INTERNATIONAL STANDARD

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Information technology — Quality of service: Framework

Technologies de l'information — Qualité du service: Cadre

Contents

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 13236 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 33, *Distributed application services*, in collaboration with ITU-T. The identical text is published as ITU-T Recommendation X.641.

Annex A forms an integral part of this International Standard. Annexes B to E are for information only.

Introduction

The purpose of this Recommendation | International Standard is to provide a common basis for the coordinated development and enhancement of the wide range of standards that specify or reference Quality of Service (QOS) requirements or mechanisms in an Information Technology (IT) environment. It offers a means of developing or enhancing standards relating to QOS and provides concepts and terminology that will assist in maintaining the consistency of related standards. This Recommendation | International Standard is complementary to existing ITU-T Recommendations which define performance objectives and network signalling of QOS and it is not the intention of this Framework to lead to a need to revise any such Recommendations.

The initial work in developing this Framework for QOS was done with the objective of supplementing and clarifying the description of QOS contained in the Basic Reference Model of Open Systems Interconnection (OSI) (see ITU-T Rec. X.200 | ISO/IEC 7498-1). It is recognised, however, that management of QOS is important not only in OSI communications but also in a much wider context, and that there is value in encouraging a common approach to QOS that can extend to other IT and communications architectures, to distributed processing in general and to Open Distributed Processing (ODP) in particular.

Hence this Recommendation | International Standard is structured and written in such a way as to make it easy for many communities to adopt its approach, concepts, terminology and definitions. Its concepts and terms are defined without reference to any particular architecture, so that they can be adopted and applied by other communities to a variety of architectures and protocols. This general treatment is supplemented by examples from OSI, ODP and elsewhere.

To assist the OSI community, Annex A defines how the general framework applies to the specific case of OSI communications, both peer-to-peer and multi-peer.

This QOS Framework contains an introduction, a scope and field of application and a set of QOS-related definitions and abbreviations. The concepts of QOS are introduced in clause 5, which also highlights user requirements. Clause 6 defines QOS characteristics with respect to the user requirements. Clauses 7, 8 and 9 cover QOS management, QOS mechanisms and the expression of specific QOS requirements, respectively. QOS verification is discussed in clause 10, and conformance, consistency and compliance are discussed in clause 11.

Annexes are provided which stipulate:

- the model of QOS for OSI;
- statistical derivations of characteristics;
- a standards structure with respect to QOS;
- a discussion of the issue of ‘cost’; and
- a bibliography.

Other standards communities are encouraged to study this Recommendation | International Standard and, in the interests of consistency, to consider the adoption of the parts that are relevant to their field, when this can be accomplished to good effect, without destabilisation of existing Recommendations | International Standards.

INTERNATIONAL STANDARD

ITU-T RECOMMENDATION

INFORMATION TECHNOLOGY – QUALITY OF SERVICE: FRAMEWORK

1 Scope

This QOS Framework is a structured collection of concepts and their relationships which describes QOS (Quality of Service) and enables the partitioning of, and relationships between, the topics relevant to QOS in Information Technology (IT) to be expressed by a common means of description. In particular, this QOS Framework is directed at IT systems and their use in providing Open Distributed Processing services.

This QOS Framework is intended to assist those designing and specifying IT systems, and those defining communications services and protocols, by providing guidance on QOS applicable to systems, services and resources of various kinds. It describes how QOS can be characterized, how QOS requirements can be specified, and how QOS can be managed.

This QOS Framework defines terminology and concepts for QOS in IT. It introduces the concept of QOS characteristics, which represent the fundamental aspects of QOS that are to be managed in various ways; and it defines a number of QOS characteristics of particular importance. These definitions are independent of how QOS is represented or controlled in a real system.

This Framework describes how QOS requirements can be expressed, and identifies a number of QOS mechanisms (such as three-party negotiation) that can be used as components of QOS management functions to meet QOS requirements of various kinds. It also describes the circumstances in which various combinations of mechanisms may be appropriate.

This QOS Framework provides a basis for the specification of extensions and enhancements to existing or planned standards, as a result of the need for, and application of, the QOS concepts defined in this Recommendation | International Standard. It is not the intent of this Recommendation | International Standard to destabilise any existing Recommendations | International Standards; rather, it is intended that this QOS Framework may be used by:

- developers of new or revised IT-related standards which define or use QOS mechanisms; and
- IT users expressing requirements for QOS.

This QOS Framework does not attempt to provide a basis for the specification of performance objectives or network signalling of QOS in public communications networks. The QOS aspects of these communications services are addressed by other ITU-T Recommendations.

The intent of this Recommendation | International Standard is to provide a common vocabulary to both service providers and service users. Nothing in this Recommendation | International Standard should be construed as placing requirements on either service providers or service users. It is hoped that a common approach and vocabulary for QOS will assist multiple service providers to deliver end-to-end QOS to end-systems.

This QOS Framework specifically excludes the detailed specification of QOS mechanisms. It is not the intent of this Recommendation | International Standard to serve as an implementation specification, to be a basis for appraising the conformance of implementations, or to define particular services and protocols. Rather, it provides a conceptual and functional framework for QOS which allows independent teams of experts to work productively on the development of Recommendations | International Standards.

As applied to OSI, this QOS Framework is consistent with the OSI Basic Reference Model in that it describes operations and mechanisms which are assignable to layers as specified in the OSI Basic Reference Model. It is consistent with the OSI Management Framework (see ITU-T Rec. X.700 | ISO/IEC 7498-4) and the Systems Management Overview (see ITU-T Rec. X.701 | ISO/IEC 10040) in its assignment of functions to management entities. In Annex A, this QOS Framework presents a model of QOS for OSI which identifies the entities that participate in the management of QOS, defines the flow of QOS-related information between them and describes how this information is used.

2 Normative references

The following Recommendations and International Standards contain provisions which, through reference in this text, constitute provisions of this Recommendation | International Standard. At the time of publication, the editions indicated were valid. All Recommendations and Standards are subject to revision, and parties to agreements based on this Recommendation | International Standard are encouraged to investigate the possibility of applying the most recent edition of the Recommendations and Standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of the ITU maintains a list of currently valid ITU-T Recommendations.

2.1 Identical Recommendations | International Standards

- ITU-T Recommendation X.200 (1994) | ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model.*
- ITU-T Recommendation X.210 (1993) | ISO/IEC 10731:1994, *Information technology – Open Systems Interconnection – Basic Reference Model: Conventions for the definition of OSI services.*
- ITU-T Recommendation X.746 (1995) | ISO/IEC 10164-15:1995, *Information technology – Open Systems Interconnection – Systems management: Scheduling function.*
- ITU-T Recommendation X.902 (1995) | ISO/IEC 10746-2:1996, *Information technology – Open distributed processing – Reference Model: Foundations.*

2.2 Paired Recommendations | International Standards equivalent in technical content

- CCITT Recommendation X.700 (1992*), Management framework for Open Systems Interconnection (OSI) for CCITT applications.*

  ISO/IEC 7498-4: 1989, *Information processing systems – Open Systems Interconnection – Basic Reference Model – Part 4: Management Framework.*

2.3 Additional references

- CCITT Recommendation X.140 (1992), *General Quality of Service parameters for communication via public data networks.*

3 Definitions

For the purposes of this Recommendation | International Standard, the following definitions apply.

3.1 Basic Reference Model of Open Distributed Processing definitions

This Recommendation | International Standard uses the following term drawn from ITU-T Rec. X.902 | ISO/IEC 10746-2:

- Quality of Service (QOS): A set of qualities related to the collective behaviour of one or more objects.

3.2 Basic Reference Model – OSI Management Framework definitions

This Recommendation | International Standard uses the following term drawn from CCITT Rec. X.700 | ISO/IEC 7498-4:

- Managed Object (MO): The OSI Management view of a resource within the OSI Environment that may be managed through the use of OSI Management protocol(s).

3.3 Service Conventions definitions

This Recommendation | International Standard uses the following terms drawn from ITU-T Rec. X.210 | ISO/IEC 10731:

- (N)-service-facility;
- (N)-service-provider;
- (N)-service-user;

– Requester;

– Acceptor.

NOTE – In this Recommendation | International Standard, *service provider* is a generic term to indicate the provision or use of a service at some point in a system. It should not be confused with the provision of a commercial service by any commercial agency.

3.4 OSI Basic Reference Model definitions

This Recommendation | International Standard uses the following terms drawn from ITU-T Rec. X.200 | ISO/IEC 7498-1:

– (N)-entity;

– (N)-layer;

– (N)-protocol;

– (N)-protocol-data-unit;

– (N)-service;

– (N)-service-access-point;

– (N)-subsystem;

– open system;

– OSI environment.

3.5 QOS Framework definitions

3.5.1 QOS concepts and modelling definitions

3.5.1.1 QOS category: A group of user requirements that leads to the selection of a set of QOS requirements.

3.5.1.2 QOS characteristic: A quantifiable aspect of QOS, which is defined independently of the means by which it is represented or controlled.

3.5.1.3 QOS management: Any set of activities performed by a system or communications service to support QOS monitoring, control and administration.

3.5.1.4 QOS mechanism: A specific mechanism that may use protocol elements, QOS parameters or QOS context, possibly in conjunction with other QOS mechanisms, in order to support establishment, monitoring, maintenance, control, or enquiry of QOS.

3.5.1.5 QOS of OSI communications: A set of qualities related to the provision of an (N)-service, as perceived by an (N)-service-user.[1)]

3.5.1.6 QOS policy: A set of rules that determine the QOS characteristics and QOS management functions to be used.

3.5.2 Information-oriented definitions

3.5.2.1 QOS context: QOS information that is retained, interpolated or extrapolated by one or more entities and used in managing QOS: it is further classified into requirement context and data context.

3.5.2.2 QOS data: QOS information other than QOS requirements, e.g. warnings, QOS measures and information used in QOS enquiries.

3.5.2.3 QOS information: Information related to QOS: it is classified into QOS context (when retained in an entity) and QOS parameters (when conveyed between entities); and it is classified into QOS requirements (if it expresses a requirement for QOS) and QOS data (if it does not).

3.5.2.4 QOS measure: One or more observed values relating to a QOS characteristic.

3.5.2.5 QOS parameter: QOS information that is conveyed between entities as part of a QOS mechanism; parameters are classified into requirement parameters and data parameters; the information conveyed may relate to one or more QOS characteristics.

[1)] This definition of QOS is a specialisation of the definition of QOS given in 3.1 above, as applied to OSI communications.

3.5.2.6 QOS requirement: QOS information that expresses part or all of a requirement to manage one or more QOS characteristics, e.g. a maximum value, a target, or a threshold; when conveyed between entities, a QOS requirement is expressed in terms of QOS parameters.

3.5.2.7 QOS operating target: QOS information that represents the target values of a set of QOS characteristics, derived from QOS requirements.

3.5.3 Management function definitions

3.5.3.1 QOS alert: The use of QOS mechanisms to signal to an entity that some limit has been reached or threshold crossed.

3.5.3.2 QOS attribute: An attribute of a managed object relating to QOS.

3.5.3.3 QOS control: The use of QOS mechanisms to modify conditions so that a desired set of QOS characteristics is attained for some systems activity, while that activity is in progress.

3.5.3.4 QOS enquiry: The use of QOS mechanisms to determine properties of the environment relating to QOS.

3.5.3.5 QOS establishment: The use of QOS mechanisms to create the conditions for some systems activity, before that activity occurs, so that a desired set of QOS characteristics is attained.

3.5.3.6 QOS maintenance: The use of QOS mechanisms to maintain a set of QOS characteristics at required values for some systems activity, while the activity is in progress.

3.5.3.7 QOS management function: A function specifically intended to meet a user or application requirement for QOS, provided by one or more QOS mechanisms.

3.5.3.8 QOS monitoring: The use of QOS measures to estimate the values of a set of QOS characteristics actually achieved for some systems activity.

4 Abbreviations

For the purposes of this Recommendation | International Standard, the following abbreviations apply:

ASO	Application Service Object
CHQ	Controlled Highest Quality
CL	Connectionless
CO	Connection-oriented
GDMO	Guidelines for the Definition of Managed Objects
IT	Information Technology
LAN	Local Area Network
LQA	Lowest Quality Acceptable
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
(N)-PCF	(N)-Policy Control Function
(N)-PDU	(N)-protocol-data-unit
(N)-PE	(N)-protocol-entity
(N)-QCF	(N)-QOS Control Function
(N)-SAP	(N)-service-access-point
(N)-SDU	(N)-service-data-unit
ODP	Open Distributed Processing
OSI	Open Systems Interconnection
OSIE	OSI Environment
PDU	Protocol Data Unit

QMF	QOS Management Function
QOS	Quality of Service
SAP	Service Access Point
SDU	Service Data Unit
SNPA	Sub-network Point of Attachment
SP	System Performance
SQCF	System QOS Control Function
TCCA	Time-Critical Communications Architecture
TCCS	Time-Critical Communications System
TPDU	Transport PDU
TSAP	Transport SAP
UIU	User Information Unit

5 Concepts of this QOS Framework

5.1 Introduction

This clause develops a set of fundamental concepts for QOS. It contains a description of concepts for the information and functional aspects of QOS including:

- 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 policies and the QOS management functions that realize them;
- basic QOS mechanisms that combine to form QOS management functions;

- QOS categories that represent the particular sets of user requirements for QOS imposed by certain environments (such as time-critical communications), or by systems-level policy;
- the stages of an activity at which QOS can be managed.

These concepts are described in a way that highlights the operation of QOS management. It begins by discussing the inherent QOS characteristics and then considers how QOS requirements drive the selection and use of QOS management functions and QOS mechanisms.

Figure 5-1 shows the relationships between the fundamental QOS concepts.

5.2 The service to which QOS applies

In this QOS Framework, as in the expression ‘Quality of Service’, the term ‘service’ is to be understood in a very general sense so as to permit the widest possible application of the Framework. Specifically, it includes (but is not necessarily limited to):

- the provision of processing and information repository functions by entities, objects, applications, applications processes, etc.; for example, time-delay and reliability-related characteristics apply to these;

  NOTE – the terms used to denote these entities, etc., depend upon the architectural models applicable to the particular distributed systems environments in which QOS is to be represented: the term ‘entity’ is used in the Framework in a neutral sense, i.e. with no implication for the choice of architectural model.

- interactions between entities, objects, applications, etc.;
- information held in the system; for example, confidentiality and lifetime characteristics apply to information;
- communications services;
- (the possibility of use of) physical equipment.

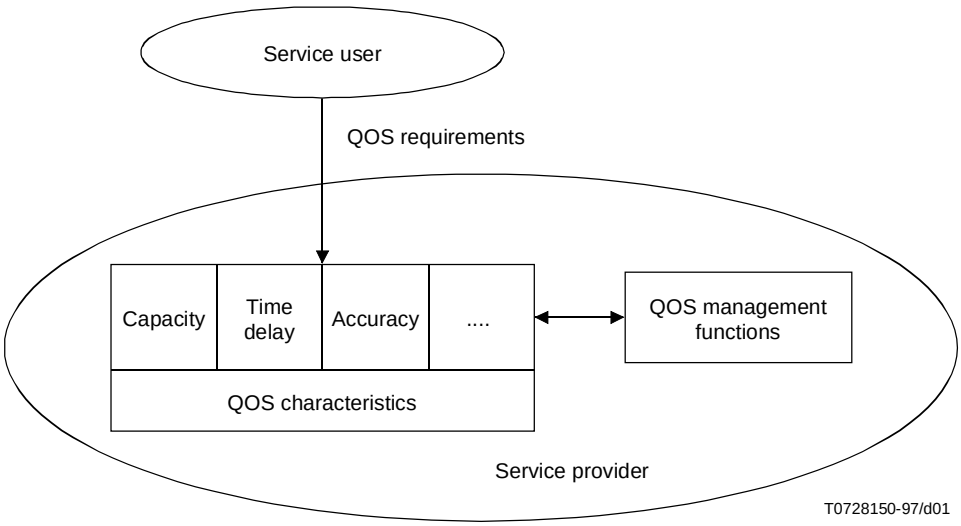

Figure 5-1 – Relationships between QOS concepts

5.3 QOS characteristics

The term QOS characteristic is used in this QOS Framework in a particular sense. A QOS characteristic represents some aspect of the QOS of a system, service or resource that can be identified and quantified. It denotes the true underlying state of affairs for the item, as opposed to any measurement or control parameter. QOS characteristics are defined independently of the means by which they are represented or controlled.

QOS characteristics are intended to be used to model the actual, rather than the observed, behaviour of the systems that they characterize.

NOTE – For example, the characteristic of transit delay (of something) between two points is the actual time that occurs between the instants of passage of that thing past those points. This transit delay can never be known exactly, although it can be approximated by measurement. Further, requirements can be stated concerning transit delay – such as that it must not exceed a specified value.

Some QOS characteristics are considered to be generic characteristics, some are specialisations of these characteristics and others are derived characteristics. (For further discussion of QOS characteristics see clause 6.)

5.4 User QOS requirements and QOS policies

QOS management activities are driven by user requirements, the systems and communications environment, and the policies that are in force for the activity. User requirements are quantified and expressed as a set of QOS requirements (which is a type of QOS information).

Although a user's requirements may vary considerably in detail between individual instances of an activity, the QOS characteristics of interest and the QOS management functions employed will typically be determined by the type of system and distributed application that are to be supported and the types of network technology used. It is not expected that every system or network will implement every or any type of QOS mechanism. Systems and communications networks will be designed, procured or configured in accordance with one or more QOS policies, which will determine which QOS characteristics and QOS management functions are to be used.

Some systems and networks will need to be configurable to operate with different QOS policies, requiring that different sets of QOS management functions be available.

5.5 QOS requirements, QOS parameters and QOS context

A user requirement originates with a user entity that wishes to use a service, such as communications, and is formulated into one or more QOS requirements. These QOS requirements can be expressed as QOS parameters (when they need to be conveyed between entities) and QOS context (when they are retained in an entity).

In general, an activity is initiated by a user entity, whose requirements for QOS are either conveyed dynamically to the provider of the service as QOS parameters, or made available to the service provider as QOS context, or a combination of the two. The QOS parameters are conveyed to some or all of the entities involved in providing the service and possibly also to the corresponding application process.

Entities that receive QOS requirements analyse them and determine the QOS management functions or mechanisms that are required to meet them. This may involve generating further, typically more detailed, QOS requirements and conveying them to other entities as QOS parameters. The receiving entities analyse the QOS requirements they receive, and may generate yet further QOS requirements to be conveyed to other entities, and so on. One common example of this process is QOS negotiation across multiple layers during OSI connection establishment.

Thus, in general, a QOS parameter is a vector or scalar value that is conveyed between entities, either in the same system or in different systems.

NOTE – In this Recommendation | International Standard the use of the term 'QOS parameter' is specifically limited to conveyed values. Some documents do not distinguish between QOS characteristics and QOS parameters, and use the term QOS parameters for both.

For example, it may be a QOS requirement that the transit delay of data units between two points should not exceed a stated maximum, or that the average transit delay should be close to a stated target. In such cases, it is the true transit delay that is the characteristic. The QOS requirement will be expressed as QOS parameters (or QOS context) giving maximum or target values, for example. The interactions between entities will use QOS parameters to convey the relevant QOS information.

Depending on the exact requirement, the QOS parameters conveyed (or the QOS context retained) may be of different kinds, including:

- a desired level of characteristic, i.e. a target of some kind;
- a maximum or minimum level of a characteristic, i.e. a limit;
- a measured value, used to convey historical information;
- a threshold level;
- a warning or signal to take corrective action; or
- a request for operations on managed objects relating to QOS, or the results of such operations.

QOS requirements may relate to a number of QOS characteristics and, at least in principle, express trade-offs between them.

QOS requirements may apply to a single instance of information transfer or interaction, or may apply to multiple transfers or interactions (e.g. over a given period of time, for the duration of a connection or association, or for the duration of some longer provision of service, such as a customer subscription).

5.6 QOS management functions and QOS mechanisms

QOS management refers to all the activities relating to the control and administration of QOS within a system or network.

The term QOS management function (QMF) refers to any function designed to assist in satisfying one or more user QOS requirements. QMFs will in general have a number of components, which are called QOS mechanisms (e.g. three-party QOS negotiation).

A QOS mechanism is performed by one or more entities to meet one or more QOS requirements. Thus QOS mechanisms are driven by QOS requirements expressed as QOS parameters received by the entities that perform them, or made available to them as QOS context. The operation of a QOS mechanism may be local processing (e.g. reservation of resources, setting window sizes, etc.) which by itself meets the QOS requirement; or it may involve the generation of further QOS requirements and their communication to other entities, as described in 5.5. It may lead to the invocation of further QOS mechanisms.

The activities that may be supported by QMFs include:

- establishment of QOS for a set of QOS characteristics;
- monitoring of the observed values of QOS;
- maintenance of the actual QOS as close as possible to the target QOS;
- control of QOS targets;
- enquiry upon some QOS information or action; and
- alerts as a result of some event relating to QOS management.

NOTE – QOS requirements are commonly met (in current static environments) by being built into the systems configuration by systems design, by systems dimensioning, by the procurement of suitable services, or by dedicating resources. In more dynamic environments, increased use of QMFs is likely to be necessary to establish the environment, to monitor and control the environment during use and to capture historic information about system operation.

5.7 QOS categories

Different user application types will have different requirements for establishing QOS and for controlling and maintaining the actual QOS achieved. For example, the QOS requirements for video streams are typically very different from those for database update transactions.

These different types of user or application requirement, which are termed QOS categories, lead to the choice of particular sets of QOS characteristics to be managed. Subclause 6.4 identifies a number of fundamental QOS categories.

5.8 Initiation of QOS management

QOS management involves the use of different QMFs at different points in a system activity. The QOS requirements for a particular activity or set of activities can be expressed and/or conveyed in different ways and at different times in relation to the events or activities whose QOS is to be managed.

QOS management would be used at the following stages of an activity (related to 7.1.1):

- before initiation, when predictions are made about the QOS situation to gauge what mechanisms may be necessary to achieve some objective;
- at initiation of the activity – The QOS requirements can be negotiated between the service users and service provider at establishment time (e.g. when a connection is being established); and
- during the activity – The QOS requirements may change during the operational period of the activity due to changed requirements, detected performance loss, explicit indications from the service provider, or explicit indications from one or more third parties.

For any specific activity, the selection of the most appropriate stages to carry out QOS management depends on the type of QOS requirement and the duration of the activities to which it relates.

6 Definition of QOS characteristics

6.1 Introduction

This clause develops the concept of QOS characteristics (in 6.2) and defines a number of QOS characteristics of importance to communications and processing (in 6.3).

A QOS characteristic is a quantifiable aspect of QOS, which is defined independently of the means by which it is represented or controlled. It represents the true underlying state of affairs, as opposed to any measurement or control parameter, and can therefore be thought of as a quantity in a mathematical model of a (distributed) system. Thus, in defining a QOS characteristic such as throughput, the intention is to say what throughput means. This is distinct from how it may be measured, controlled, requested, negotiated, and so on, which are discussed in later subclauses.

The values that may be taken by QOS characteristics include not only numbers (e.g. Booleans, integers, reals, complex numbers, etc.), but also vectors, matrices, ranks and names of states.

Efforts are made to achieve maximum consistency of definition across different characteristics by defining ‘generic’ characteristics, and then both specialising them to particular environments and deriving others from them. This is discussed in 6.2.1 below.

It is recognised that the characteristics defined in this clause will not meet all future QOS requirements. Hence 6.2.2 gives guidance on how QOS characteristics should be defined. The definitions in 6.3 follow this guidance.

This clause also identifies a number of QOS categories.

6.2 Aspects of QOS characteristic definition

6.2.1 Generic, specialised and derived characteristics

6.2.1.1 Specialisation

Many QOS characteristics can be applied to a variety of circumstances. For example, one can define the transit delay of frames in a Local Area Network (LAN) supporting a real-time process-control environment, or of network access protocol PDUs between two SNPAs. Similarly one can define the throughput of a connection, or of any other communications channel.

In such cases it is important to have a common underlying definition of the characteristic that can be applied to all the particular circumstances. To achieve this, the first step is to define a 'generic characteristic' independently of what it is applied to; and the second is to define various 'specialisations' that may or must be applied in order to make the characteristic concrete and useable in practice. So, for example, 6.3 first defines *time delay* as a generic characteristic. It then defines some specialised characteristics from *time delay*, one of which is *transit delay*. It then identifies various further specialisations that may or must be applied to make the characteristic concrete; these include specifying the type of data transferred, the points between which transit is defined, and so on.

Thus, there can be several levels of specialisation of a characteristic, for example:

- time delay;
- transit delay;
- transit delay between two TSAPs;
- transit delay of an Expedited TPDU between two TSAPs;
- transit delay of an Expedited TPDU between two TSAPs for a given T-connection.

Furthermore, a different sequence of specialisation would lead to further characteristics, e.g.:

- transit delay between two TSAPs for a given T-connection.

This approach achieves consistency in two ways. First it gives consistency between different uses of the fundamental concept of the characteristic in different circumstances in that they share a common abstract definition; and second it can be used to give consistency between quite different characteristics where the same specialisations are applied.

Specialisation makes an abstract characteristic more concrete. In any practical application of QOS management a characteristic must be completely specialised, so that it is clear what its values mean. But when developing widely-applicable QOS mechanisms, it may be valuable to work with characteristics at appropriate levels of abstraction. For example, a throughput negotiation mechanism can be defined generically, with the intention that it would be specialised by protocol designers to apply to particular channels and data streams.

This Recommendation | International Standard does not identify or define all the possible specialisations that may be necessary in practice, but does include a subset that may find wide application.

6.2.1.2 Derived characteristics

Some characteristics can be defined as (mathematical) functions of others. These are termed 'derived' characteristics.

One important type of derivation is *statistical*. For example, from the characteristic *throughput* one can derive mean throughput, maximum throughput, minimum throughput, variance of throughput, etc. Technically the statistical derivations are regarded as functions of a random variable that represents the 'base' characteristic from which they are derived.

The following statistical derivations are defined in this Recommendation | International Standard:

- maximum, minimum and range;
- mean;
- variance and standard deviation;
- n-percentile;
- statistical moments.

The precise definitions of these functions are given in Annex B.

The specialisations that apply to a statistical derivation are exactly those that apply to the base characteristic from which it is derived. From *time delay*, for example, one can derive the characteristics *mean transit delay*, v*ariance of transit delay between two TSAPs*, and so on. Thus, the statistical derivations can be regarded as orthogonal to the specialisations, as illustrated in Figure 6-1.