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Corrigendum 1

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

Internet protocol aspects – Quality of service and network performance

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Roadmap for the quality of service of interconnected networks that use the Internet protocol

Corrigendum 1

Recommendation ITU-T Y.1545 (2013) – Corrigendum 1

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Recommendation ITU-T Y.1545

Roadmap for the quality of service of interconnected networks that use the Internet Protocol

Corrigendum 1

Summary

Recommendation ITU-T Y.1545 is intended as a guide to help regulators and network service providers meet QoS performance objectives.

Traditional packet networks have been built under the principle that networks will operate on the basis of an unguaranteed best-effort packet delivery. The best effort paradigm has been spectacularly successful in supporting non-real-time data applications (e.g., email and file transfer); this principle assigns the responsibility for detecting and correcting transmission problems to the customer equipment and higher-level protocols that require better network support.

However, the best-effort delivery principle does not provide a reliable quality of user experience in interactive voice telephony and other demanding real-time applications when network bandwidth limitations increase considerably delay, jitter and packet loss. These applications work best across networks that can deliver "better than best-effort" performance for various characteristics.

This corrigendum introduces changes related to the withdrawal of IEEE 802.1D.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.1545	2013-05-14	12	11.1002/1000/11938
1.1	ITU-T Y.1545 (2013) Cor. 1	2021-05-13	12	11.1002/1000/14705

Keywords

Network service provider, NSP, quality of service, QoS, QoS classes.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Roadmap for the quality of service of interconnected networks that use the Internet Protocol

Corrigendum 1

Editorial note: This is a complete-text publication. Modifications introduced by this corrigendum are shown in revision marks relative to Recommendation ITU-T Y.1545 (2013).

1 Scope

This Recommendation:

- Recommends performance objectives of packet-based networks accepted across a UNI for each defined packet network QoS class, addressing "end-to-end network" or bearer QoS.
- Recommends packet marking and handling mechanisms designed for indicating the accepted packet network QoS class for a given incoming IP packet on a UNI or NNI.
- Addresses procedures for the measurement of the QoS performance of packet-based networks, namely MPLS, Ethernet and IP.

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.800] Recommendation ITU-T E.800 (2008), *Definitions of terms related to quality of service*.

[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.1541] Recommendation ITU-T Y.1541 (2011), *Network performance objectives for IP-based services.*

[ITU-T Y.1543] Recommendation ITU-T Y.1543 (2007), *Measurements in IP networks for inter-domain performance assessment*.

[IETF RFC 3432] IETF RFC 3432 (2002), *Network performance measurement with periodic streams*.

3 Terms and definitions

3.1 Terms and definitions defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 IP packet loss ratio [ITU-T Y.1540]: The ratio of total lost IP packets to total transmitted packets in a population of interest.

3.1.2 interconnection [ITU-T E.800]: Is the physical and logical linking of public communications networks used by the same or a different service provider in order to allow the users of one service provider to communicate with users of another service provider, or to access services provided by another service provider.

3.1.3 measurement point [ITU-T Y.1540]: The boundary between a host and an adjacent link at which performance reference events can be observed and measured. Consistent with [b-ITU-T I.353], the standard Internet protocols can be observed at IP measurement points. [b-ITU-T I.353] provides more information about MPs, for digital services.

3.1.4 network performance [ITU-T E.800]: Is the ability of a network or network portion to provide the functions related to communications between users.

3.1.5 populations of interest [ITU-T Y.1540]: For the *end-to-end case*, the population of interest is usually the total set of packets being sent from SRC to DST. The measurement points in the end-to-end case are the MP-UNIs at the SRC and DST as shown in Figure 1.

3.1.6 quality of service [ITU-T E.800]: Is the totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service.

3.1.7 service level agreement [ITU-T E.800]: Is a formal document listing a set of performance characteristics and target values (or range) to be delivered for a service or portfolio of services by the service provider.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 host: A host is a computer that communicates using the Internet protocols. A host implements routing functions (i.e., it operates at the IP layer) and may implement additional functions including higher layer protocols (e.g., TCP in a source or destination host) and lower layer protocols (e.g., ATM).

3.2.2 IP packet delay variation (IPDV): The difference between the actual IPTD of a packet and a reference IPTD for a packet population of interest. IPDV is also referred to as "jitter", and is usually reported in milliseconds.

3.2.3 IP packet transfer delay (IPTD): The one-way time interval between the moment the first bit of an IP packet crosses the MP at the source (entry point of a network) and the moment the last bit of the same packet crosses an MP at the destination (exit point of the network). IPTD is also referred to as "delay" or "latency".

3.2.4 network service provider: An organization that provides Internet access to Internet service providers. A network service provider offers a direct access to the Internet backbone, network services or interexchange carriers.

3.2.5 packet network: A network that uses the Internet protocol or other similar frame-based protocols such as Ethernet and MPLS.

3.2.6 parameter: A quantifiable characteristic of a service with specified scope and boundaries.

3.2.7 probing packet: An individual IP packet associated with active performance testing, i.e., a test packet [ITU-T Y.1543].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AF Assured Forward

DF Default Forward

DiffServ	Differentiated Service
DSCP	Differentiated Service Code Point
EF	Expedited Forward
ER	Edge Router
IP	Internet Protocol
IPDV	IP Delay Variation
IPLR	IP Packet Loss Ratio
IPTD	IP Transfer Delay
LAN	Local Area Network
MP	Measurement Point
MPLS	Multiprotocol Label Switching
MS	Microsoft
MTU	Maximum Transmission Unit
NNI	Network-to-Network Interface
NP	Network Performance
NS	Network Section
NSP	Network Service Provider
PHP	Per Hop Behaviour
QoS	Quality of Service
SLA	Service Level Agreement
TE	Terminal Equipment
UNI	User Network Interface
UTC	Universal Coordinated Time
VLAN ID	Virtual Local Area Network Identification
VoIP	Voice over IP
VTC	Video Teleconference

5 Conventions

None.

6 Basic reference architecture

The performance objectives in this Recommendation are expected to be measured over packets in a population of interest that enter a network at a source user-network interface (UNI), travel along a path through one or more concatenated packet network sections, and exit through a destination UNI, possibly connected to a different network, as depicted in Figure 1.

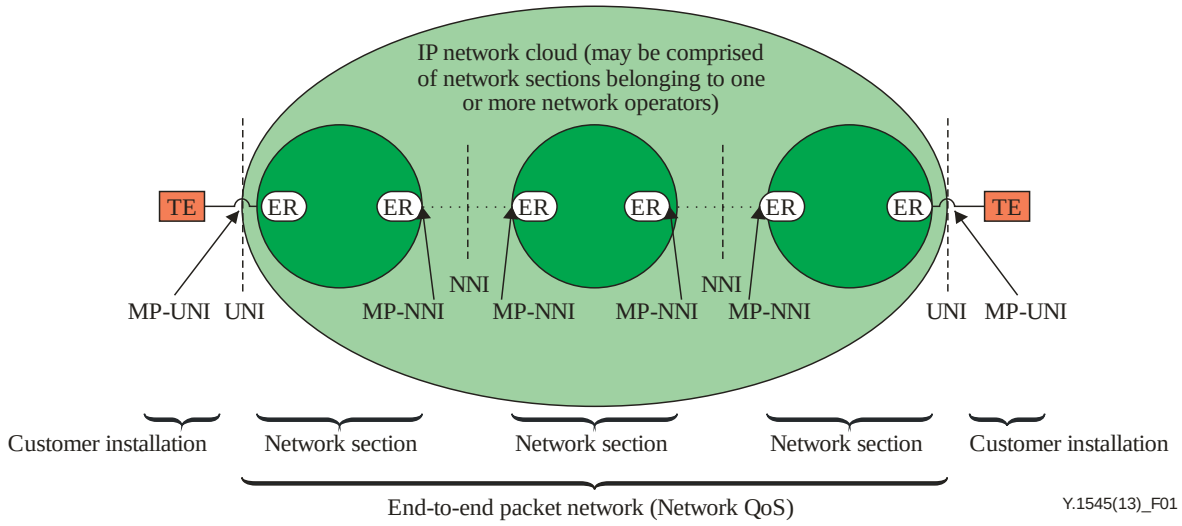

Figure 1 – End-to-end packet network [ITU-T Y.1541]

A network service provider (NSP) is expected to only measure its own network section (UNI-to-NNI or NNI-to-NNI), and rely on reports from other interconnected NSPs to derive the UNI-to-UNI performance likely to be experienced by an end-user's traffic.

7 Guidelines

7.1 QoS parameters

This Recommendation considers the following quality of service parameters:

- IPTD (IP transfer delay)
- IPDV (IP delay variation) sometimes referred as jitter
- IPLR (IP packet loss ratio)

7.2 Quality of service (QoS) classes and network performance objectives

The QoS classes and related performance objectives for packet-based networks to be applied by NSPs are described in Table 1.

Table 1 – QoS classes of packet networks [ITU-T Y.1541]

QoS Class	Applications	Network performance parameter			Comments
		IPTD	IPDV	IPLR	
Class 0	Voice over IP (VoIP) video teleconference (VTC)	≤ 100 ms	≤ 50 ms	≤ 10^{-3}	PSTN-quality VoIP (or voice telephony) Real-time, jitter sensitive, high interaction
Class 1	Voice over IP (VoIP) video teleconference (VTC)	≤ 400 ms	≤ 50 ms	≤ 10^{-3}	Satellite-quality VoIP Real-time, jitter sensitive, interactive
Class 2	Transaction data	≤ 100 ms	U	≤ 10^{-3}	Signalling Highly interactive
Class 3	Transaction data	≤ 400 ms	U	≤ 10^{-3}	Business data (e.g., e-banking) Interactive

Table 1 – QoS classes of packet networks [ITU-T Y.1541]

QoS Class	Applications	Network performance parameter			Comments
		IPTD	IPDV	IPLR	
Class 4	Video streaming	≤ 1 s	U	$\leq 10^{-3}$	File transfer Low loss only (short transactions)
Class 5	Traditional applications of default IP networks	U	U	U	Best effort
NOTE – U means "unspecified" or "unbounded". For more information, see [ITU-T Y.1541].					

7.3 Packet marking

- A single NNI or UNI may carry traffic from several applications, intended for multiple packet network QoS classes. In order for the receiving network to apply the appropriate treatment to each packet in accordance with the desired packet network QoS class, the packets shall be marked in an appropriate way by the sender. Refer to Table I.1 for more information on packet marking.
- The QoS class agreements should be implemented by associating packet markings (e.g., type of service precedence bits or differentiated service code point) with a specific QoS class.

7.4 Packet handling

- When a packet is received for a supported packet network QoS class, the receiving network provider shall transport it according to the service level agreement it has established with the sender network provider. When multiple network sections are present in a UNI-to-UNI path, the transfer capacities available for each QoS class at the point of NNI should be considered and agreed upon between all network providers in the path.
- When a received packet is marked for a packet network QoS class that is not supported within the sender's service agreement with the receiving network service provider, then the receiving network provider should carry the received packet in another agreed class but with the sender's marking preserved.
- To avoid packet re-ordering, it is recommended that packets belonging to the same flow should be allocated to the same packet network QoS class and given the same treatment in network queues.

7.5 Network performance

A network service provider should state what the performance objectives of a packet service across their network are, using the metrics in clause 7.2, for each QoS class offered.

7.6 Performance measurement

The purpose of performance measurement of QoS parameters is to ensure that the performance objectives are achieved.

7.6.1 Performance measurement of traffic (or test traffic)

- When verifying performance of an end-user's service, measurement using probing packets is typically appropriate.
- Probing packets should be generated only for each packet network QoS class contracted to be carried for the end-user by the NSP.
- Traffic performance is verified by measuring the performance parameters of a population of packets as they cross one or more network sections.
- Probing packets for each packet network QoS class should be evenly distributed throughout the test packets of a population [IETF RFC 3432].
- Probing packets should traverse the same path as the user's packets that have the same packet network QoS class. The same QoS treatment should be provided to test traffic as is provided to end-user traffic along the path. In particular, the packet marking of test traffic should be the same as for user traffic for the packet network QoS class to be measured.
- Any individual stream of probing packets should not be sent at a higher data rate than is committed for an individual stream of end-user traffic.
- Test traffic should be transmitted with uniform packet length.
- Test traffic may be transmitted with uniform inter-packet spacing, or the inter-packet spacing may have a random distribution. If a uniform inter-packet spacing is used then the test procedure should conform to [IETF RFC 3432].
- The probe payload size should be set at up to 20 octets (for classes 0 and 1) and 256 octets of probe payload size (for classes 2, 3 and 4), [ITU-T Y. 1543].
- The information field size and protocol used must be recorded.
- When the sum of the committed data rates for all contracted packet network QoS classes exceeds the maximum committed capacity of the service, then the service is overbooked. In such cases, the test data rate for each packet network QoS class with a lesser priority should be reduced in accordance with the service contract such that the service is not overbooked.
- The measurement time should be indicated when reporting the results using UTC.

7.6.2 Performance measurement duration (or test duration)

The test duration should be recorded with the corresponding measured metrics:

- A measurement interval (roll-up period) of 5 minutes for all packet network QoS classes (0, 1, 2, 3 and 4), according to [ITU-T Y.1543].
- Probe packet transmission period (continuous) of 100 ms for all packet network QoS classes (0, 1, 2, 3 and 4) [ITU-T Y.1543].
- At the end of a test, measuring equipment (receiving the probing packets) should continue to listen for and count packets for at least 3 seconds after the traffic generator has ceased transmitting the test packet stream.

7.7 Performance monitoring

- The purpose of performance monitoring is to confirm that ongoing delivery of the packet transport service is achieved within the performance objectives for the relevant packet network QoS classes.
- Monitoring is an intrinsic measurement method, intended to enable ongoing service assurance while the end-user's service is in line with the contracted service.
- When monitoring, the performance of a connection should be based on:
  - ✓ observing the end-user's traffic; or
  - ✓ introducing test traffic into the same physical path taken by the end-user's traffic.

- Packet performance should be measured and recorded in each monitoring period over a population-of-interest of 1500 packets, spread uniformly throughout the monitoring period.
- It is the responsibility of each NSP to establish the duration and frequency of its monitoring period in accordance with its operational policies and procedures.
- Measurements should not have an impact on end-user traffic and should include a repetition of measurement intervals to assist ongoing monitoring.
- The time between measurement intervals should be every 15 minutes [IETF RFC 3432].

7.8 Reporting

- The NSP should report the performance values periodically as may be required to the regulatory authority and performance values by the interconnected NSPs at least on a monthly basis. Moreover, the reporting should not exceed 10 working days from the end of each month. Each NSP should provide both a hard copy and a soft copy (word processor or spreadsheet) version of their reports.
- The NSP should retain quality of service data, including all measurements and related records, for a minimum of twelve (12) months after the end of the "reporting period" or as may be otherwise directed by the regulatory authority.

NOTE – All measurements, such as packets captured, etc., should be defined (by means of a common measurement data format). Otherwise, different NSPs might use different tools and provide different measurement data, which would increase the difficulty in interoperability.

- It is recommended that the following points be taken into consideration in the agreements (SLA signed between the two or more NSPs) to be signed by the NSPs, as a minimum:
  - ✓ Content and format of such reports
  - ✓ Agreed processes for the exchange of hard copies of the measurement results
  - ✓ Methods for the electronic exchange of measurement reports
  - ✓ The agreement should respect the time-frame of reporting given in this paper
  - ✓ One or more agreed threshold value(s) for each parameter with indications of severity.
- When the performance measurement of a network section exceeds an agreed threshold value for a parameter, the NSP should report the incident to its interconnected NSP and to the regulatory authority.
- It is recommended that reports, when an agreed threshold value is exceeded, should contain the following information, as a minimum:
  - ✓ Date
  - ✓ Time in UTC (at the commencement of the measurement interval)
  - ✓ Location of end points
  - ✓ Measurement/report period
  - ✓ Measurement type
  - ✓ Measurement statistics
  - ✓ Brief reason.

7.9 Publication

Regulatory authorities may, after analysis, mandate or request NSPs to make the necessary amendments or corrections to the measurements submitted by NSPs. Regulatory authorities should thereafter publish the measurements within one (1) month after the relevant end of the "*reporting period*" to which the measurements apply, with or without additional notes or comments.

Appendix I

Mapping between DiffServ, MPLS and Ethernet

(This appendix does not form an integral part of this Recommendation.)

This appendix introduces the mapping between differentiated service, multi-protocol label switching and Ethernet, as shown in Table I.1.

Table I.1 – Mapping table of DiffServ, MPLS and Ethernet [ITU-T Y.1541], [b-ITU-T Y.1566], [b-ITU-T Y.2113], [b-IETF RFC 4594], [b-IEEE 802.1p] and [IETF RFC 3270]

Packet network QoS class	Description	Layer 3 packet marking: DSCP (Diffserv Code Point)	Layer 2 packet marking		Applications
			MPLS (class of service)	Ethernet (priority code point)	
Classes 0, 1	Jitter sensitive	EF (Expedited forward)	5	5 (default) or 6	Telephony
Classes 2, 3, 4	Low latency	AF (Assured forward)	4, 3 or 2	4, 3 or 2	Signalling, interactive Data
Class 5	Best efforts	DF (Default forward)	0	0	Web browsing, Email

NOTE 1 – DiffServ is a service model which can offer several levels of service assuring differing QoS needs. DiffServ divides the traffic into a small number of classes and treats each class differently. In a DiffServ network, the edge router does admission control and ensures that only acceptable traffic is injected into the network. The remaining routers inside the DiffServ architecture network utilize the DSCP (DiffServ code point) in making scheduling behaviour known as a PHB (per hop behaviour) suitable for the particular class. A number of PHBs may be defined and enforced throughout a DiffServ network. For more information on DiffServ, refer to [b-IETF RFC 4594], [IETF RFC 2598] and [IETF RFC 2597].

NOTE 2 – MPLS is a connection-oriented technology which enables traffic engineering in packet-based networks. MPLS integrates the label swapping paradigm with network layer routing. Label swapping is accomplished by associating fixed-length labels with routes and using the label value to forward packets, including the procedure for determining the value of any replacement label. Label switching routers (LSRs) use link-level forwarding to provide a simple and fast packet-forwarding capability. For more information about MPLS, refer to [IETF RFC 3270] and [b-IETF RFC 3031].

NOTE 3 – [b-IEEE 802.1Q] defines an Ethernet frame format which allows inclusion of VLAN ID and priority. The IEEE Standard 802.1Q tagged frame defines a 3-bit field which accordingly specifies the QoS priority levels. ~~For more information on the QoS priority levels in the Ethernet, refer to [b-IEEE 802.1D].~~

Appendix II

Sharing of bearer QoS budgets

(This appendix does not form an integral part of this Recommendation.)

1) When a service passes through multiple interconnected networks, it is necessary for the end-to-end performance targets to be met so that the impairment budgets are shared between each of the networks in a fair way [b-ITU-T Y.1542].

2) The end-to-end expectation for each of these parameters can then be calculated as follows:

   - ✓ IPTD: Sum of the individual network mean values.
   - ✓ IPLR: Multiplication of the probabilities of successful transmission.

     $IPLR=1 – \{(1 – IPLR_{NS1}) \times (1 – IPLR_{NS2}) \times (1 – IPLR_{NS3}) \times (1 – IPLR_{NS4})\}$
   - ✓ IPDV: No practical method for calculating expected IPDV is available. The best that can be done is an estimate of the probability that IPDV exceeds a target.

3) For a clear understanding of the "*partitioning of bearer QoS*" and how to calculate the *end-to-end IP network performance (expected end-to-end IPTD, IPLR and IPDV)*, please refer to Appendices II, III and IV of [b-ITU-T Y.1542].

NOTE – The method described in Appendix I of [b-ITU-T Y.1542] (static divisor approach) is not recommended here.

Bibliography

[b-ITU-T I.353] Recommendation ITU-T I.353 (1996), *Reference events for defining ISDN and B-ISDN performance parameters*.

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[b-ITU-T Y.1566] Recommendation ITU-T Y.1566 (2012), *Quality of service mapping and interconnection between Ethernet, Internet protocol and multiprotocol label switching networks*.

[b-ITU-T Y.2113] Recommendation ITU-T Y.2113 (2009), *Ethernet QoS control for next generation networks*.

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[b-IEEE 802.1Q] IEEE Standard 802.1Q (2018), *IEEE standard for local and metropolitan area networks – Bridges and Bridged Networks.*~~IEEE Standard 802.1Q (2011), *IEEE standard for local and metropolitan area networks – Virtual Bridged Local Area Networks*~~.

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Differentiated Services.

[b-IETF RFC 3270] IETF RFC 3270 (2002), *Multi-Protocol Label Switching (MPLS) Support of Differentiated Services.*

[b-IETF RFC 4594] IETF RFC 4594 (2006), *Configuration Guidelines for DiffServ Service Classes*.

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