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SERIES Y: GLOBAL INFORMATION  
INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS  
AND NEXT-GENERATION NETWORKS

Internet protocol aspects – Quality of service and network  
performance

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## **Network performance objectives for IP-based services**

Recommendation ITU-T Y.1541

## ITU-T Y-SERIES RECOMMENDATIONS

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*For further details, please refer to the list of ITU-T Recommendations.*

# Recommendation ITU-T Y.1541

## Network performance objectives for IP-based services

### Summary

This Recommendation defines classes of network quality of service (QoS) with objectives for Internet Protocol network performance parameters. Two of the classes contain provisional performance objectives. These classes are intended to be the basis for agreements among network providers, and between end users and their network providers.

Appendix I provides information about how asynchronous transfer mode (ATM) might support IP layer performance. Appendix II discusses alternatives for defining IP delay variation. Appendix III presents the hypothetical reference paths (HRP) against which the ITU-T Y.1541 QoS objectives were tested for feasibility. Appendix IV gives example computations of packet delay variation. Appendix V discusses issues that must be considered whenever IP measurements are made. Appendix VI describes the relationship between this Recommendation and the IETF-defined mechanisms for managing QoS. Appendix VII gives estimates of speech transmission quality for the hypothetical reference paths of Appendix III. Appendix VIII discusses digital television transport on IP networks. Appendix IX estimates transmission control protocol (TCP) file transfer performance on paths conforming to ITU-T Y.1541 objectives. Appendix X gives example calculations for combining delay variation measurements from multiple sections to estimate user network interface to user network interface (UNI-UNI) performance, and Appendix XI estimates the packet loss requirement for digital circuit emulation.

### History

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| 2.3     | ITU-T Y.1541 (2006) Amd. 3 | 2008-05-30 | 12          |
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## FOREWORD

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# Recommendation ITU-T Y.1541

## Network performance objectives for IP-based services

### 1 Introduction and Scope

#### 1.1 Introduction

Customers require network performance levels that, when combined with their hosts, terminals, and other devices, satisfactorily support their applications. The adoption of IP-based network services [IETF RFC 791] has not changed this fact, except that networks must be constrained in terms of packet transfer performance parameters (as defined in [ITU-T Y.1540]).

Traditional application performance requirements are well-understood, but several key contributors are often beyond the network service provider's control (e.g., home networks, LAN, application gateways, terminals, hosts, and other customer devices). We note that objectives on the performance of customer equipment are available, such as [ITU-T P.1010] for VoIP terminals and gateways, and combining these objectives with specific network performance levels (as appendices of this Recommendation illustrate), a view of application performance can be directly related to network performance.

In response, service providers have agreed on network performance levels that they will work together to meet, and have codified the numerical objectives in this Recommendation. Agreement on levels of network performance is highly beneficial, because it constrains a critical and often dominating factor in application performance [ITU-T I.350].

The objectives are organized in sets called network quality of service (QoS) classes (in Table 1) that can be matched with well-designed customer equipment to satisfactorily support various applications (as indicated in Table 2). Classes with provisional objectives are found in Table 3. The number of classes has been deliberately kept small to simplify the engineering of paths traversing multiple operators' networks, so the objectives in each class must satisfy the needs of multiple applications. Readers of this Recommendation should plan for at least eight classes when considering protocol fields and values, since future expansion of the classes is possible.

The objective values result from analysis of key applications such as conversational telephony, multimedia conferencing, reliable data exchange using TCP, and digital television, in concert with network feasibility analysis. The appendices provide significant, detailed testimony as to how the objectives in the network QoS classes can be used to determine the end-to-end (application) quality provided. Another factor in the development of objective values has been network feasibility. When paths span wide geographical distances, very long propagation times will prevent low delay objectives from being met, thus additional classes are required to address these cases.

It is important to clarify how designers of new applications should make use of the ITU-T Y.1541 classes. Designers should consider the packet performance objectives as representative of well-managed IP-based networks and include mitigations for these impairment levels in their designs. Only after application requirements have been carefully rationalized and a range of impairment mitigations have been examined, should new QoS classes be considered to address unmet requirements.

The network QoS classes form an important link in the chain of developments required to assure end-to-end performance. They are part of the lexicon for QoS negotiation among users and networks, especially when signalling protocols communicate QoS requests on a dynamic basis.

Verification that the service meets network objectives is another key area of customer interest. This has been addressed here through recommended evaluation intervals, packet payload sizes, and other aspects useful to measurement designers. In addition, the UNI-UNI objectives are directly verifiable by users, in contrast with objectives that apply to non-user interfaces or utilize information unknown to customers, such as route distance.

## 1.2 Scope

This Recommendation specifies network (UNI-UNI) IP performance values for each of the performance parameters defined in [ITU-T Y.1540]. The specific performance values vary, depending on the network QoS class. This Recommendation defines eight network QoS classes, two of which are provisional. This Recommendation applies to international IP network paths (UNI-UNI). The network QoS classes defined here are intended to be the basis of agreements between end-users and network service providers, and between service providers. The classes should continue to be used when static agreements give way to dynamic requests supported by QoS specification protocols.

The QoS classes defined here support an extremely wide range of applications, including the following: conversational telephony, multimedia conferencing, digital video, and interactive data transfer. Designers of new user applications should first consider using the existing QoS classes, and possibly include technologies to mitigate packet transfer impairments in their design. If one or more packet transfer requirements is not satisfied, then a new class may be considered rather than modifying the current/stable classes. However, any desire for new classes must be balanced with the requirement of feasible implementation, and the number of classes must be small for implementations to scale in global networks. Thus, the extent of user application coverage may expand over time, and readers of this Recommendation are urged to consult the latest version, including the appendices.

Since the QoS classes have been developed to support user applications, their numerical objectives are likely to support the same applications on networks using alternate technologies or combinations of technologies, providing that the fundamental transfer unit has a one-to-one correspondence with IP packets as used here (no fragmentation), and that the overhead of the alternate technology is a non-substantial addition to the IP header (e.g., multi-protocol label switching (MPLS) label and Ethernet frame overhead).

The QoS objectives are primarily applicable when access link speeds are at the T1 or E1 rate and higher. This limitation recognizes that IP packet serialization time is included in the definition of IP packet transfer delay (IPTD), and that sub-T1 access rates can produce serialization times of over 100 ms for packets with 1500 octet payloads. Also, this Recommendation effectively requires the deployment of network QoS mechanisms on access devices in order to achieve the IP packet delay variation (IPDV) objective, especially when the access rate is low (e.g., T1 rate). Network designs may include lower access rates if:

- 1) Network planners understand the effect of additional serialization time on the user network interface (UNI) to UNI objective for IPTD.
- 2) QoS mechanisms limit the access contribution to IPDV, and the UNI to UNI objective for IPDV is met. The current IPDV objective is necessary to achieve high quality application performance, as Appendices III and VII clearly show.

This Recommendation provides the network QoS classes needed to support user-oriented QoS categories. Accordingly, this Recommendation is consistent with the general framework for defining quality of communication services in [ITU-T G.1000], and with the end-user multimedia QoS categories needed to support user applications given in [ITU-T G.1010].

NOTE – This Recommendation utilizes parameters defined in [ITU-T Y.1540] that can be used to characterize IP services that are provided using IPv4 and IPv6. [ITU-T Y.1540] was used as the foundation of MPLS performance parameters in [ITU-T Y.1561] and Ethernet service performance parameters in [ITU-T Y.1563]. Applicability or extension to other protocols is for further study.

## 2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T E.651] Recommendation ITU-T E.651 (2000), *Reference connections for traffic engineering of IP access networks*.
- [ITU-T G.1000] Recommendation ITU-T G.1000 (2001), *Communications Quality of Service: A framework and definitions*.
- [ITU-T G.1010] Recommendation ITU-T G.1010 (2001), *End-user multimedia QoS categories*.
- [ITU-T I.350] Recommendation ITU-T I.350 (1993), *General aspects of quality of service and network performance in digital networks, including ISDNs*.
- [ITU-T P.1010] Recommendation ITU-T P.1010 (2004), *Fundamental voice transmission objectives for VoIP terminals and gateways*.
- [ITU-T Y.1221] Recommendation ITU-T Y.1221 (2010), *Traffic control and congestion control in IP-based networks*.
- [ITU-T Y.1231] Recommendation ITU-T Y.1231 (2000), *IP Access Network Architecture*.
- [ITU-T Y.1540] Recommendation ITU-T Y.1540 (2011), *Internet protocol data communication service – IP packet transfer and availability performance parameters*.
- [ITU-T Y.1561] Recommendation ITU-T Y.1561 (2004), *Performance and availability parameters for MPLS networks*.
- [ITU-T Y.1563] Recommendation ITU-T Y.1563 (2009), *Ethernet frame transfer and availability performance*.
- [IETF RFC 791] IETF RFC 791 (1981), *Internet Protocol, DARPA Internet Program Protocol Specification*.

## 3 Abbreviations, acronyms and conventions

### 3.1 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

|      |                              |
|------|------------------------------|
| AF   | Assured Forwarding           |
| ATM  | Asynchronous Transfer Mode   |
| BBER | Background Block Error Ratio |
| BE   | Best-Effort                  |
| CBR  | Constant Bit Rate            |
| CDV  | Cell Delay Variation         |



|          |                                                                |
|----------|----------------------------------------------------------------|
| CER      | Cell Error Ratio                                               |
| CLR      | Cell Loss Ratio                                                |
| CMR      | Cell Misinsertion Ratio                                        |
| CS       | Circuit Section                                                |
| DBW      | Dedicated Bandwidth                                            |
| DS       | Differentiated Services                                        |
| DST      | Destination host                                               |
| EF       | Expedited Forwarding                                           |
| ESR      | Errored Second Ratio                                           |
| FEC/I    | Forward Error Correction and Interleaving                      |
| FIFO     | First-In, First-Out                                            |
| FTP      | File Transfer Protocol                                         |
| GW       | Gateway                                                        |
| HRE      | Hypothetical Reference Endpoint                                |
| HRP      | Hypothetical Reference Path                                    |
| IP       | Internet Protocol                                              |
| IPDV     | IP packet Delay Variation                                      |
| IPER     | IP packet Error Ratio                                          |
| IPLR     | IP packet Loss Ratio                                           |
| IPOT     | Octet based IP packet Throughput                               |
| IPPT     | IP Packet Throughput                                           |
| IPRE     | IP packet transfer Reference Event                             |
| IPRR     | IP packet Reordering Ratio                                     |
| IPTD     | IP packet Transfer Delay                                       |
| ISP      | Internet Service Provider                                      |
| LL       | Lower Layers, protocols and technology supporting the IP layer |
| LP       | Loss Period                                                    |
| LAN      | Local Area Network                                             |
| MP       | Measurement Point                                              |
| MPLS     | Multi-Protocol Label Switching                                 |
| MPLS-FRR | MPLS-Fast Re-Route                                             |
| MTBA     | Mean Time Between visible Artefacts                            |
| MTBISO   | Mean Time between IP Service Outages                           |
| MTTISR   | Mean Time to IP Service Restoral                               |
| NS       | Network Section                                                |
| NSE      | Network Section Ensemble                                       |
| NSP      | Network Service Provider                                       |

|      |                                   |
|------|-----------------------------------|
| OSPF | Open Shortest Path First          |
| PDB  | Per Domain Behaviour              |
| PDH  | Plesiochronous Digital Hierarchy  |
| PHB  | Per Hop Behaviour                 |
| PIA  | Percent IP service Availability   |
| PIU  | Percent IP service Unavailability |
| PLC  | Packet Loss Concealment           |
| QoS  | Quality of Service                |
| R    | Router                            |
| RSVP | Resource Reservation Protocol     |
| RTP  | Real-Time Transport Protocol      |
| RTT  | Round Trip Times                  |
| SACK | Selective Acknowledgements        |
| SBW  | Statistical Bandwidth             |
| SDH  | Synchronous Digital Hierarchy     |
| SESR | Severely Errored Second Ratio     |
| SPR  | Spurious Packet Ratio             |
| SRC  | Source host                       |
| TC   | Transfer Capability               |
| TCP  | Transmission Control Protocol     |
| TDMA | Time Division Multiple Access     |
| TE   | Terminal Equipment                |
| ToS  | Type of Service                   |
| TS   | Transport Stream                  |
| TTL  | Time To Live                      |
| UDP  | User Datagram Protocol            |
| UNI  | User Network Interface            |
| VoIP | Voice over Internet Protocol      |
| VTC  | Video Teleconference              |

### 3.2 Conventions

|          |                                                                                |
|----------|--------------------------------------------------------------------------------|
| E1       | Digital hierarchy transmission at 2.048 Mbit/s                                 |
| E3       | Digital hierarchy transmission at 34 Mbit/s                                    |
| $M_{av}$ | The minimum number of packets recommended for assessing the availability state |
| N        | The number of packets in a throughput probe of size N                          |
| pkt      | IP datagram (IP packet)                                                        |
| T1       | Digital hierarchy transmission at 1.544 Mbit/s                                 |

|                  |                                                                                        |
|------------------|----------------------------------------------------------------------------------------|
| T <sub>3</sub>   | Digital hierarchy transmission at 45 Mbit/s                                            |
| T <sub>av</sub>  | Minimum length of time of IP availability; minimum length of time of IP unavailability |
| T <sub>max</sub> | Maximum IP packet delay beyond which the packet is declared to be lost                 |

#### 4 Transfer capacity, capacity agreements, and the applicability of QoS classes

This clause addresses the topic of network transfer capacity (the effective bit rate delivered to a flow over a time interval), and its relationship to the packet transfer quality of service (QoS) parameters defined in [ITU-T Y.1540], and the objectives specified here.

Transfer capacity is a fundamental QoS parameter having primary influence on the performance perceived by end users. Many user applications have minimum capacity requirements; these requirements should be considered when entering into service agreements.

It is assumed that the user and network provider have agreed on the maximum access capacity that will be available to one or more packet flows in a specific QoS class (except the Unspecified class). A packet flow is the traffic associated with a given connection or connectionless stream having the same source host (SRC), destination host (DST), class of service, and session identification. Other documents may use the terms microflow or subflow when referring to traffic streams with this degree of classification. Initially, the agreeing parties may use whatever capacity specifications they consider appropriate, so long as they allow both network provider enforcement and user verification. For example, specifying the peak bit rate on an access link (including lower layer overhead) may be sufficient. The network provider agrees to transfer packets at the specified capacity in accordance with the agreed QoS class.

When the protocols and systems that support dynamic requests are available, the user will negotiate a traffic contract. Such a contract specifies one or several traffic parameters (such as those defined in [ITU-T Y.1221], or RSVP) and the QoS class, and applies to a specific flow.

The network performance objectives may no longer be applicable when there are packets submitted in excess of the capacity agreement or the negotiated traffic contract. If excess packets are observed, the network is allowed to discard a number of packets equal to the number of excess packets. Such discarded packets must not be included in the population of interest, which is the set of packets evaluated using the network performance parameters. In particular, discarded packets must not be counted as lost packets in assessing the network's IP packet loss ratio (IPLR performance). A discarded packet might be retransmitted, but then it must be considered as a new packet in assessing network performance.

It is a network privilege to define its response to flows with excess packets, possibly based on the number of excess packets observed. When a flow includes excess packets, no network performance commitments need be honoured. However, the network may offer modified network performance commitments.

#### 5 Network performance objectives

This clause discusses objectives for the user information transfer performance of public IP services. These objectives are stated in terms of the IP layer performance parameters defined in [ITU-T Y.1540]. A summary of the objectives can be found in Table 1 together with its associated general notes. All values in Table 1 are stable.

NOTE – From a users' perspective, network QoS objectives contribute to only part of the transmission performance (e.g., mouth-to-ear quality in voice over IP). Appendix VII provides pointers to the appropriate Recommendations in this area.

## 5.1 General discussion of QoS

The QoS class definitions in Table 1 present bounds on the network performance between user network interfaces (UNI). As long as the users (and individual networks) do not exceed the agreed capacity specification or traffic contract, and a path is available (as defined in [ITU-T Y.1540]), network providers should collaboratively support these UNI-to-UNI bounds for the lifetime of the flow.

The actual network QoS offered to a given flow will depend on the distance and complexity of the path traversed. It will often be better than the bounds included with the QoS class definitions in Table 1.

Static QoS class agreements can be implemented by associating packet markings (e.g., Type of Service precedence bits or Diff-Serv Code Point) with a specific class.

Protocols to support dynamic QoS requests between users and network providers, and between network providers, are under study. When these protocols and supporting systems are implemented, users or networks may request and receive different QoS classes on a flow-by-flow basis. In this fashion, the distinct performance needs of different services and applications can be communicated, evaluated, and acknowledged (or rejected, or modified).

## 5.2 Reference path for UNI to UNI QoS

Flows contain one or more packets and each packet in a flow follows a specific path from UNI to UNI.

NOTE – The phrase "End-to-End" has a different meaning in Recommendations concerning user QoS classes, where end-to-end means, for example, from mouth to ear in voice quality Recommendations. Within the context of this Recommendation, end-to-end is to be understood as from UNI-to-UNI.

The UNI-to-UNI performance objectives are defined for the IP performance parameters corresponding to the IP packet transfer reference events (IPRE). The UNI-to-UNI IP performance objectives apply from user network interface-to-user network interface in Figure 1. The UNI-to-UNI IP network path includes the set of network sections (NS) and inter-network links that provide the transport of IP packets transmitted from the UNI at the SRC side to the UNI at the DST side; the protocols below and including the IP layer (layer 1 to layer 3) may also be considered part of an IP network. Network sections (defined in [ITU-T Y.1540]) are synonymous with operator domains, and may include IP access network architectures as described in [ITU-T E.651] and [ITU-T Y.1231]. The reference path in Figure 1 is an adaptation of the ITU-T Y.1540 performance model.

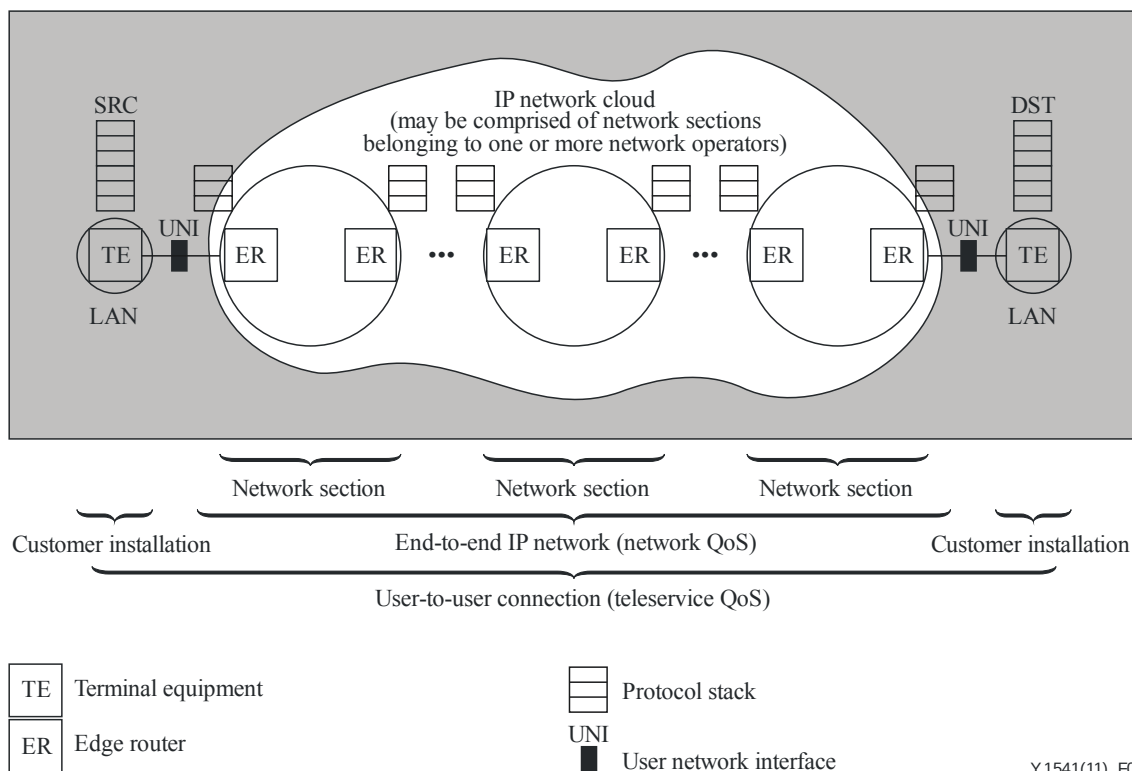


**Figure 1 – UNI-to-UNI reference path for network QoS objectives**

The customer installation includes all terminal equipment (TE), such as a host and any router or LAN if present. There will be only one human user in some applications. It is important to note that specifications for TE and the user-to-user connection are beyond the scope of this Recommendation. The edge routers that connect with the terminal equipment may also be called access gateways.

Reference paths have the following attributes:

- 1) IP clouds may support user-to-user connections, user-to-host connections, and other endpoint variations.
- 2) Network sections may be represented as clouds with edge routers on their borders, and some number of interior routers with various roles.
- 3) The number of network sections in a given path may depend upon the class of service offered, along with the complexity and geographic span of each network section.
- 4) The scope of this Recommendation allows one or more network sections in a path.
- 5) The network sections supporting the packets in a flow may change during its life.
- 6) IP connectivity spans international boundaries, but does not follow circuit switched conventions (e.g., there may not be identifiable gateways at an international boundary if the same network section is used on both sides of the boundary).

### 5.3 Network QoS classes

This clause describes the currently defined network QoS classes. Each network QoS class creates a specific combination of bounds on the performance values. Any flow that satisfies all the performance objectives of a QoS class can be considered fully compliant with the normative recommendations of this Recommendation for that class. This clause includes guidance as to when

each network QoS class might be used, but it does not mandate the use of any particular network QoS class in any particular context.

**Table 1 – IP network QoS class definitions and network performance objectives**

| Network performance parameter | Nature of network performance objective                                           | QoS Classes                 |                             |                    |                    |                    |                     |
|-------------------------------|-----------------------------------------------------------------------------------|-----------------------------|-----------------------------|--------------------|--------------------|--------------------|---------------------|
|                               |                                                                                   | Class 0                     | Class 1                     | Class 2            | Class 3            | Class 4            | Class 5 Unspecified |
| IPTD                          | Upper bound on the mean IPTD (Note 1)                                             | 100 ms                      | 400 ms                      | 100 ms             | 400 ms             | 1 s                | U                   |
| IPDV                          | Upper bound on the $1 - 10^{-3}$ quantile of IPTD minus the minimum IPTD (Note 2) | 50 ms (Note 3)              | 50 ms (Note 3)              | U                  | U                  | U                  | U                   |
| IPLR                          | Upper bound on the packet loss probability                                        | $1 \times 10^{-3}$ (Note 4) | $1 \times 10^{-3}$ (Note 4) | $1 \times 10^{-3}$ | $1 \times 10^{-3}$ | $1 \times 10^{-3}$ | U                   |
| IPER                          | Upper bound                                                                       | $1 \times 10^{-4}$ (Note 5) |                             |                    |                    |                    | U                   |

General notes:

The objectives apply to public IP networks. The objectives are believed to be achievable on common IP network implementations. The network providers' commitment to the user is to attempt to deliver packets in a way that achieves each of the applicable objectives. The vast majority of IP paths advertising conformity with [ITU-T Y.1541] should meet those objectives. For some parameters, performance on shorter and/or less complex paths may be significantly better.

An evaluation interval of 1 minute is suggested for IPTD, IPDV, and IPLR and, in all cases, the interval must be recorded with the observed value. Any minute observed should meet these objectives.

Individual network providers may choose to offer performance commitments better than these objectives.

"U" means "unspecified" or "unbounded". When the performance relative to a particular parameter is identified as being "U", ITU-T establishes no objective for this parameter and any default ITU-T Y.1541 objective can be ignored. When the objective for a parameter is set to "U", performance with respect to that parameter may, at times, be arbitrarily poor.

NOTE 1 – Very long propagation times will prevent low end-to-end delay objectives from being met. In these and some other circumstances, the IPTD objectives in classes 0 and 2 will not always be achievable. Every network provider will encounter these circumstances and the range of IPTD objectives in Table 1 provides achievable QoS classes as alternatives. The delay objectives of a class do not preclude a network provider from offering services with shorter delay commitments. According to the definition of IPTD in [ITU-T Y.1540], packet insertion time is included in the IPTD objective. This Recommendation suggests a maximum packet information field of 1500 bytes for evaluating these objectives.

NOTE 2 – The definition of the IPDV objective (specified in [ITU-T Y.1540]) is the 2-point IP packet delay variation. See [ITU-T Y.1540] and Appendix II for more details on the nature of this objective. For planning purposes, the bound on the mean IPTD may be taken as an upper bound on the minimum IPTD and, therefore, the bound on the  $1 - 10^{-3}$  quantile may be obtained by adding the mean IPTD and the IPDV value (e.g., 150 ms in class 0).

**Table 1 – IP network QoS class definitions and network performance objectives**

NOTE 3 – This value is dependent on the capacity of inter-network links. Smaller variations are possible when all capacities are higher than the primary rate (T1 or E1), or when competing packet information fields are smaller than 1500 bytes (see Appendix IV).

NOTE 4 – The class 0 and 1 objectives for IPLR are partly based on studies showing that high quality voice applications and voice codecs will be essentially unaffected by a  $10^{-3}$  IPLR.

NOTE 5 – This value ensures that packet loss is the dominant source of defects presented to upper layers, and is feasible with IP transport on ATM.

### 5.3.1 Nature of the network performance objectives

The objectives in Table 1 apply to public IP networks, between MPs that delimit the end-to-end IP network. The objectives are believed to be achievable on common implementations of IP networks.

The left-hand part of Table 1 indicates the statistical nature of the performance objectives that appear in the subsequent rows.

The performance objectives for IP packet transfer delay are upper bounds on the underlying mean IPTD for the flow. Although many individual packets may have transfer delays that exceed this bound, the average IPTD for the lifetime of the flow (a statistical estimator of the mean) should normally be less than the applicable bound from Table 1.

The performance objectives for 2-point IP packet delay variation (defined in [ITU-T Y.1540]) are based on an upper bound on the  $1 - 10^{-3}$  quantile of the underlying IPTD distribution for the flow. The  $1 - 10^{-3}$  quantile allows short evaluation intervals (e.g., a sample with 1000 packets is the minimum necessary to evaluate this bound). Also, this allows more flexibility in network designs where engineering of delay buildout buffers and router queue lengths must achieve an overall IPLR objective on the order of  $10^{-3}$ . Use of lower quantile values will result in under-estimates of de-jitter buffer size, and the effective packet loss would exceed the overall IPLR objective (e.g., an upper quantile of  $1 - 10^{-2}$  may have an overall packet loss of 1.1%, with  $\text{IPLR} = 10^{-3}$ ). Other statistical techniques and definitions for IPDV are being studied as described in Appendix II, and Appendix IV discusses IPDV performance estimation.

The performance objectives for the IP packet loss ratios are upper bounds on the IP packet loss for the flow. Although individual packets will be lost, the underlying probability that any individual packet is lost during the flow should be less than the applicable bound from Table 1.

Objectives for less-prevalent packet transfer outcomes and their associated parameters are for further study, such as the spurious packet ratio (SPR) defined in [ITU-T Y.1540].

### 5.3.2 Evaluation intervals

The objectives in Table 1 cannot be assessed instantaneously. Evaluation intervals produce subsets of the packet population of interest (as defined in [ITU-T Y.1540]). Ideally, these intervals are:

- Sufficiently long to include enough packets of the desired flow, with respect to the ratios and quantiles specified.
- Sufficiently long to reflect a period of typical usage (flow lifetime), or user evaluation.
- Sufficiently short to ensure a balance of acceptable performance throughout each interval (intervals of poor performance should be identified, not obscured within a very long evaluation interval).
- Sufficiently short to address the practical aspects of measurement.

For evaluations associated with telephony, a minimum interval of the order of 10 to 20 seconds is needed with typical packet rates (50 to 100 packets per second), and intervals should have an upper limit on the order of minutes. A value of 1 minute is suggested and, in any case, the value used must be recorded with the observed value, along with any assumptions and confidence intervals. Any minute observed should meet the IPTD, IPDV, and IPLR objectives of Table 1. Minimally acceptable estimation methodologies are intended for future revisions of this Recommendation.

Methods to verify achievement of the objectives are for further study. Either continuous or non-continuous evaluation may be used. One possible method of measurement is given in [b-IETF RFC 3432], where the requirement for random measurement start times and evaluation intervals of finite length result in a non-continuous evaluation.

### 5.3.3 Packet size for evaluation

Packet size influences the results for most performance parameters. A range of packet sizes may be appropriate since many flows have considerable size variation. However, evaluation is simplified with a single packet size when evaluating IPDV, or when the assessment is targeting flows that support constant bit rate sources. Therefore, a fixed information field size is recommended. Information fields of either 160 octets or 1500 octets are suggested, and the field size used must be recorded. Also, an information field of 1500 octets is recommended for performance estimation of IP parameters when using lower layer tests, such as bit error measurements.

### 5.3.4 Unspecified (unbounded) performance

For some network QoS classes, the value for some performance parameters is designated "U". In these cases, ITU-T sets no objectives regarding these parameters. Network operators may unilaterally elect to assure some minimum quality level for the unspecified parameters, but ITU-T does not recommend any such minimum.

Users of these QoS classes should be aware that the performance of unspecified parameters can, at times, be arbitrarily poor. However, the general expectation is that mean IPTD will be no greater than 1 second.

NOTE – The word "unspecified" may have a different meaning in Recommendations concerning B-ISDN signalling.

### 5.3.5 Discussion of the IPTD objectives

Very long propagation times will prevent low UNI-to-UNI delay objectives from being met, e.g., in cases of very long geographical distances, or in cases where geostationary satellites are employed. In these and some other circumstances, the IPTD objectives in classes 0 and 2 will not always be achievable. It should be noted that the delay objectives of a class do not preclude a network provider from offering services with shorter delay commitments. Any such commitment should be explicitly stated. See Appendix III for an example calculation of IPTD on a global route. Every network provider will encounter these circumstances (either as a single network, or when working in cooperation with other networks to provide the UNI-to-UNI path), and the range of IPTD objectives in Table 1 provides achievable network QoS classes as alternatives. Despite different routing and distance considerations, related classes (e.g., classes 0 and 1) would typically be implemented using the same node mechanisms.

According to the definition of IPTD in [ITU-T Y.1540], packet insertion time is included in the IPTD objectives. This Recommendation suggests a maximum packet information field of 1500 bytes for evaluating the objectives.

### 5.3.6 Guidance on class usage

Table 2 gives some guidance for the applicability and engineering of the network QoS classes.

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**Table 2 – Guidance for IP QoS classes**

| QoS class | Applications (examples)                                        | Node mechanisms                                              | Network techniques                     |
|-----------|----------------------------------------------------------------|--------------------------------------------------------------|----------------------------------------|
| 0         | Real-time, jitter sensitive, high interaction (VoIP, VTC)      | Separate queue with preferential servicing, traffic grooming | Constrained routing and distance       |
| 1         | Real-time, jitter sensitive, interactive (VoIP, VTC).          |                                                              | Less constrained routing and distances |
| 2         | Transaction data, highly interactive (Signalling)              | Separate queue, drop priority                                | Constrained routing and distance       |
| 3         | Transaction data, interactive                                  |                                                              | Less constrained routing and distances |
| 4         | Low loss only (short transactions, bulk data, video streaming) | Long queue, drop priority                                    | Any route/path                         |
| 5         | Traditional applications of default IP networks                | Separate queue (lowest priority)                             | Any route/path                         |

NOTE – Any example application listed in Table 2 could also be used in class 5 with unspecified performance objectives, as long as the users are willing to accept the level of performance prevalent during their session.

Traffic policing and/or shaping may also be applied in network nodes.

Table 2 conveys one of the principles of QoS class development, that the requirements of multiple applications are addressed by a single set of network performance objectives. This approach keeps the number of QoS classes small and manageable. Figure 2 below illustrates the approach of satisfying applications with common performance requirements in a single QoS class (for example, applications 2, 3, and 4 are all satisfied by QoS classes Y and Y\*, where Y\* modifies one or more performance requirements based on network feasibility).

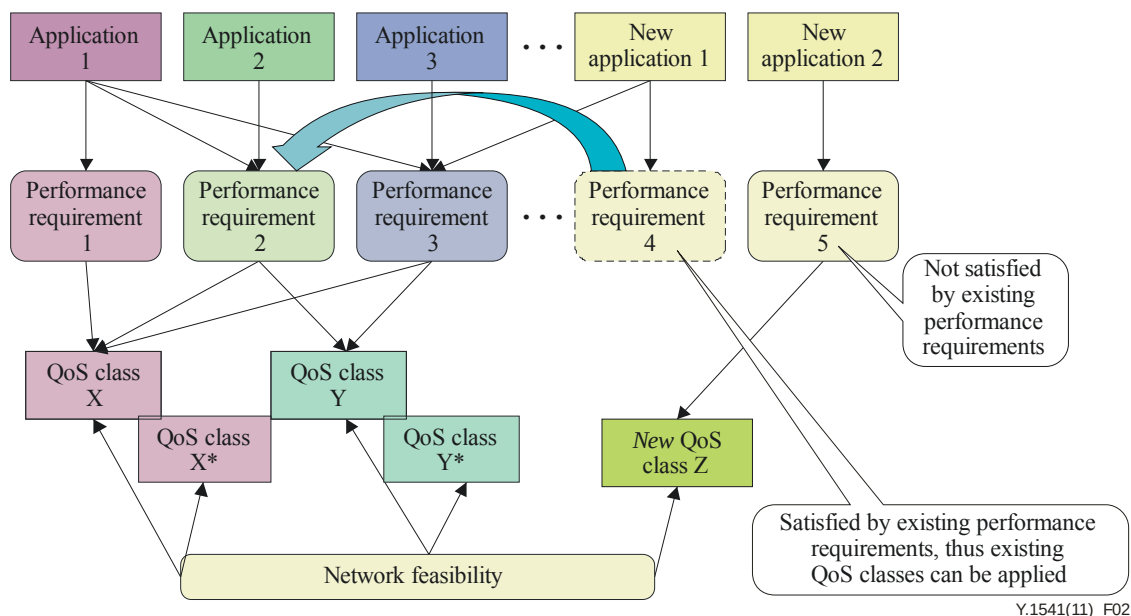


**Figure 2 – Principle of multiple applications supported by a lesser number of QoS classes**

With the growing number of user applications, it is important that new applications consider first how their requirements are similar to the applications already supported and seek to satisfy their requirements using one of the existing QoS classes.

### 5.3.7 Provisional network QoS classes

This clause presents a set of provisional network QoS classes. The distinction between these classes (see Table 3) and those in Table 1, is that the values of all objectives are provisional and they need not be met by networks until they are revised (up or down), based on real operational experience.

In this revision, there is agreement that the applications which provided the original rationale for the IPLR in Table 3 have evolved. In at least one case (IPTV) the performance objectives of Table 1 may now be sufficient (see Appendix VIII). New applications with strict performance needs are emerging, and their requirements are for further study. However, the provisional status of the classes and numerical objectives in Table 3 remains unchanged in this revision, pending further study and agreement.

**Table 3 – Provisional IP network QoS class definitions and network performance objectives**

| Network performance parameter | Nature of network performance objective                                           | QoS Classes        |         |
|-------------------------------|-----------------------------------------------------------------------------------|--------------------|---------|
|                               |                                                                                   | Class 6            | Class 7 |
| IPTD                          | Upper bound on the mean IPTD                                                      | 100 ms             | 400 ms  |
| IPDV                          | Upper bound on the $1 - 10^{-5}$ quantile of IPTD minus the minimum IPTD (Note 1) | 50 ms              |         |
| IPLR                          | Upper bound on the packet loss ratio                                              | $1 \times 10^{-5}$ |         |
| IPER                          | Upper bound                                                                       | $1 \times 10^{-6}$ |         |
| IPRR                          | Upper bound                                                                       | $1 \times 10^{-6}$ |         |

**General notes:**

Evaluation intervals for these classes should be 1 minute or longer. Evaluations should use 1500 byte payloads. An evaluation interval of 1 minute is suggested for IPTD, IPDV, and IPLR, and any minute observed should meet these objectives.

One rationale for the IP packet loss ratio (IPLR) objective was to minimize the effect of loss on TCP capacity, even when TCP parameters and the operating system have been tuned, and the large windows option has been utilized. Appendix IX provides background information on this and other support rationales. TCP selective acknowledgements (SACK), multi-path connections, and revised congestion control may reduce the loss objective, and they are subjects of further study.

The value for IPLR specified above, is not sufficient to support all the quality levels envisioned by the community of digital video users, and forward error correction and interleaving (FEC/I) or other forms of packet loss mitigation are required. Appendix VIII supplies background on the quality expectations of video transport users, and multiple forms of packet loss mitigation needed to produce low loss ratios.

The objective for IP packet error ratio (IPER) was set so as to contribute insignificantly to the overall packet loss.

The IP packet reordering ratio (IPRR) has been defined in [ITU-T Y.1540]. Reordered packets may appear as lost to a TCP sender, depending on the distance from their original positions. Therefore, the IPRR was set so as to contribute insignificantly to the overall packet loss.

New performance parameters for stream repair have been agreed and included in [ITU-T Y.1540]; they are applicable to the user applications considered in this Table. The role of these new metrics in network QoS performance objectives is for further study.

**Table 3 – Provisional IP network QoS class definitions and network performance objectives**

| Network performance parameter                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Nature of network performance objective | QoS Classes |         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|-------------|---------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                         | Class 6     | Class 7 |
| <p>The value for IPDV is under study, and contributions are invited to examine the rationale and feasibility of other (lower) values. In particular, if this table's scope was restricted to a higher category of access speeds than Table 1, then considerably lower IPDV objectives are possible (as Appendix IV shows).</p> <p>NOTE 1 – The definition of the IPDV objective (specified in [ITU-T Y.1540]) is the 2-point IP packet delay variation. See [ITU-T Y.1540] and Appendix II for more details on the nature of this objective. For planning purposes, the bound on the mean IPTD may be taken as an upper bound on the minimum IPTD, and therefore the bound on the <math>1 - 10^{-5}</math> quantile may be obtained by adding the mean IPTD and the IPDV value (e.g., 150 ms in class 6).</p> |                                         |             |         |

These classes are intended to support the performance requirements of high bit rate user applications that have more stringent loss/error requirements than those supported by classes 0 through 4 in Table 1.

Discussions of broadcast quality television transport on IP may be found in Appendix VIII. Appendix IX estimates TCP file transfer performance on paths conforming to [ITU-T Y.1541] objectives. Appendix XI estimates the packet loss requirement for digital circuit emulation. Some of these appendices are expected to be revised following further study, and new appendices may be added to describe models of new user applications and the estimated performance requirements based on those models.

## 6 Availability objectives

This clause will include information about availability objectives based on the availability parameter defined in [ITU-T Y.1540]. The objectives require more study, since fundamental network design options are rapidly changing.

## 7 Achievement of the performance objectives

Further study is required to determine how to achieve these performance objectives when multiple network providers are involved. There are promising standards development activities that are intended to complete other aspects needed for UNI-UNI QoS assurance.

Clause 8 gives the relationships for concatenating the performance levels of two or more network sections to determine whether the UNI-UNI objectives are met.

## 8 Concatenating network sections and their QoS values

### 8.1 Introduction

This clause addresses the estimation of the UNI-UNI performance of a path, knowing the performance of sub-sections. The purpose is to provide standard relationships to compose these UNI-UNI estimates.

These relationships produce reasonably accurate estimates of the UNI-UNI performance. Errors in the estimation process are believed to be in balance with potential errors of the individual values themselves. When the values come from recent measurements or modelling activities, they can be subject to considerable error if conditions are not stationary, or the principal assumption of independence between network sections does not hold.