 QoS management functions

The management of QoS refers to all activities related to monitoring and administration of QoS in a system or a network. The term **QoS management function** (QMF) refers to any function created in order to meet one or more of the requirements of QoS. The QoS management functions usually have different components called **QoS mechanisms**. A management mechanism of QoS is performed by one or more entities to meet the QoS requirements.

The activities performed by QMF are:

- QoS establishment by a set of QoS characteristics;

- QoS monitoring on observed values;
- maintaining the current QoS close to that desired;
- investigating information about the QoS;
- alerting on results of special events related to the management of QoS.

1.2.5.2 Phases of a Qos activity

The management of QoS requires the use of different QMF at different times of a system activity.

QoS requirements can be expressed in different ways or at different times for an activity related to the different events occurring in the management of QoS.

The management of QoS can be performed in different phases of activity:

- before to start, when we make predictions on the situation of QoS to evaluate what mechanisms to use to achieve the objectives;
- beginning of the activity, for example, user and service provider can negotiate the QoS requirements in a given time (for example, when they establish the connection);
- during the activity, QoS requirements can change during the operational period of activity due to changed requirements, explicit indication from the service provider, explicit indication from one or more parties or the condition of the network (for example, because there's an heavy traffic).

More formally, any activity related to QoS can be divided into three phases, described below.

- **Prediction phase**: the purpose is to predict aspects of system behaviour so that the entity can initiate appropriate QoS mechanisms. At this stage, entities will typically make QoS enquiry to assess, for example, the current load on the system or the QoS currently reached.
- **Establishment phase**: in this phase, the purpose is to create conditions so that the desired values of QoS characteristics are achieved for some system activities before the activities begin. The phase is usually initiated by a service user or a third party which wants to establish requirements on one or more QoS characteristics. The parameters of QoS requirements assume values that indicate an operating target, a lower or higher limit or a threshold. Limits and thresholds are also called "*trigger points*" : during the establishment phase is necessary to

impose or negotiate a number of trigger points together with an operating target, as shown in Figure 1.2.

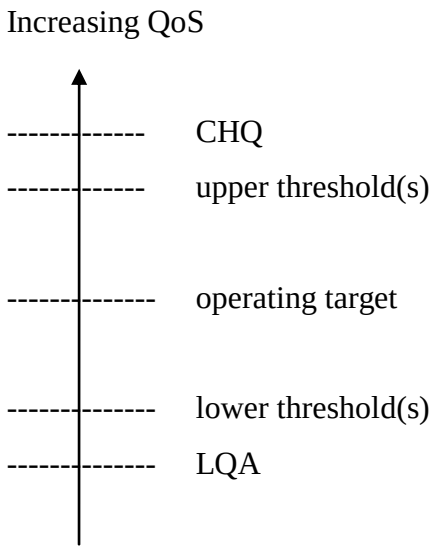

Figure 1.2 - QoS threshold and limits

We use the terms "*high quality*" and "*low quality*" rather than numerical values, because for some characteristics high numerical values may correspond to high quality whereas for others, such as *transit delay*, high quality is represented by a low numerical value.

There are two types of limits:

• a *Lowest Quality Acceptable* (LQA) limit, below which the QoS "should not" fall;

• a *Controlled Highest Quality* (CHQ) limit, above which the QoS "should not" go.

During this phase, the activities called "*Levels of Agreement*" takes place, actions leading the service provider and the user to agree on the levels of QoS to maintain.

There are three levels of agreement: ***best effort***, ***compulsory*** or ***guaranteed***.

The weakest agreement is that all parties use the *best effort* (the first request that arrives is served) to meet user requirements but there is no assurance that the QoS negotiated is reached or provided.

In the *compulsory* level of agreement the service may be aborted if the QoS degraded below the agreed level. The agreed QoS is not guaranteed.

In the *guaranteed* level of agreement, the agreed QoS must be ensured so that the required level is reached. The QoS is guaranteed and it define the limits within which forcing QoS.

- **Operational phase**: The goal of this phase is to meet the agreements made during establishment phase to initiate appropriate steps to achieve the objectives. At this stage entities perform monitoring, maintenance and QoS enquiries.

This division does not aim to divide any activity in three stages performed in sequence but rather to classify the QoS mechanisms. Moreover, not all QMF require all three phases.

1.2.5.3 QoS mechanisms

This paragraph classifies a number of general mechanisms that can be used to meet user requirements identified in the previous steps that can be applied to any QoS characteristic rather than being specific to any particular QoS characteristic.

There are mechanisms performed during the phase of prediction, the establishment phase and operational phase.

Prediction phase mechanisms include:

- investigating historical information on QoS measures which reflect previous levels of QoS achieved;
- analysis of historical information on QoS measures;
- prediction of QoS characteristics in the system;
- calculation of potential perturbation to reach the QoS request;
- evaluation of levels of QoS parameters to be requested during establishment phase;
- checking that requests will not conflict with admission control policies.

Established phase mechanisms include:

- assignment of operating targets, limits, thresholds for QoS characteristics and decide what action should be taken if the QoS is not maintained;
- initializing conditions and mechanisms needed in the operational phase.

At this stage, the **negotiation mechanisms** of QoS takes place to establish operational levels for the QoS characteristics and actions to be taken if the levels are not maintained. Each characteristic can be subject to a particular negotiation depending on the application that is to be supported: for example, the *throughput* can be negotiated for "*connection- wide*" if it's important that all parties must receive all data transmitted by a single party without loss or, if the loss can be tolerated, the throughput can be negotiated separately for each receiver by "*receiver selected*" negotiation.

Operational phase mechanisms support:
- QoS monitoring;
- QoS maintenance;
- QoS enquiry;
- QoS alert.

In particular, the mechanisms for maintaining QoS that aim to maintain QoS to acceptable levels include, among others, *tuning mechanisms* designed to adjust the measured QoS to achieve the QoS requested.

This mechanisms are useful for "tuning" the provided QoS to achieve the QoS requested by the user, since QoS can change dynamically as a result of several factors (e.g. resources that become bottlenecks, additional service users, etc).

The tuning mechanisms may be *internal* or *external*:

- ***System internal tuning***: a "feedback loop" has be introduced for the control of the internal system performance. The service provider can adjust the values of certain characteristics of internal performance to reach the negotiated QoS. The following steps have to be performed:

  a) calculate required system performance (SP) from negotiated QoS;

  b) measure actual system performance;

  c) calculate the difference between the required system performance and the measured system performance;

  d) reset the structures of the system to achieve negotiated QoS.

- ***System external tuning***: this mechanism is applied to the systems without system internal tuning. The negotiated QoS will be controlled from the user's

point of view and the calculation of the performance difference is carried out. The external tuning is useful to meet user requirements and it is necessary to make the mapping from QoS to SP and SP to QoS. The operations included in this mechanism are:

a) measurement of the service-relevant performance parameters;

b) translation the SP values in QoS values;

c) calculation of QoS differences;

d) act on the QoS- related components (end systems or transmission service).

1.3 QoS verification

QoS verification is the process that compares the requested QoS with the observed and measured QoS in one or more designs, implementations, testing and operational phases of a given service.

The Framework places the QoS verification outside the description of the QoS management activities, as if testing was a stand-alone activity, which can be performed both before a service is delivered and during its utilization by the users.

The lifecycle of an implementation of a service is divided into three main phases and each involves special activities needed to verify the QoS.

In the first phase, the *service design stage*, it may be verify that the project meets the desired QoS requirements as expressed by the service users.

In the second phase, the *testing stage*, the parameters of system performance may be verified and controlled.

During the final phase, *service operation*, it verifies that the current QoS provided to the users of the service matches the QoS agreed within the service contract.

Achieved QoS depends on system/service performance used: QoS verification includes a comparison between the requested QoS and the measured QoS. A *QoS verification statement* can be formulated as follows:

IF (SP constraints) THEN (QoS requirements)

and means: all QoS measures relating to parameter values are checked if the network was controlled according to the specified constraints on system performance.

The constraints on performance system may be functions that return a Boolean value which take the value *true* if the QoS measures meet the relationship specified by the user requirements.

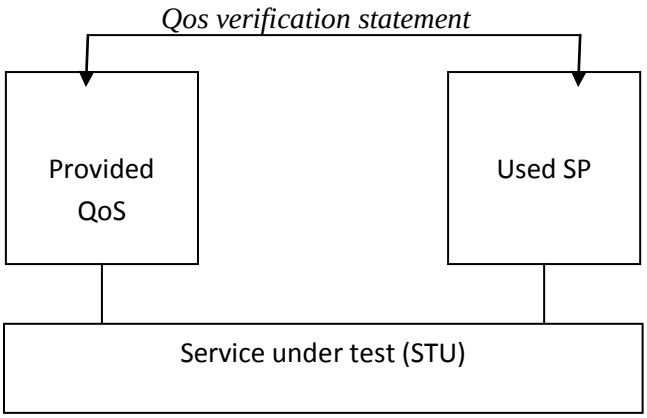

Figure 1.3 - *QoS verification statement*

2. TECHNICAL REPORT ISO/IEC TR 13243 (11/1999)

Information technology – Quality of service – Guide to methods and mechanism [3]

2.1 Introduction

The document was produced to promote the use of methods and mechanisms for the management of Quality of Service (QoS) in different types of communications, environments and systems.

The Technical Report uses the concepts and terminology of the QoS Framework [2].

The aim is to support the design, testing and the specification of *Information Technology* (IT) systems, communications and service protocols, defining the QoS managing functions and QoS mechanisms for particular environments and technologies and improving other related-QoS activities.

This Technical Report identifies and catalogs current standards and specifications concerning the definitions of QoS characteristics, QoS mechanisms and methods and also include definitions of certain methods and mechanisms that are widely considered applicable.

The term **method** is used in a very general sense to include every process, function, etc., relevant to the QoS at all stages of the life cycle of the system.

Many *Recommendations* refer to the various aspects of QoS.

The document provides a list of all documents that refer to QoS and QoS characteristics that are defined in them at low level and high-level (in Section 5).

The Technical Report, as mentioned, incorporates the definitions of QoS Framework and focuses on QoS mechanisms, in particular, on the **QoS negotiation** and **QoS filters**, not carefully dealt in [2]. In addition, the Technical Report describes the **QoS verification**, an activity aims to test the quality of service from its design, explaining in detail the various stages of verifying that the QoS Framework introduced only in a very general level.

2.2 Phases of QoS management activity

QoS management is an important research topic for many universities, institutes and organizations. As described in the QoS Framework [2], QoS management activities plan three stages:

- **Prediction phase**: during this phase we try to predict behavioral aspects of the system so that the entity can initialize appropriate QoS mechanisms.
- **Establishment phase**: in this phase we create the conditions such that the values of desired QoS characteristics are achieved by some system activities before the activity starts.
- **Operational phase**: The goal of this phase is to meet the agreements made in the previous phase and perform appropriate actions to achieve the goals.

2.2.1 Methods and mechanisms for prediction phase

As defined in [4], the prediction phase include the following activities:

• investigation and analysis on historical information on QoS measures, which reflect the previous level of QoS achieved;

• estimates of QoS characteristics in the system;

• calculation of the potential perturbation to the specific requirements of QoS required;

• assessment of the levels of QoS parameters that must be applied during the establishment phase;

• verifying that the requests do not conflict with the admission policies.

2.2.2 Methods and mechanisms for establishment phase

The methods and mechanisms for the establishment phase of QoS include:

- methods to reach QoS agreements, including negotiation mechanisms;
- mechanisms for resource allocation;
- initialization mechanisms.

2.2.2.1 Methods to reach QoS agreement

QoS agreements can be achieved by a variety of means such as negotiation, management of security policies and so on.

For QoS negotiation, there are three cases, described below.

1) QoS negotiation in peer-to-peer communications

The concept of QoS negotiation between two peer entities is also discussed in [2], in a fairly general way and it may involve only two peer entities or include the provider of a communication service between them. In general, the mechanisms of *three-party negotiation* are used, including two users and a provider.

We defines **two negotiation mechanisms** between three parties:

- the first mechanism uses a single parameter and allows the negotiation from a proposed maximum;
- the second mechanism allows the parties to specify the ranges in which they are able to operate and they can agreed on a limit, a value or a threshold within a range.

Each mechanism provides an initial user who proposes an initial value, which can be modified by other parties, and there is a degree of symmetry because the result of negotiation must be a value acceptable to all parties to the communication.

As mentioned, the negotiation may involve a single parameter (*single parameter negotiation*) or limits for the parameter (*bounded negotiation*).

In the following descriptions of the two negotiation mechanisms, the terms increase, high value, better value and upper limit should be understood in the sense of higher quality while the terms decrease, low value, worst value and lower limit must be understood in the sense of lower quality. In fact, the values that reveal an higher quality could be high values (in the case of *throughput*) or small values (in case of the *transmission delay*).

a) single parameter negotiation

1) The user called *initiator* (the peer initiating communication) proposes a value to the provider P.

2) The provider could refuse the request. Instead, when the provider accepts the request, could select a new P' value that is not better than the initial value proposed by the initiator, namely $P' \leq P$. The provider gives this value to the *responder* (the second peer).

3) The responder user could refuse the request but, if accepted, could select a new value V that is not better than the one proposed by the provider, $V \leq P' \leq P$.

4) The provider leaves the V value unchanged.

5) The selected value, V, is returned to the initiator and it is the value of agreement.

b) bounded negotiation

1) The initiator user specifies a desired operating range, providing a lower limit L and an upper limit U, where $L \leq U$.
2) The provider could refuse the request if it knows that cannot satisfy the user, for example, if it cannot guarantee at least the lower limit. If the provider does not refuse the request but cannot operate over the full range proposed by initiating user, it could determine a new value U' for the upper limit, which is worse than the proposed value U, $L \leq U' \leq U$ (the provider could also choose to work internally to a higher quality but does not report this fact to the responder).

   The provider does not alter the value of the lower limit L. The new upper limit U' and lower limit are provided to responders.
3) The responder could refuse the request, if accepted, it could select a value V belonging to range defined by L e U', $L \leq V \leq U'$. The value V is returned to the provider.
4) The provider leaves the V value unchanged.
5) The V value is selected and returned to the initiator, it is the value of agreement.

The two mechanisms are illustrated in Figure 2.1.

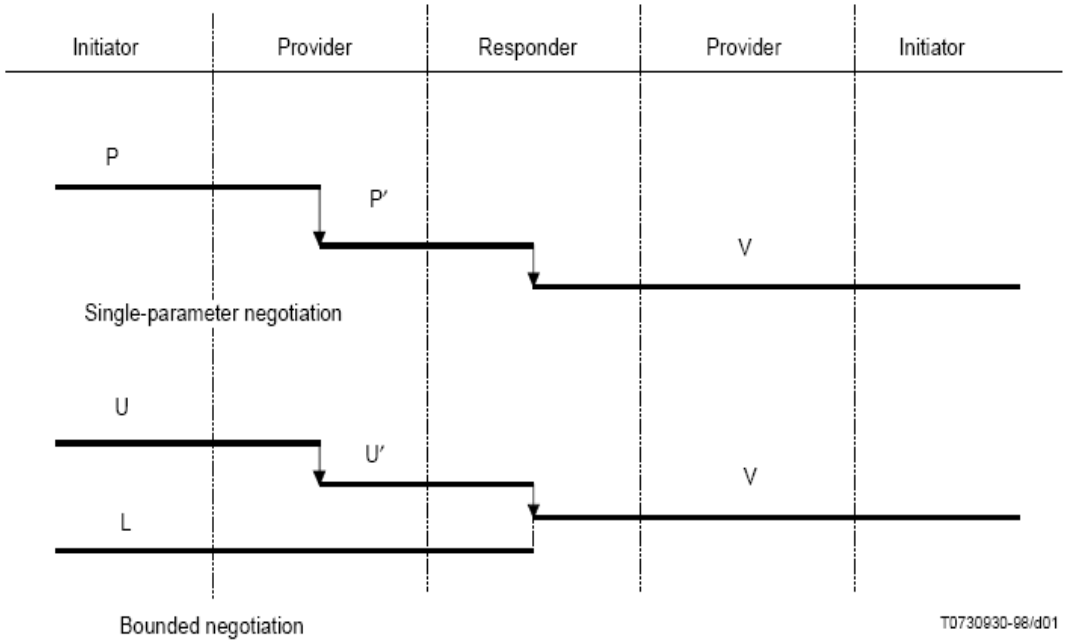

Figure 2.1 - QoS values negotiation

The two mechanisms can also be realized by adopting some restrictions, which may depend on the behavior of the parties: for example, *bilateral negotiation mechanisms* is a restricted version of the mechanisms described above and stipulate that the provider does not modify the values received by the initiator and pass them to responder, leaving them unchanged. In addition, a user could only negotiate thresholds with the provider if the user wishes to be informed when the QoS reaches a certain level.

2) QoS negotiation in 1xN multicast connection

A 1xN multicast connection is a special case of multipeer communication and provides a connection between a sender and N receivers. In establishing this kind of connection, there is a first problem about the QoS negotiation and the selection of participants to connection, for example, a QoS requirement imposed by the sender may be beyond the capacity of providers in some regions and then some receivers could be excluded from the connection. The negotiation in a 1xN multicast connection involves a choice between two mechanisms, as also mentioned in the QoS Framework [2]:

- *connection-wide*, where the same value for the QoS characteristic between all participants in the connection is negotiated;

- *receiver-selected*, where separate values of QoS characteristic are negotiated for each receiver, representing an agreement between the sender, the service provider and the particular receiver.

The mechanism of connection-wide negotiation can be applied to QoS characteristics:

- that specify attributes apply to the 1xN multicast connection as a whole (such as *security* or *confidentiality* of data);

- for which the value perceived by the receiver is dependent upon the behavior of the sender or of the service provider as a whole, or for application reasons must be the same for all receivers. Examples could be *throughput*, in cases where data may not be lost, or *transit delay*, in cases where it is required to ensure synchronization across multiple receivers.

Receiver-selected negotiation mechanisms may be applied to those QoS characteristics for which there exists no application requirement to agree on a connection-wide value. Examples could be *transit delay* or *throughput*, if loss of data can be tolerated.

In addition, receiver-selected negotiation for a 1xN multicast connection is performed for each of the N receivers independently: the *three-party negotiation* can be used for each of N negotiations.

For the mechanisms of connection-wide negotiation is necessary to extend the mechanisms described above (*single parameter* or *bounded negotitiation*) to ensure that a common single QoS agreement is negotiated to all recipients and that the negotiated value is consistent with each constraint identified during the negotiation process (for example, a limit on the local capacity of provider to one of the receivers).

When a QoS characteristics is negotiated through the connection-wide mechanism, it's necessary to inform all participants of the outcome of the three-party negotiation.

We define five mechanisms:

- *single-parameter negotiation*, that includes the negotiation of the upper limits provided by the parties and not be imposed lower limits;
- *bounded negotiation of a lower limit* or a lower threshold;
- *bounded negotiation of an upper limit* or a higher threshold;
- *bounded negotiation of an operational target* (operating target);
- *negotiation of the combined upper and lower limits*.

When we have many receivers with different properties in different environments, **QoS filters** can be used. A QoS filter can support different levels of QoS for different receivers in the same multipeer group. The differences between the receivers can be related to the end systems, network or user applications. Participants to the connection are not aware of the use of filters: in fact, the source can provide a stream of data to a single level of QoS while the N receivers receive the stream flows unfiltered or filtered at different levels of QoS.

The Report also provides a list of different types of filters that can be adopted according to data stream characteristic that they alter, for example, a filter that acts on the *throughput* could discard data for some peer to meet some of the constraints on throughput imposed by other participants and ensure them a greater flow of data.

3) QoS negotiation in a MxN multicast connection

In this case, there are M stations (<N) who want to transmit to N stations in multicast mode. The M stations are called "*focal stations*." Depending on the case, the N stations may be able to transmit in unicast mode to the other stations. The QoS negotiation is on the M multicast connections. One of the focal station is chosen as the "*owner*" of the multicast connection and typically, the owner station has a special role in initiating and terminating multicast establishment procedures, in order to ensure that the group membership rules are correctly applied and that the procedures terminate correctly.

Two types of procedures can be used to negotiate QoS characteristics in this case:

- a "*Step wise arbitration*" procedure, which is composed of superimposed 1 × N negotiations and can make use of the mechanisms of negotiation or connection-wide-receiver selected.

  In this case, the station owner does not operate in the negotiation.
- an "*Owner arbitration*" procedure in which the owner station controls the individual MxN negotiations.

2.2.2.2 Mechanisms for resource allocation

As mentioned in the QoS Framework [2], the establishment phase includes the QoS mechanisms for resource allocation. One of this mechanism is the *Resource Reservation Protocol* (RSVP).

2.2.2.3 Initialization mechanisms

As defined in the QoS Framework [2], the QoS establishment phase includes the initialization of operational phase mechanisms. Typically this is achieved by local means that are not subject to standardization.

2.2.3 Method and mechanism for operational phase

The mechanisms for the operational phase include:

- monitoring mechanisms;
- mechanisms for maintenance, such as *resources allocation*, *admission control* and *tuning*, which aim to meet the desired levels of QoS;
- filters, mechanisms that manipulate information in order to alter certain properties related to QoS and implement an intelligent selection of data, a conversion of data or split the flow of data;
- enquiry mechanisms;
- alerts mechanisms.

2.3 QoS verification methods

The QoS Framework [2] considers QoS verification as an independent activity, or outside of the prediction, initialization and operational phases because they focus on services already available.

The verification of QoS, as mentioned in [2], is performed at different stages of the service implementation life cycle, starting from the service designing and then performed at the end of deployment to execute the testing and, finally, when the service is made available to users.

2.3.1 QoS verification at the design stage

The service design phase of the service lifecycle starts from a set of requirements on the service and derives a complete system design. The design process is characterized by stepwise refinement, and involves a formalization of informal service requirements.

At the end of the design phase, there is a verification that the system (resulting from the design) actually meets the desired service requirements.

The requirements of the service are related to the expected behavior of the system but also to non-functional aspects such as reliability, security, etc.

The design verification starts by the set of service requirements, functional and non-functional, and a model of abstract service that separates the two types of requirements is built. Through the formalization of the functional behavior of the system, the QoS characteristics are underlined and assigned them the values that respond to user requests.

The designer also adds to the model information about the performance and the end result of the process is *performance enhanced model* of the service.

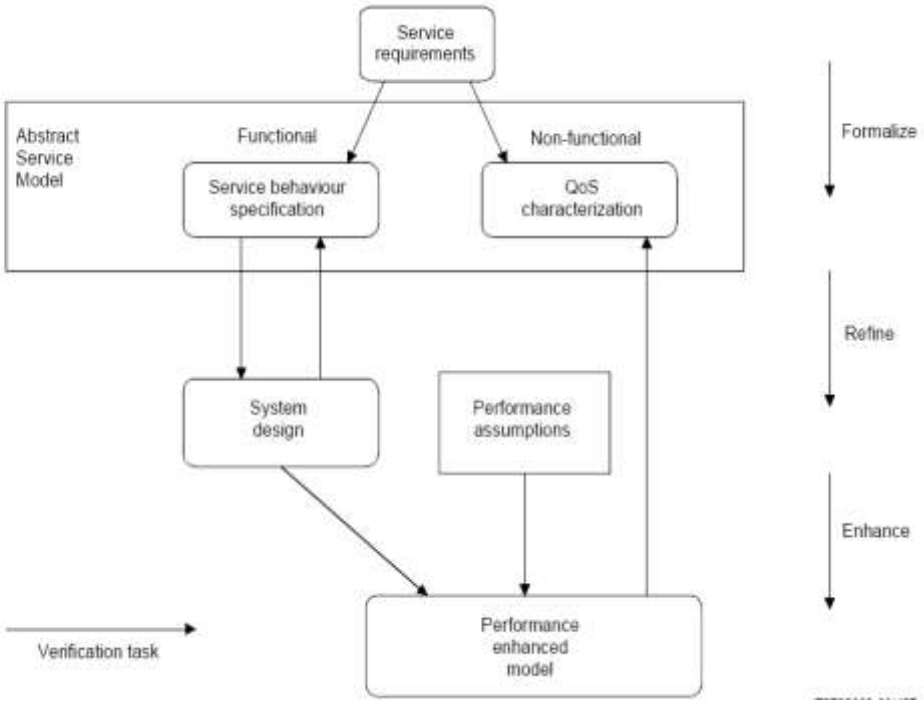

Figure 2.2 - Model of QoS verification at the design stage

2.3.2 QoS verification at testing stage

During the testing phase, the objective of QoS verification is to ensure that the implementation of the service covers all the QoS requirements.

The figure below shows a distributed architecture for QoS testing. The *Service Under Test* (SUT) has access to their service resources. The role of service users is covered by *Local tester* and gray ovals representing the measuring points between *Local testers* and *SUT* for measuring the QoS provided by the service, while the ovals between the SUT and resources are used to measure the QoS received by the service resources.

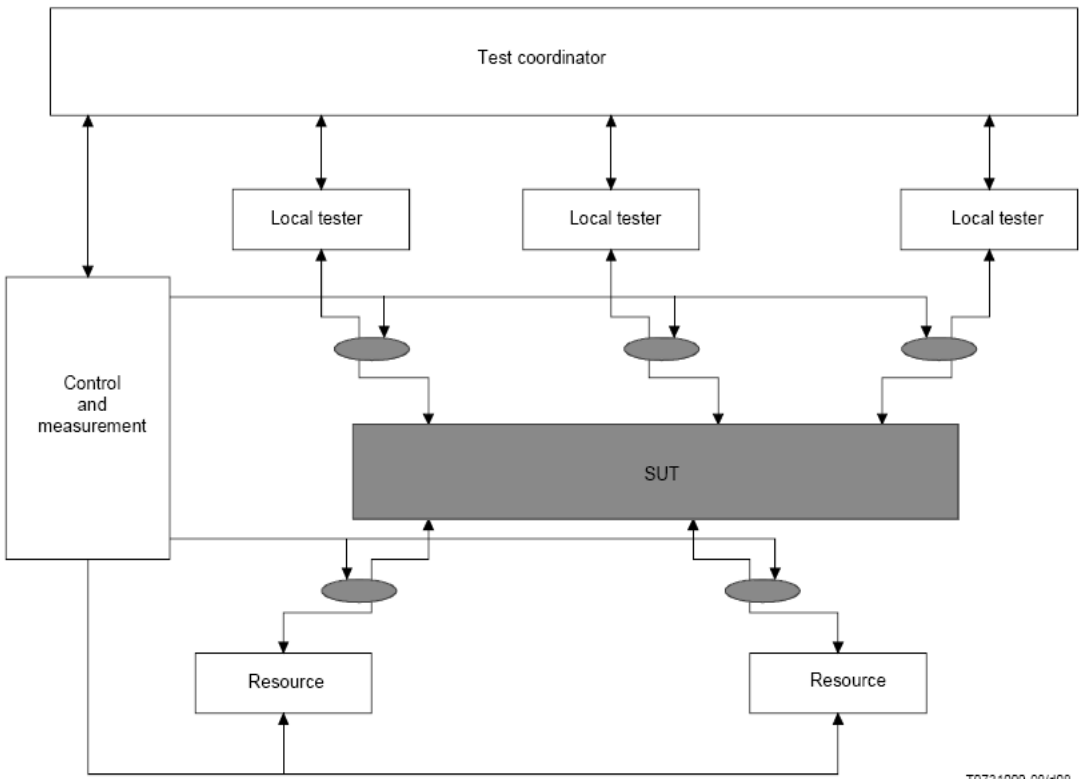

Figure 2.3 - Model of QoS verification at testing stage

2.3.3 QoS verification at the operation stage

If a service that offers the QoS is based on the *best effort* might not be able to guarantee a certain level of QoS and the resulting QoS presented to the user may be different from the requested value. A service that offers a *guaranteed* level of QoS should monitoring the QoS provided to the user and the QoS actually received by services resources continually.

When certain threshold values are reached, actions according to a predefined policy (e.g. reservation of additional resources) could be taken and internal management mechanisms used to keep to the contracted level can be used.

3. ITU-T Recommendation G.1000 (11/2001) Communications quality of service: a framework and definitions [4]

3.1 Introduction

ITU has developed a **Recommendation** to provide a Framework and definitions for the QoS and establishing an uniform approach to quality of service, so as to remove the confusion resulting from different Framework and inconsistent definitions.

A consistent approach to QoS can be used to plan and developing new networks and monitoring the quality of service on existing networks.

The document illustrates a matrix that can be useful in determining the QoS **criteria** for communication services. QoS criteria are similarly intended to QoS *characteristics* mentioned in [2] because they represent some aspects of QoS of a system, service or resource that can be identified and quantified.

The QoS criteria of a telecommunication service can be determined using the following matrix. The matrix is useful to identify the users QoS criteria before launching a new service. This matrix may be used for any telecommunications service to determine the requisite QoS criteria. After determining the quality criteria, parameters and performance objectives set can be defined.

		Service quality criteria						
		Speed 1	Accuracy 2	Availability 3	Reliability 4	Security 5	Simplicity 6	Flexibility 7
Service function								
Service management	Sales & pre-contract activities 1							
	Provision 2							
	Alteration 3							
	Service support 4							
	Repair 5							
	Cessation 6							
Connection quality	Connection establishment 7							
	Information transfer 8							
	Connection release 9							
Billing 10								
Network/service management by customer 11								

Figure 3.1 - Matrix to facilitate identification of communications QoS criteria

The document presents four points of view of QoS that make significant the definition of quality for all entities involved in a communication system: user, network operator and service provider.

The document, as we said, describes the quality of service from different point of view, repeating the concept already introduced, that QoS can be analyzed from different perspectives that reflect the vision of the provider and user. Furthermore, the document is linked to the previous for the definitions of quality and service quality, making reference to [1].

There is no reference to the concepts introduced in QoS Framework [2] like categories, management functions, QoS mechanisms but the document aims to clarify what is understood as a QoS criterion in telecommunications.

In this report, however, the goal is not down in detail in the particular service (telecommunication service or other) but it would leave the analysis to a very general level.

In addition, the document aims to be a reference to support network planning, development of networks and monitoring the quality of service but it is limited only to describe the perspectives for QoS and it doesn't consider any mechanism, procedure or strategy that we must follow to ensure a certain level of quality for a system; it seems to be rather brief to represent a Framework that would provide an applicable approach to a variety of communication services.

3.2 Four viewpoints of QoS

According to this ITU recommendation, there are four different viewpoints of QoS:

- **customer's QoS requirements**, a statement on the level of quality required by applications used by a user of a service, which can be expressed in non-technical language;
- **QoS offered by service provider** (or planned/targeted QoS), a statement of the level of quality expected to be offered to the customer by the service provider;
- **QoS achieved or delivered by the service provider**, a statement on the current level of quality achieved and provided the user;
- **QoS perceived by customer**, a statement on the level of quality that the user experiences. This definition of QoS perceived by customer approaches to the definition of *QoE* mentioned above, described as the quality resulting from the comparison

between what he would like that the product offered (or expectations), and his perception of current performance of the product.

The figure below shows the relationship between the four viewpoints of QoS.

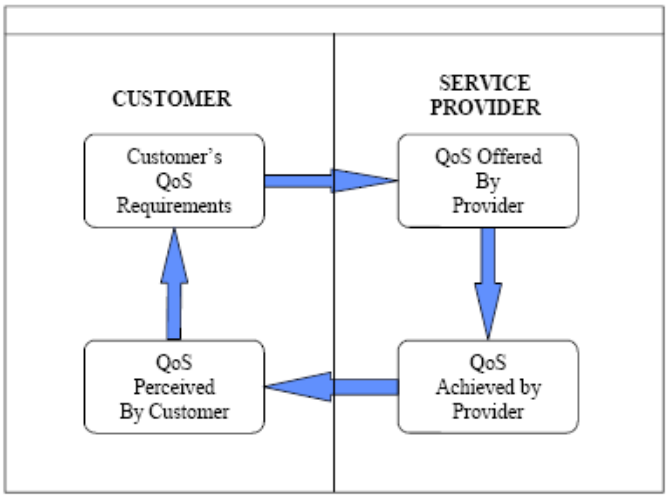

Figure 3.2 - Four viewpoints of QoS

3.2.1 Customer's QoS requirements

User QoS requirements express the level of quality required by a particular service, which can be expressed in non-technical language. The customer is not concerned with how a particular service is provided, or with any aspects of the network internal design, but only with the resulting *end-to-end* service quality.

The quality for users is expressed through parameters affecting aspects of service from his point of view and on the results received by himself.

3.2.2 QoS offered by service provider

QoS offered by service providers is the level of quality that the provider aims to offer to the customer. This level of quality is expressed by values assigned to the QoS parameters (*reliability*, *flexibility*, *security*...). This can be a basis for ensuring the *Service Level Agreements* (SLA).

Each service has its own set of QoS parameters. The service provider can express offered QoS in terms non-technical for users and in technical terms for the company.

3.2.3 QoS achieved or delivered by service provider

QoS delivered by the service provider indicates the quality level achieved in a given time and provided to the user. This is expressed by values assigned to the parameters, which should be the same specified in the offered QoS: we can then compare the values of the parameters of offered QoS with the values of the parameters of achieved QoS to determine the performance.

3.2.4 QoS perceived by customer

The QoS perceived by customer expresses the level of quality experienced by the user. It is expressed in terms of degrees of satisfaction and not in technical terms: it can be assessed by customer surveys and from customer's own comments on levels of service.
The perceived QoS can be used by the service provider to determine user satisfaction of the service quality.

3.2.5 Relationship between the four viewpoints of QoS

Customer QoS requirements can be considered the starting point for the definition of QoS, a subset of them is the input for the provider of service for determining the QoS to offer the customer. The service provider may not always be in a position to offer customers the level of QoS that they require: consideration such as the cost of quality, strategic aspects of business or other aspects may influence the offered level of quality. The requirements may also play a crucial role in the monitoring of a system in order to describe the actual achieved quality.
Relationship between the different perspectives provide the basis for a practical and effective service quality management.

4. ITU-T Recommendation E.860 (06/2002) Framework of a service level agreement [5]

4.1 Introduction

In recent years, we have seen an exponential growth of the services offered by the network and, consequently, the increasing competition, promoted also by performance user requirements, produces a great pressure upon network/service provider. The latter, having committed especially in reducing costs in recent years, nowadays they must focus on improving QoS to differentiate its products from those of their competitors.

Moreover, the situation is complicated by the growing demand for global services involving many providers. Then, the roles of all entities involved in the provision of a service and relations between them must be analyzed. The objective is to identify the responsibilities of each provider and ensure the QoS required from user.

A useful instrument in the formalization of that relationship between the entities is the ***Service Level Agreement*** **(SLA)**, which is the result of a negotiation between two or more parties with the aim of reaching a common understanding about service provided, its quality, different responsibilities and priorities, etc..

This recommendation describes the general structure of a SLA, adopting an approach independent of the type of service and technology used. This approach is especially useful in *multi-provider* environments (or environments where the user does not receive the service from one provider but from different ISPs), which are becoming a very frequent reality.

The document introduces and resumes the terms and definitions for QoS, describes the structure of a SLA, its components and its application in a multi-provider environment, explaining the concept of *one stop responsibility*.

4.2 Quality of Service definitions and terms

The standardization of terms and definitions concerning QoS is important for two main reasons:

- to avoid the confusion introduced by contrasting terms and definitions;
- to maintain the consistency between different groups involved in the development of telecommunication standards.

The following definitions are extracted from the ITU E.800 [1].

4.2.1 Entity

An *entity* is a generic unit involved in using/providing a service.

It's characterized by its states and transitions (as shown below) and interacts with other entities through its results (*outputs*).

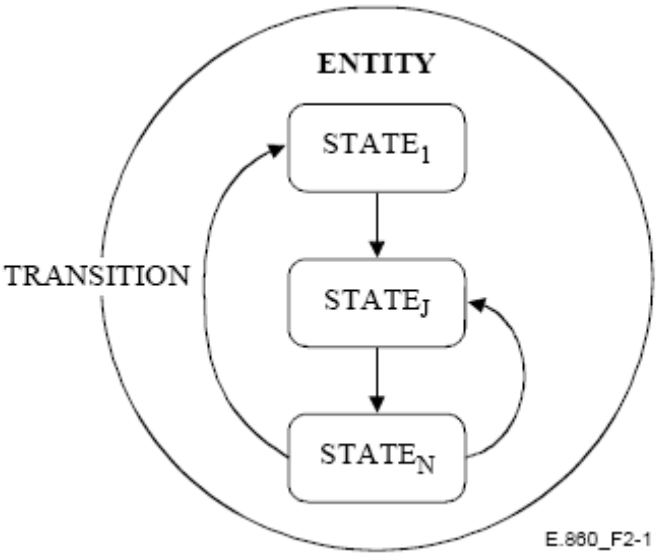

Figure 4.1 - Entity states and transitions

An entity that provides a service to another entity is called ***Provider*** while an entity that receives a service is called ***User***. The term user indicates an end user, a regulatory authority (for example, the authority for the guarantee of communications, which regulates competition between different providers and protecting the rights of users) or a service provider (the latter, when receiving service from another provider, behaves as if it were a user).

4.2.2 Interaction points and interfaces

An ***interaction point*** is a point where two entities can exchange information.

A group of interaction points at the logical boundary between two entities is an ***interface***.

Figure 4.2 shows the points of interaction of an interface.

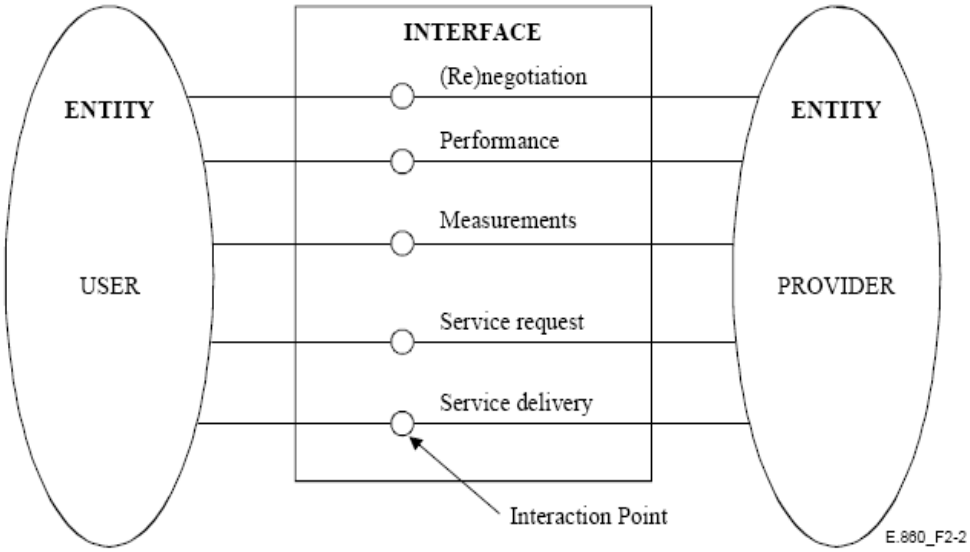

Figure 4.2 - Interaction points and interface

Sometimes, an interaction point between user and provider may not belong to their logical interface although this point remains under the control of the provider.

Interaction points can be located on a horizontal interface (between domain of the same functional level) or on vertical interface (between domains of different functional level) as shown in Figure 4.3.

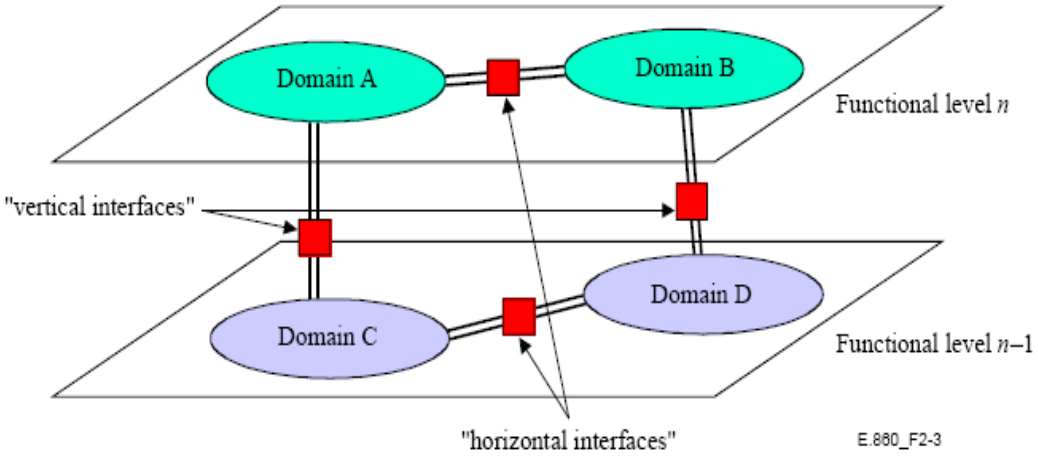

Figure 4.3 - Vertical and horizontal interfaces

It is often useful to group multiple entities together in one; obviously, the corresponding interfaces should be redefined in a convenient way.

4.2.3 Service, service element and Service Access Point

A service is a group of functions provided by an organization to a user through an interface.

Interaction points localized on the interface between the service provider domain (**SP**) and the user's domain are called ***Service Access Point*** **(SAP)** and represent the points where the service is delivered. The definition of SAP is very important because all components of the service located between the SAPs in SLA are under the responsibility of the SP. More SAP can be grouped into a ***SAP GROUP*** to guarantee certain levels of performance.

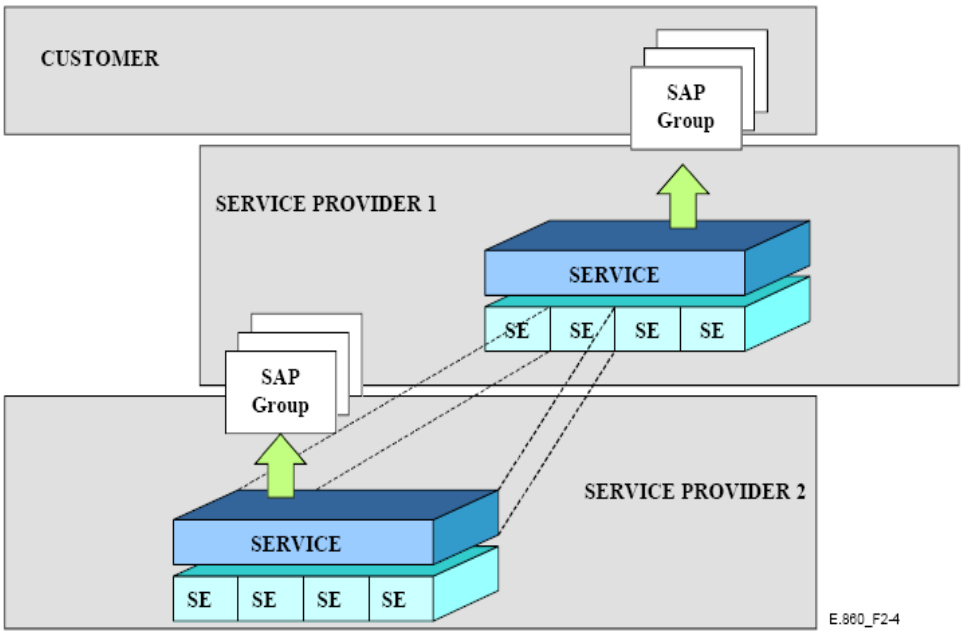

Figure 4.4 - Service composition

The example in Figure 4.4 shows a user who buys a service from SP1 concluding an agreement that contains the responsibilities and obligations related to QoS; in respect of this agreement, the performance parameters can be provided in correspondence of SAP group by the provider to the user. To deliver the service, the SP1 combines several ***service elements*** (**SE**), which may be at its own disposal or obtain them from other providers.

4.2.4 Quality of Service

Quality of Service is defined in E.800 [1] as "*the collective effect of service performance which determines the degree of satisfaction of a user of the service*."

To get a definition used in an SLA, in this recommendation the QoS is described as "*degree of conformance of the service delivered to a user by a provider, in accordance with an agreement between them*": this definition can be considered a subset of the previous definition. The second definition of QoS is more market oriented, although, in both definitions, QoS is assessed from the user viewpoint (we could consider QoE): this is, in fact, the factor that determines the success or the failure of the service, as already emphasized several times.

4.2.5 Relationship between Quality of Service and Network Performance

The overall quality of a telecommunication service, as perceived by the user, is influenced by many factors related to the performance parameters of the network.

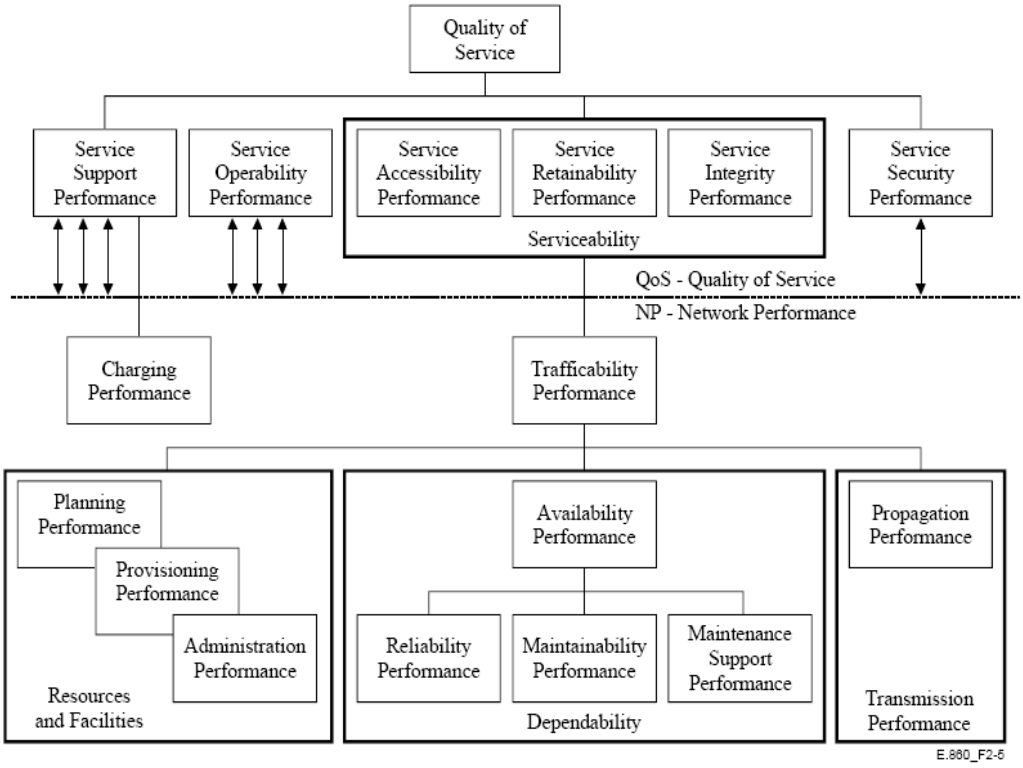

Figure 4.5 - QoS parameters organization

Figure 4.5 shows the many characteristics of a telecommunications service: for the definitions and concepts in the figure we can be to refer to [1].

The essential aspect, while estimating a service, is the user opinion and his satisfaction to the provider, which is the only entity that directly interacts with him. The level of satisfaction comes from the perception of various aspects of the service (support, operability, serviceability, security) which are influenced by the characteristics of the network.

The purpose of this recommendation is not take into consideration the performance of the terminal user but it is referred to the end-to-end network quality, as perceived by the end user.

4.3 Description of a Service Level Agreement

A *Service Level Agreement* is a formal contract between two or more entities, reached after a negotiation, in order to determine the characteristics of the service, responsibilities and obligations of each party. An SLA may include statements about performance, billing, service delivery and compensation (for example, how to compensate a level of quality unreachable).

Every report on performance may include only QoS parameters agreed in the corresponding SLA. The part of a SLA, referring to QoS is called *QoS Agreement* and includes a formal program agreed between two entities to measuring, monitoring and deciding the parameters of QoS with the aim of achieving the QoS required by end user and determine its satisfaction .

4.3.1 Structure of a SLA

A SLA refers to all services exchanged between two entities (*multi-service SLA*) and is made up of one common part (*Service Level Agreement*) and other service specified parts (*QoS Agreement*).

This approach avoids repetitions and simplifies the addition of new services in the SLA.

The general structure of an SLA is illustrated in Figure 4.6 and shows both the common parts and specification parts:

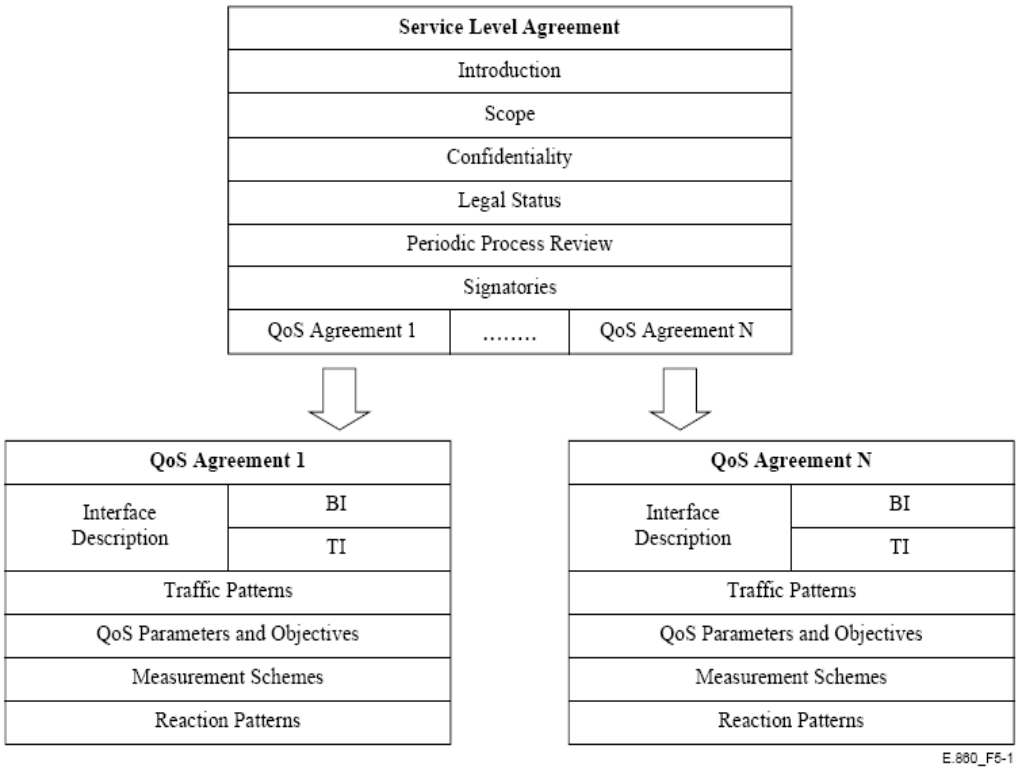

Figure 4.6 - Generic structure of a SLA

The common part of the SLA, the *Service Level Agreement*, consists of:

- *introduction*: describes the purpose of the SLA, which can be:

  - to define service levels that all entities must guarantee for user satisfaction;

  - assisting two entities (user, network/service provide) in exchanging information with suitable QoS and Network Performance;

  - to provide base notions and measurement and parameters for the realization of the agreement.

- *scope*: it describes, in general manner, the service which the SLA dealt with and the target performance.
- *confidentiality*: it specifies the treatment of the agreement and the sharing of information between the parties involved. It's in the interests of all parties that confidential information is not available to entities which are not part of the agreement (for example, an SP who is the competitor should not become aware of confidential information). This does not apply to public SLA signed with Regulatory authority, which collect information in the public domain.
- *legal status*: it defines legal aspects of the agreement.

- *review process*: it defines the frequency (daily, monthly, yearly) and the format (paper or electronic) with which QoS information has to be exchanged. It can also specify the frequency of revisions of the QoS agreement, so that it can be up to date with new technologies and user expectations. This part of the SLA can be optional.
- *signatories*: authorized representatives of all parties could sign the agreement to ensure all obligations taken by the parties.

The part on each *QoS Agreement* include:

- *interface description*: an interface is the logical boundary between the two entities and is composed of a group of interaction points. These points are always near the user's domain and allow him to exchange information with the service provider that, at least virtually, controls all points of interaction.

  According to the type of information exchanged, can be distinguished in:

  - *business interface* (BI): interface consists of interaction points always located between user and SP, used for specific QoS agreement functions as well as the negotiation, the report on performance and reaction patterns (the latter are activated when the level of QoS agreed is not provided).

  - *technical interface* (TI): its interaction points exchange service specific information and allow measurements from which to derive the QoS parameters. Sometimes interaction points did not affect the primary SP if part (or all) of the service is delegated to sub-providers.

  It will clarify the difference between the two types of interfaces with the following figures.

  In the case in figure 4.7, the user negotiates an agreement (SLA1) with SP A for the supply of a service; on its side, SP A buy one or more SE from SP B and agrees SLA2 with the latter.

  Of course, every SLA implies the existence of a BI between the corresponding entities (pair user-provider).

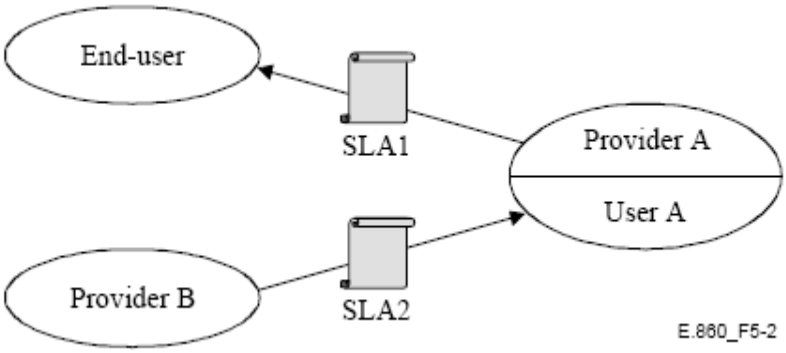

Figure 4.7 - Business relationship between entities

See now the situation from a technical point of view.

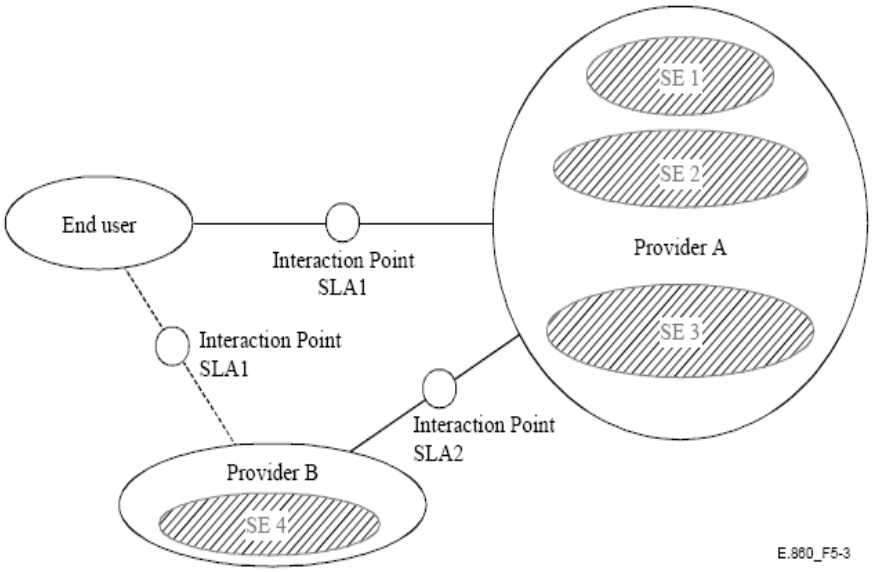

Figure 4.8 - Technical interaction points of SLA1 and SLA2

In figure 4.8 interaction points of IT on SLA1 and 2 are illustrated. For SLA1, we may notice two interaction points: one between the end user and SP A and another between the end user and SP B. The interaction between user and SP B refers to an indirect relationship because there is no real agreement between the two entities. This means that the user should refer only to SP A for all the failures affecting the service even though he receives part of it from SP B. For this reason, indirect relationship with the sub-providers are often hidden to users.

- *Traffic patterns*: in order to manage the resources, each entity must know the characteristics of the traffic that it receives from other entities (the traffic at input points). If we consider also that the outgoing traffic for an entity is the incoming traffic for another entity then the statement "*the QoS agreement must include a description of all traffic exchanged*" is easily justified. Also the conditions or thresholds that allow the activation of reaction patterns by receiving entities must be specified. In this way, when the incoming traffic does not conform to an agreement, the receiving entity can react with specific mechanisms, as well as *traffic shaping*.
- *QoS parameters and objectives*: definition of QoS parameters is a essential moment in the development of an SLA and, in particular, together with its correspondent QoS agreements.

  The behavior of all entities involved with the QoS agreement is influenced by the QoS parameters: for the same reason, once defined, the QoS parameters must be expressed in a clear and convenient way, with a simple language for end-user and a more technical for service providers.

  The QoS is evaluated by assigning values to the appropriate QoS parameters: also in [2] it was underlined that the parameters express a precise characteristics of the service, as the maximum tolerable transmission delay. As mentioned earlier, the QoS is affected in a more or less direct manner, by network performance. This leads to classify the QoS parameters such as *direct* or *indirect* where:

  - *a direct parameter* refers to a specific SE and it is determined by collecting direct observations of events at its points of interaction.

  - *an indirect parameter* is defined as a function of other direct parameters.

  The objectives of QoS can be expressed as target values, thresholds and intervals set of QoS parameters.
- *Measurement schemes*: once the QoS parameters and objectives have been achieved, the entities should agree upon definitions of measurement and schemes.

  The descriptions of these methods could include a description of what, when, where and who could perform the procedures for measuring and testing

processes and how they might be made the measurements is not specified as this depends on specific technologies and is not of interest the user. In general, measurements for a primary parameter of QoS are carried out at specific *measurement points*. These points are simple interaction points where the events of reference and their results can be observed. Once obtained the primary QoS parameters, parameters of the second-level can be derived as functions of these values.

Typical measurements made on the network may include:

- service provision;
- service restoration;
- fault occurrence rate (reported by users and/or detected by the network);
- availability of interconnections;
- reports on the problems of clients (complaints and/or errors);
- traffic performance.

Furthermore, in order to consider QoS from the perspective of the customer, survey of market addressing the users can be very useful.

- *reaction patterns*: a *reaction* is a process that is activated in a more or less automated way whenever agreements on traffic patterns and on QoS parameters are not fulfilled.

  The typical examples are:

  - the reactions of the provider on incoming traffic which differs from the description in the SLA;
  - the behavior of a user when the service provider does not provide the QoS agreed in the SLA.

  In general, to describe a reaction, we can imagine a process with input, patterns of reaction and output, as shown in Figure 4.9:

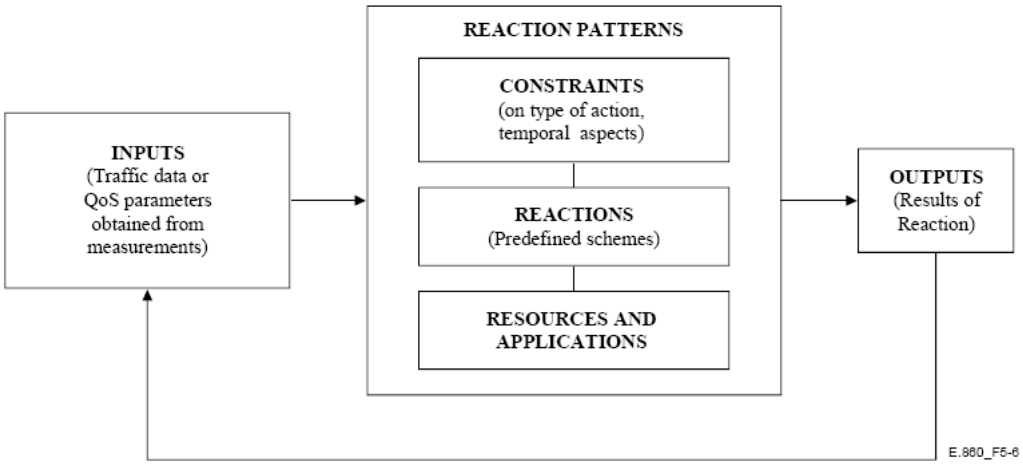

Figure 4.9 - Reaction patterns

On the input side, measurements are made on QoS and on traffic to detect errors, incoming traffic does not conform to the agreed model of traffic or inadequate QoS. Once the measures are obtained, they are compared with target values in the SLA (constraints). The output of the reaction is obtained by the results of the comparison and the available resources. Possible outputs of reaction are:

- no action;
- monitoring the achieved QoS;
- adopt policies of traffic through the traffic modeling and/or admission control;
- reallocating resources;
- warning signals to users/SP when thresholds are reached;
- suspending or aborting the service.

4.3.2 A general procedure

A procedure that allows to apply in an efficient way the structure of the SLA proposed before can be illustrated in Figure 4.10. The *input* includes a description of the service, the entities involved, a description of their roles and their relationships (the so-called *Business Model*). The procedure identifies the service elements provided to the primary provider by its sub-provider and all the interfaces (both BI and TI) that will be used. The *outputs* are the service delivery configuration with the description of a SLA for each pair user-provider identified during the procedure.

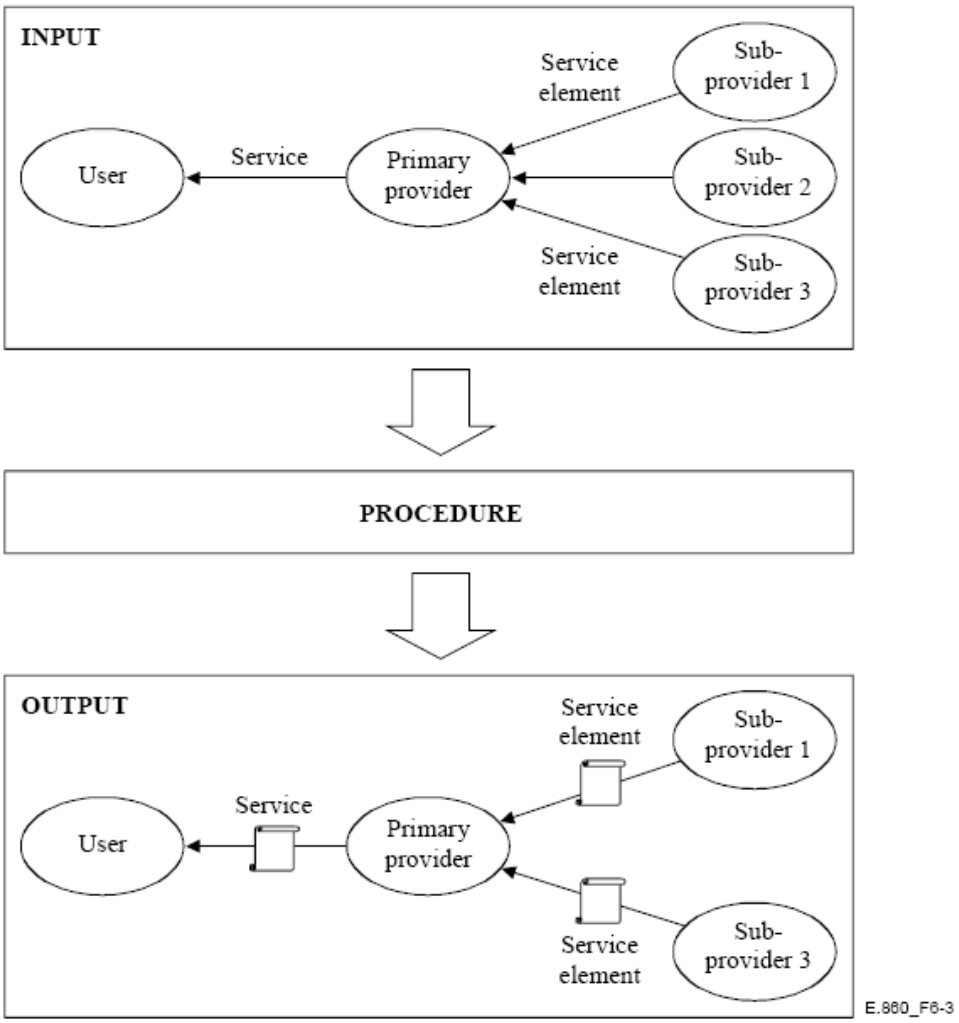

Figure 4.10 - Methodology for SLA process

A way to implement a similar procedure can be illustrated in Figures 4.11 and 4.12, where we can see two main steps: the first attempts to identify the SLAs to be concluded and the second step regulates the conditions in each SLA.

In particular, in Figure 4.11 the relationship between user and provider and technical relationship between the provider and its sub-providers are identified, to try to make these relationship in terms of a SLA and it decides if it's necessary to open a new contract because the old SLA has to be reformulated.

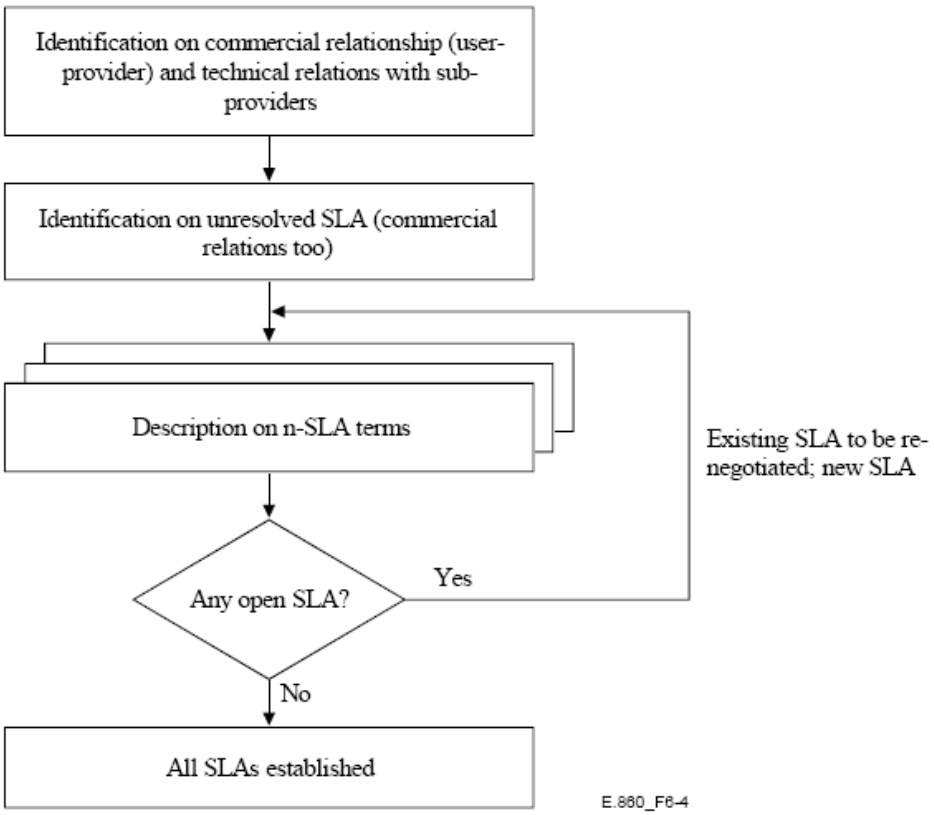

Figure 4.11 - Step 1,individuaction of relevant SLA

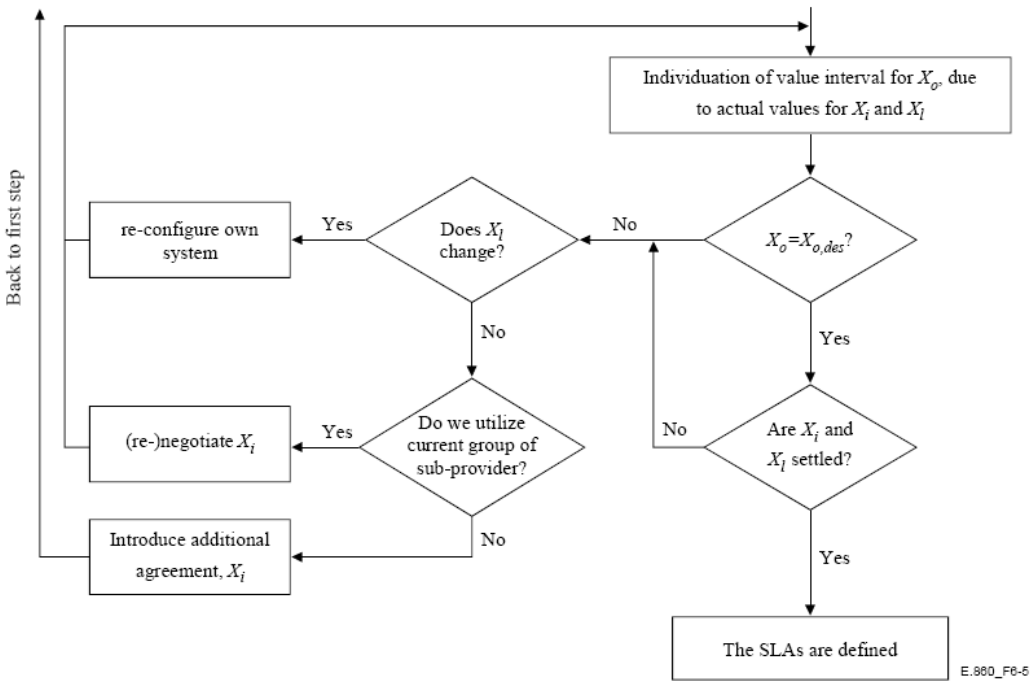

Figure 4.12 - Step 2, individuation of the SLA content

In figure 4.12, $X_{o,des}$ is the agreed QoS level between primary provider and end user, X_i e X_l represent the QoS levels that primary provider obtains, respectively, from its *sub-provider* and by the resources in its domain while X_o is the QoS actually delivered to end user. The viewpoint is that of the primary provider.

4.4 Approach to *multi-provider* environment

In a multi-provider environment, the relationship between different SPs can be very complex. A primary SP which wants deliver a service to a user, often uses the SE provided by other SPs and consequently it becomes more complex to ensure the level of QoS stated in the SLA. Then it's necessary to define the responsibilities of all entities involved in service delivery and, above all, to coordinate all activities to achieve the agreed levels of QoS.

To simplify the resolution of this problem, we can apply the concept of "*one stop responsability*". This concept is based on SLA signed between the two entities and especially on QoS conditions.

The possible content of an SLA is illustrated in Figure 4.13:

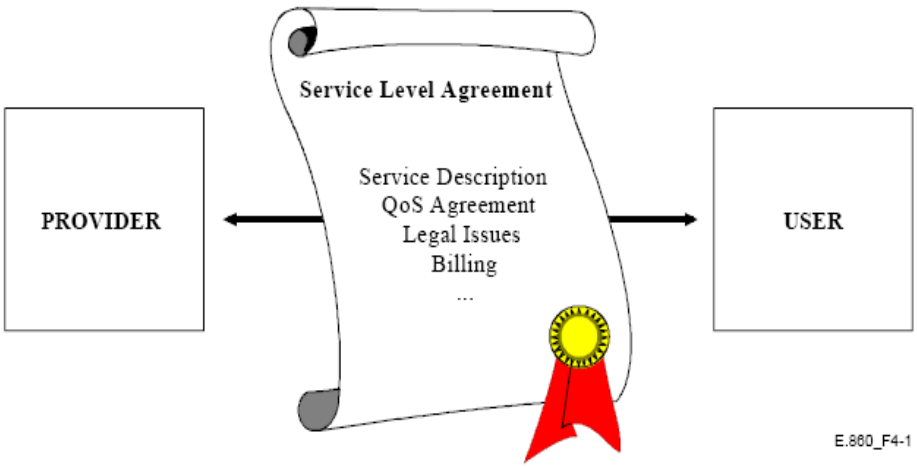

Figure 4.13 - *One stop responsability* and SLA

The mechanism of one stop responsability, agreed between provider and user in the SLA, allows a user to consider a primary service provider (which provides the SLA) as the only responsible for the overall QoS received. In this way, the primary provider, since problems that occur depend on the services received by the other SPs, can apply

the technique of one stop responsability to its sub-providers. Applying the one stop responsability in a recursive way to any entity (provider and sub-provider) involved in providing the service, the service agreed with end user is guaranteed.

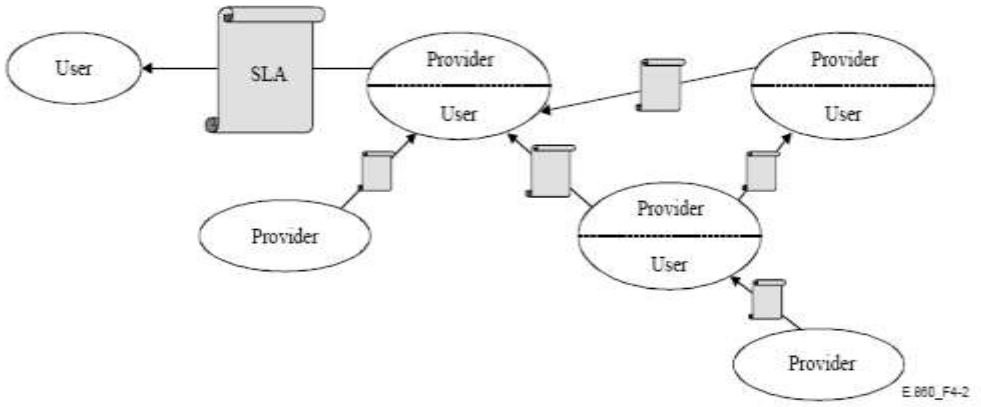

Figure 4.14 - Application of the *one stop responsability* concept

In this way, with one stop responsability and the recursive application of SLAs, the complex problem of providing the service in a multi-provider environment is decomposed into elementary relationship between entities (pair user-provider). However, this implies that the primary SP could provide a flexible QoS to its users because the quality of the service elements (provided by its sub-provider) can oscillate within the agreed intervals.

We consider when a SLA between end user and service provider is agreed, for a connection that goes through different SP domains. A traditional approach to the multi-provider environment consists to realize an association between the entities (SPs) in which all the parties agree on a common document (the *end-to-end* SLA, described in the next paragraph) which concerns parameters, goals and techniques for measuring QoS. The document is then used to formulate the SLAs between each pair of entities and between the entities and their customers. This approach ensures that end-to-end QoS of connections that pass through different providers, will meet the agreed QoS with the end user in the SLA.

Figure 4.15 illustrates the scheme just described.

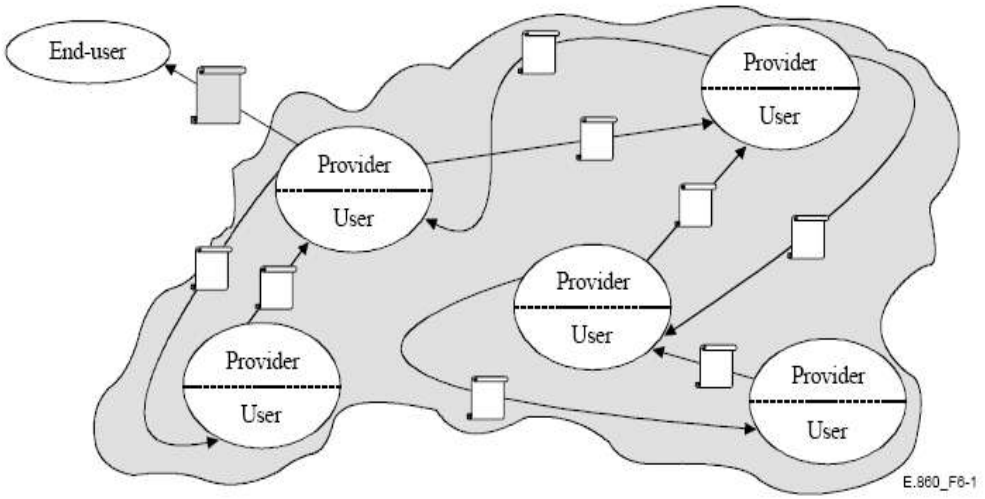

Figure 4.15 - Association of entities involved in realization of end-to-end QoS

Another method, which is a special case of the previous, is to create a chain of SLA between each pair user-provider involved in providing the same service. The chain starting from the SLA between the end user and the primary provider that states the end-to-end QoS; for its side, the primary provider, taking into account the promised performance will contracts SLAs with the sub-provider and so on the mechanism continues in a recursive manner.

The 4.16 figure is a representation of the chain of SLA.

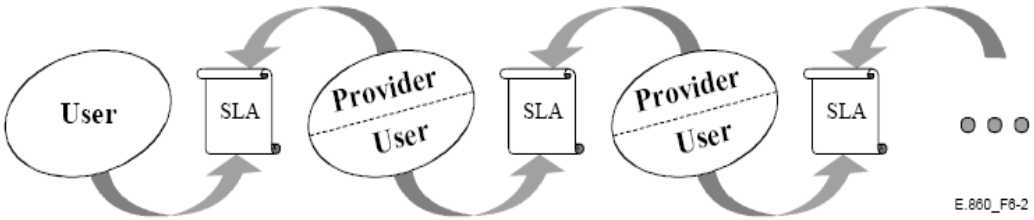

Figure 4.16 - Chain of SLA

4.5 End-to-End Service Level Agreement

Sometimes, in a connection end-to-end, in addition to SLAs between each pair of entities involved, it is also useful to have a **End-To-End SLA** as mentioned in the previous paragraphs.

This report is a SLA between all entities in order to reach a common understanding about QoS issues.

Some of the issues addressed by this SLA can be:

- type of service;
- technical constraints;
- definition of QoS/performance parameters for the end-to-end relationship;
- notification of action in case of problems;
- common management policies;
- security.

5. ITU-T Recommendation E.802 (02/2007) Framework and methodologies for the determination and application of QoS parameters [8]

5.1 Introduction

The ITU-T recommendation E.802 provides a Framework and methodologies for the identification of QoS **criteria** relevant to users and a guideline for the conversion of these criteria in QoS parameters that can be used to evaluate the QoS of telecommunication services.

The guidelines also help to extrapolate the user requirements for QoS and to assign priority to different parameters.

A **QoS parameter**, in this recommendation, is *a definition of the scope of a QoS criterion with clear boundaries and explicit measurement method to enable a quantifiable or qualifiable value to be assigned*.

It's important to clarify if this definition of parameter differs from that of the standard [2] and what relationship between the definitions of parameter, feature and QoS policies exist.

The definition of QoS parameter, previously provided by the standard [2], is the following: *an information on QoS shared between entities that is part of a QoS mechanism and may be related to one or more QoS characteristics*.

A QoS **criterion**, as we said in [4], can be understood as a QoS **characteristic** (which in [2] is *the set of some aspects of QoS of a system, service or resource that reflect a real aspect of entity*) and, in this view, the two definitions of parameters could represent the same concept as having the effect of making the criterion or characteristic measureable.

It can therefore achieve the following interpretation: a QoS criterion (or characteristic) (for example, the *transmission delay*) can be measured by the value that assumes the QoS parameter (for example, the *maximum transmission delay*) and this represents the objective of the QoS criterion.

The document is presented as an extension of **ITU-T Recommendation G-1000** [4], where the QoS criteria have been only mentioned (in the description of the identification criteria matrix) but nothing has been said about how those criteria should

be translated into QoS parameters.

QoS criteria are interesting for both users and service providers and, initially, are used by network providers/services to ensure users the level of QoS required (for example, the parameters of network performance that contribute to QoS).

QoS criteria are based on "user's QoS requirements," one of the four points of view of QoS mentioned in Recommendation ITU-T G.1000. These criteria, with slight modifications, can be used to express the QoS offered, the QoS delivered and the QoS perceived by user, mentioned in [4].

This Framework introduces three models for the identification of QoS criteria of every telecommunications service. All models, or a combination of them, can be used for a special service to identify most, if not all, QoS criteria.

From a list of identified QoS criteria, we can choose a certain number of them to form a subset of the QoS requirements requested (that may represent the **QoS categories** of ISO standard [2]).

The guidelines explain how to convert the identified QoS criteria in measurable QoS parameters and how to measure these parameters.

QoS parameters can be used for various purposes:

- to specify the level of quality of service in customer telecommunications services contracts or in the description of the terms and conditions of the service;
- to compare the level of quality and quality commitments of services for different service providers;
- to prepare long-term studies on the attributes of quality of a specific service;
- to prepare statistics, reports and publications on the quality of service;
- to make regulatory proposals that include specification of the minimum level of quality (for example, on universal services, regulation of interconnection) and services monitoring through reports on regular basis and statistics for specific situations.

5.2 QoS criteria and QoS parameters

The recommendation provides a set of terms, some of these are already mentioned in previous documents.

As anticipated, the document is related to Recommendation ITU-T G.1000 [4] about the QoS criteria. The definition of criterion is : *a single characteristic of a product or service that is observable and/or measurable*.

The definition is similar to that of QoS characteristic of the ISO standard.

As discussed above, for *QoS parameter* we intend a definition of the scope of a QoS criterion with clear boundaries and explicit measurement method to enable a quantifiable or qualifiable value to be assigned. Therefore, we distinguish in:

- **objective (quantitative) parameters**: parameters that can be measured with instruments and the performance value assigned may be classified as objective parameters.
- **subjective (qualitative) parameters**: parameters that can be expressed using human judgments and understanding may be classified as qualitative or subjective parameters.

In this document, as in the previous document, it gives great importance to the criteria or qualitative parameters of a system and this may reflect the importance of the perception of the user of the system and therefore, the importance of subjectivity, as it is also explained in [6]. If we want that a system meets user requirements, we must try to quantify the subjectivity, the **QoE**.

The Framework provides definitions of functional and non-functional characteristics or criteria which are a very important role for both the user and the service provider and they are the set of QoS criteria that appear in the matrix of Recommendation G .1000 [4].

- **Accuracy**: a performance criterion that describes the degree of correctness with which a function is performed. The function may or not may not be performed with the speed desired.
- **Reliability**: reliability can be interpreted in two ways:

  1) probability that a product or system will perform as required for a specific period of time;

2) the ability to perform the required functions under specific conditions in a given period of time.

- **Availability**: the availability of an item is to be in the state to perform a required function at any given moment of time or in any instant of time within a given period of time.
- **Flexibility**: the degree of variability of a function within the boundaries of technical and operational characteristics of service.
- **Simplicity**: ease and lack of complexity in the benefit to the user of a service function.
- **Security**: security can be:

  1) the protection of information availability, integrity and confidentiality;

  2) the ability to minimize the vulnerability of resources;

  3) the ability to prevent fraud and protection of information.
- **Speed**: a performance criterion that describes the time interval required to perform a function or the rate at which the function is performed. The function may or not may be performed with the desired accuracy.

These quality criteria are also considered in [7] where the quality of the network is divided into four main areas of quality perception by the user and in [4] to describe the quality offered by service providers.

To identify QoS criteria and to determine the objectives and methods of measurement parameters, some basic aspects must be considered:

- QoS criteria may be specified on an *end-to-end* basis, the points at which user's terminals are connected;
- QoS parameters and criteria must be specified in terms understandable to users. Moreover, when necessary, these criteria and parameters must be specified in more technical terms for industrial use; both terms (industrial terms and customer terms) may use the definitions of ITU-T recommendations to remove ambiguities;
- different segments of the population of users can require different orders of priorities for the different parameters of performance;
- different segments of the population may require different levels of performance parameters;

- the QoS profile of a customer may vary with time and it's important for the service provider to ascertain the changing in user requirements. In the Framework for QoS [2] we said that the user requirements are provided to the provider in the form of QoS parameters or QoS context and how they can change over time. The profile consists of an order of priority of the QoS parameters and performance levels for each favorite parameter.

5.3 Identification of user's QoS criteria

Before defining QoS parameters, the relevant QoS criteria for users must be identified. *Three models* may be considered in this process, that refer to a table or a matrix: filling the fields of the matrix or table we can identify the criteria of quality and they can be assigned to the functional elements of the service.

The **functional element** of a service is a uniquely identifiable segment which collectively comprise all the features of the service.

The intention of the matrix is to establish a list with all relevant aspects that could affect the quality of service. The models can be applied by various means, like expert consultations, questionnaires, telephone or face to face interviews, case studies.

The first model, the *universal model*, illustrates the generic categories under which all QoS criteria may be grouped: almost all the QoS criteria can be grouped under the *performance*, *aesthetic*, *presentational* or *ethical* criteria.

The criteria for QoS for each telecommunication service can be determined through an iterative process of evaluation of the problems of each element belonging to the four categories mentioned, in relation to the functional elements of the service.

The second model, the *performance model*, is suitable for services based on the legacy network, both terrestrial and wireless.

The third and final model, the *four-market model* is used for multimedia services over IP networks.

5.3.1 Universal model

In this model, all the QoS criteria can be grouped under four categories: *performance, aesthetics, ethical or presentational* criteria The goal is to provide a structured approach and a model to facilitate the identification of criteria.

Each functional element of the service is examined in relation to the four predefined quality criteria. There is no fixed list of functional elements as they depend on the service under investigation and may change with the service chosen. The functional elements include all components of the service, which together cover all functional aspects of the service and the product life cycle from the provision of the service to the end of its life. Examining the matrix, we can determine the criteria for service related to the list of functional elements of telecommunication service. QoS criteria can be specified as measurable parameters.

The reference table is as follows:

	Quality components and criteria			
	Performance criteria	Aesthetic criteria	Presentational aspects	Ethical aspects
Functional elements				
1. ...				
2. ...				
3. ...				
...				
...				
...				
n. ...				

Figure 5.1 - Universal model

Performance criteria : criteria covering operational and technical factors which are related to telecommunications services. The criteria are used to determine the characteristics of these elements, the way how they perform and meet the expected results. The performance criteria may be quantitative or qualitative or a combination of both. Using the following models (*performance model* and *four-market model*) it's possible to identify the components of these performance criteria.

Aesthetic considerations: criteria and considerations related to ease of interaction between the user and telecommunication service/product and the perception of service/ product by the user. Examples of aesthetic criteria are simplicity, functionality, clarity of design, excellent use of resources, style, etc. The aesthetic quality criteria are less quantifiable than the performance criteria but they play an important role in how an

entity is held in esteem or otherwise.

Presentational aspects: criteria that determine the quality aspects concerning the way in which the service is provided to the customer. Examples of presentational aspects are: service surround, customization analysis, options pricing, etc. ..

Ethical aspects: criteria associated with how the service or product is offered to the user. These aspects can be classified as quality components such as conditions for cutting off service, safety features and so on.

For example, for a mobile telephone service we could have the following format:

	Quality components and criteria			
	Performance criteria	**Aesthetic criteria**	**Presentational aspects**	**Ethical aspects**
Functional elements				
1) Hardware (terminal equipment)		Ergonomic design of handset usability		Disposal and ecological aspects
2) Service usage	Connection set-up and release Transmission quality Fault repair time Service availability		Customization of service features Customization of billing and payments Bill presentation quality	Security features
3) Contract	Supply time			
4) Customer relations	Hotline availability Response time Complaint resolution			Disabling mobile set when reported stolen

Figure 5.2 - Universal model for a mobile telephone service

5.3.2 Performance model

This model is used to determine the criteria for the performance of telecommunications services. The goal is to provide a structured approach to analyze aspects of performance in detail. The benefit of this model is that the quality criteria identified can be easily translated into a QoS parameter since it is very detailed and closed to the understanding of network performance parameters and management functions. Then the definitions and methods to measure QoS parameters can be expressed in well known and

commonly used technical terms.

The model is based on a **matrix**, the same as described in [4], with a list of service functions on the y-axis and quality criteria on x-axis. For each service function, it can determine what kind of quality criterion is applicable to it. For each function, not all the cells of the matrix could be populated, depending on the type of service under investigation or upon the desired granularity of the quality criteria.

After determining the quality criteria, performance and quality parameters can be defined.

The following table is an example of performance model for a mobile telephone service:

		Service quality criteria						
		Speed 1	Accuracy 2	Availability 3	Reliability 4	Security 5	Simplicity 6	Flexibility 7
Service function								
Service management	Sales & pre-contract activities 1	Processing time						
	Provision 2	Supply time		Coverage				
	Alteration 3	Processing time						Ease of change in contract
	Service support 4	Response time		Availability of call centre			Professionalism of help line	
	Repair 5	Response time						
	Cessation 6	Processing time					Ease of contract cessation procedure	
Connection quality	Connection establishment 7	Call set-up time	Unsuccessful call ratio	Service availability				
	Information transfer 8	One-way delay	Speech quality		Dropped call ratio within a specific time period			
	Connection Release 9	Release time	Unreleased call ratio					
Billing 10		Billing frequency	Bill correctness complaints Bill presentation quality		Number of billing complaints within a specific time period	Fraud protection/ prevention		Availability of different billing methods (e.g., online billing)
Network/Service management by customer 11							Ease of software updates	

Figure 5.3 - Example of performance model

5.3.3 Four-market model

This model is especially suitable for multimedia services because the separation between transport and service layer is taken into account: the multimedia services consist of a complex chain of actions, from the creation of content, service management, delivery network and customer equipment.

The quality of service is perceived by a combination of different elements that are working independently of each other and a model helps to study the elements separately

and identify their quality criteria.

The four-market model consists of four components that describe the various service elements that contribute to QoS. According to the aspects of service under consideration, it may be sufficient to only identify quality criteria for one or more components.

The four components are:

- **customer's equipment**: all kinds of instruments (both hardware and software) required for the user to access the network and then to the service;
- **service transport**: all types of telecommunication networks used for the distribution of telecommunications services like terrestrial and satellite broadcast networks;
- **service provision**: all activities and functions related to the packaging, presentation and management of telecommunications services;
- **content creation**: all activities related to the generation, distribution and packaging of the content offered via a telecommunications service.

A vision of the model and of the four components is shown in Figure 5.4:

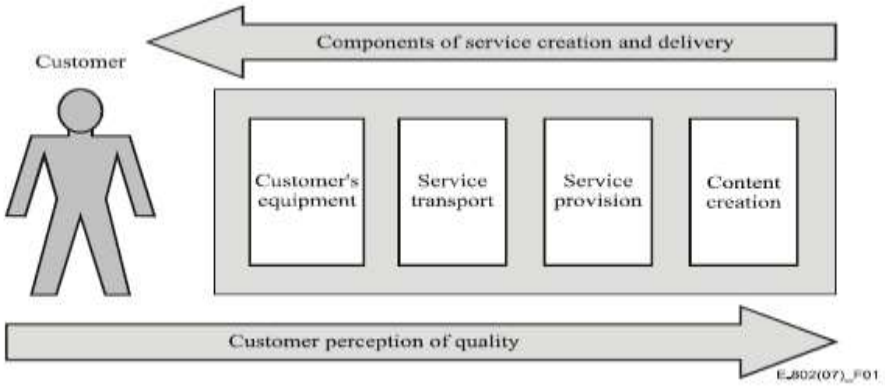

Figure 5.4 - Four-market model

For example, for music streaming and downloading service, we might have this list of criteria (not complete):

Customer equipment:

- ease of selection and playback
- ergonomic considerations of devices

- storage capacity

Service transport:

- bandwidth
- latency
- jitter and error
- distortion

Service provision:

- ease of navigation to favorite music
- security
- fair contracts

Content creation:

- technical quality of original content
- popularity of content and artists

5.4 Choice of QoS parameters

The set of QoS parameters is designed to be understood by users of different services. However, you can select a subset of the parameters for use in different circumstances: for example, a specific parameter could be significant for some users but not for others (e.g., call set-up time could be relevant in an all- analog network but not on an all-digital network).

So, users, customers, service providers, network operators and other parties interested in the use of QoS parameters can decide what parameters could be used in their specific situations. This decision must take into account:

- the purpose for which the parameters will be used;
- the quality and performance as expected by the users of state-of-art technology;
- the usefulness and relevance of the parameters from the user's perspective;
- the degree with which the parameters will ensure good performance;
- the cost and resources needed in order to measure and report each parameter.

All these issues affect the decision on what kinds of parameters (quality criteria to be examined) and the number of parameters (granularity of quality) must be chosen for the specific purpose.

Also the ISO standard [2] highlights the fact that several applications or services may have to deal with different types of performance requirements and we consider different *categories* of QoS: the standard, however, focuses on the problem of monitoring and maintaining the QoS while, in this document, the main problem is how to identify the requirements suitable to the particular environment.

5.4.1 Application of QoS parameters

A common application of QoS parameters could be the monitoring of telecommunications services and cross-checking whether quality objectives were achieved.

Also in [2] and [3] the main problems are the monitoring and maintaining the QoS and *QoS mechanisms* needed for that purpose are adopted.

Before identifying useful and meaningful quality objectives, it is important to consider the areas of application and the technical potentials of the parameters and the cost of the measurement of parameters.

The QoS parameters can be used by the service provider to manage and improve how it offers their service to users, to make sure that the quality level according to contract agreement is actually reached.

Another application of QoS parameters concerning their use made by the regulatory authorities to define quality levels for regulatory aspects of interoperability and interconnection of networks and services.

The QoS parameters can be used to assess the quality of some aspects of the service or to measure the overall quality of service as perceived by the user. Finally, the use of QoS parameters can range from an in depth quality assessing to the simple evaluation of the general perception of a service.

5.4.2 From QoS criteria to QoS parameters

Quality criteria identified from one or more models should be converted into quality parameter before they can be used to express qualitatively or quantitatively the QoS of telecommunications services. The goal is to achieve a set of uniform parameter of quality that can be used to assess the quality of service and to allow comparisons

between different services.

The QoS parameters identified must be defined unambiguously so that every service provider could be able to carry out the measurements.

The main applications for QoS parameters are the following:

- QoS parameters characterizing the quality of a service that is offered and the user satisfaction;
- QoS parameters can be used as a basis for SLAs;
- service providers and network operators can use QoS parameters to plan their purposes;
- QoS parameters can be used to specify the delivered quality (the QoS actually delivered to the user, the third viewpoint of QoS).

5.4.3 Measurement of QoS parameters

The QoS parameters are measured either **objectively** by technical means (by measuring physical attributes of the circuit, network and its components) or **subjectively** (QoS perceived, which represents the *user's QoE*) through surveys and tests on users.

Subjective measurements are performed in order to measure the QoS perceived by the user while objective measurements are used to specify the technical parameters that may be related to the perception of the user.

Since the term QoS is "*a measure for the degree of satisfaction of a user of a service*" one might assume that the methods of subjective measure can be used to assess the quality of service but they are complex and costly in terms of time and also, human judgments can lead to invalid results. Whenever possible, we prefer objective measurements that provide results well correlated with subjective measurements but more reliable.

Subjective measurements are the only way to represent aspects of the user's perception of QoS and, compared to objective measurements, they can indicate where improvements of network or customer behavior are needed, as mentioned in [6].

5.5 Guideline for defining quality objectives

Quality objectives are used to determine the maximum and minimum limits of performance and the desired level of performance of QoS parameters. For each parameter, a reference value can be specified which may be a threshold or a value in an

acceptable range, depending on the QoS parameters considered: one can think of the *trigger points* examined in the ISO standard [2].

Since the QoS parameters are focused on the user requirements concerning the quality, the user should be able to understand the significance of the reference value and be able to compare the quality perceived with the reference value.

The end user perspective should be considered before deciding what QoS parameters should be chosen and how quality objectives should be specified.

If there is no quality reference for a specific service, one will have to determine the initial objectives of quality by following the outlined steps here:

- the service under consideration must be analyzed and the quality criteria and the resulting QoS parameters must be identified; for these QoS parameters quality objectives must be specified;
- before acquiring information on current performance of the service, we must select a time period during which collect data in order to get a first impression on reasonable limits for the quality objectives that can be obtained;
- user's perspective must be taken into consideration and survey among users have to be conducted to verify their demand for quality;
- quality references obtained from the collected data (*the service providers perspective*) and the surveys (*the user's perspective*) need to be combined into final quality objectives.

5.6 Defining target values

Target values are determined in order to improve the quality of service within a specific period of time.

Also the standard [2] underlines that during the *establishment phase* of maintaining QoS, it is important to negotiate or impose a number of *trigger point* and an *operating target*. When target values are established, we need to consider the following aspects:

- the target values must be realistic, the service provider should be able of reaching the quality level because any improvement of quality requires investment in the upgrading of resources;
- the target values should be of benefit to the user or should be meaningful to the user and then cover important aspects of the service;

- the target values should be based on QoS parameters clearly measurable;
- when we establish the target values should consider diversities of services (geographical location, user expectations, social aspects): an appropriate value in a specific context might not be useful in another situation;
- the implementation stage of the service should be considered: services that are still in a transitory stage have to be treated differently than the services that are already in a stable phase.

Also this document talks about *tuning*, the mechanism for maintaining QoS described in [2], that performs the monitoring of currently achieved QoS by the system and "tune" it to the desired value. The adjustment of quality objectives requires a process of management of quality policy where the particularities of each service, the goals, the perception of users and information provided by the service provider must take into account in order to achieve the level of QoS requested by users.

6. Conclusions

The objective of this work is to clarify the fundamental concepts related to QoS, referring to official documents and trying to provide a general understanding of the quality that can be used as a basis for specific studies on QoS.

In this work, we have analyzed only the documents related to the Quality of Service standards. First, it has been highlighted how it is difficult to fully understand the concept of quality, especially when it refers to something that is abstract such as information technology services. We have used a definition of Quality of Service that is valid in an international context and we have underlined its close link to the quality perceived by the users and the non-functional aspects that are important for a user of a service.

The QoS documents have been analyzed in detail.

The principal topics are the following.

- In the **International Standard ISO/IEC** [2], key definitions concerning QoS, QoS management functions and mechanisms, QoS characteristics and phases linked to QoS activity management (prediction, establishment and operational phase), the general mechanisms (in particular, the tuning mechanism) and verification on QoS are highlighted.
- The second document, the **Technical Report ISO/IEC** [3], resumes the concepts and terms mentioned in the standard and provides a list of all documents dealt with QoS (not included in this work). The similarities with the previous document have been highlighted, the methods and the mechanisms of QoS in the three phases of prediction, establishment and operational stage have been analyzed. In particular, the *QoS negotiation* in different types of communications (p2p, multicast 1xN, multicast NxM) and QoS verification (that in [2] is only mentioned) has been emphasized.
- The **ITU-T Recommendation G.1000** [4], in the specific area of TLC services, provides definition of the quality introduced in the standard and adds others terms, examining the four perspectives for QoS (offered QoS, delivered QoS, perceived QoS and QoS requirements) and the relationship between them.

- The **ITU-T Recommendation E.860** [5] first introduces some concepts related to QoS such as entities, interaction points, interface, service access point (SAP) and describes in details the structure of an SLA and the concept of *one stop responsability* adopted in a multi-provider environment to ensure the agreed QoS in the SLA between user and primary provider.
- Finally, the last document, the **ITU-T recommendation E.802** [8], which is the most recent document on QoS, focuses on the identification of QoS criteria or QoS characteristics and their conversion into QoS parameters. Similarly with the standard [2], the general aspects of QoS criteria, the selection and the application area of QoS parameters, the identification of QoS criteria are described. The three models for the identification and classification of QoS criteria are then analyzed. Finally, it has been shown how we can define the starting values of QoS and the objective-values and regarding to these topics, the document refers to the concepts already examined in the ISO standard [2] as the definition of target values and *tuning* mechanisms.

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