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ETSI Guide

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Part 3: Network performance metrics and
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Foreword

This ETSI Guide (EG) has been produced by ETSI Technical Committee Speech and multimedia Transmission Quality (STQ), and is now submitted for the ETSI standards Membership Approval Procedure.

The present document is part 3 of a multi-part deliverable covering the QoS and network performance metrics and measurement methods, as identified below:

Part 1: "General considerations";

Part 2: "Transmission Quality Indicator combining Voice Quality Metrics";

Part 3: "Network performance metrics and measurement methods in IP networks";

Part 4: "Indicators for supervision of Multiplay services".

Introduction

The need to define Internet performance metrics and measurement methodologies stems from the need to compare different measurements and to measure performance with a reproducible and unambiguous methodology, independent from transmission technology and implementation details. Both the ITU-T Study Group 12 and the IETF IPPM Working Group have produced such definitions (see table 1), although each with a different emphasis closely linked to the historical background of both organizations. The ITU has its origins in telephony, while the IETF has a data networking background. Whereas the ITU emphasizes the evaluation of a service and its quality, the IETF measures the network and wants to provide the IT-community with an accurate, common understanding and measurement of the performance and reliability the Internet [i.3].

In most cases this results in different terminology rather than in incompatibilities; most differences in approach and emphasis serve the different intended use of each metric, but have no operational significance. In some cases the terminology used by each organisations can be mapped to the other, while in some others there is only approximate equivalence (e.g. ITU network section versus an IPPM cloud; one focuses on corresponding events while the other measures the fate of a single packet). Other terms have no correspondence. For example, ITU-T Recommendation I.380 [i.38] has a notion of an IP packet transfer reference event while IPPM defines "wire time".

Other differences between IETF and ITU-T metrics result from their intended application. ITU-T metrics seek to provide a common language for providers to communicate about performance, so the ITU-T metrics do not concentrate on performance within a single network, while the IETF focuses on performance measurement protocols and implementation. ITU-T seeks to evaluate service and to exclude unfair use, while the IETF seeks to measure network quantities and avoid biased measurement results. Due to their respective backgrounds, the ITU generally produces statistical metrics geared towards a quantitative representation of the complete end-to-end user experience while the IETF IPPM working group mainly focuses more on statistical metrics which provide a detailed technical view of different aspects of transmission quality along the network path.

Table 1: Overview of Relevant Standards

	IETF RFCs	ITU-T Recommendations
Framework	RFC 2330 [i.3]	Y.1540 [i.1], sections 1 through 5
Loss	RFC 2680 [i.6]	Y.1540 [i.1], section 5.5.6 G.1020 [i.23]
Delay	RFC 2679 [i.5] (One-way) RFC 2681 [i.7] (Round Trip)	Y.1540 [i.1], section 6.2 G.1020 [i.23] G.114 [i.22] (One-way)
Delay Variation	RFC 3393 [i.10]	Y.1540 [i.1], section 6.2.2 G.1020 [i.23]
Connectivity / Availability	RFC 2678 [i.4]	Y.1540 [i.1], section 7
Loss Patterns	RFC 3357 [i.9]	G.1020 [i.23]
Packet Reordering **Packet Duplication**	RFC 4737 [i.15]	Y.1540 [i.1], sections 5.5.8.1 and 6.6 Y.1540 [i.1], sections 5.5.8.3, 5.5.8.4, 6.8, and 6.9
Link/Path Bandwidth Capacity, Link Utilization, Available Capacity	RFC 5136 [i.31]	
Bulk Transport Capacity	RFC 3148 [i.8], RFC 5136 [i.31]	

The goal of the present document is to define network performance metrics for applications sensitive to quality of service such as Voice over IP, referring to the existing work produced by both IETF and ITU-T. The present document highlights the differences between the two standards and provides guidelines on resolving these differences, when they are due to addressing different goals.

The scope of the present document is limited to IP performance metrics relevant for data transmission over IP-based networks for use in QoS sensitive applications. For each addressed metric, the document recommends one or more measurement methods. The document only focuses on intrinsic network QoS metrics; perceived QoS metrics applicable for voice transmission are out of scope of the present document.

The remainder of the present document is organised as follows: Clause 4 describes the definitions of the most important performance metrics as defined by the standard bodies and methods for measuring them, and discusses the applicability of the definitions and the differences between them. Clause 5 discusses other metrics applicable to QoS. Finally, clause 6 gives an overview of relevant QoS measurement standards, which can be used in end to end performance evaluation.

1 Scope

The present document provides an overview of the common metric definitions and measurement method specifications upon which the interoperability of network performance measurement (also called QoS measurement) is based. Two different standardisation bodies, the Internet Engineering Task Force (IETF) and the International Telecommunication Union - Telecommunication Standardization Sector (ITU - T), have addressed this issue. The present document addresses the following points:

- Survey the existing network performance related IETF standards and how these standards can be applied to end-to-end network performance measurements. The scope of this work is also to discuss the relationship of those standards to those of ITU-T and ETSI.
- Discuss and compare definitions of metrics used to specify and assess performance in IP networks. The metrics addressed in the present document are those defined by the IETF IPPM working group and ITU-T Study Group 12. Besides comparing the different definitions, the present document gives applicability guidelines on which metric is more appropriate for a particular application, configuration or scenario.
- Define measurement methods for selected performance metrics in IP networks, addressing both active and passive methods. Clarifying guidelines are given.

NOTE: All text sections in the remainder of the present document which are enclosed in quotation marks (") and *formatted in italic style* denote citations taken verbatim from referenced documents.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.
- Non-specific reference may be made only to a complete document or a part thereof and only in the following cases:
  - if it is accepted that it will be possible to use all future changes of the referenced document for the purposes of the referring document;
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2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] ITU-T Recommendation Y.1540: "Internet protocol data communication service - IP packet transfer and availability performance parameters".

[i.2] Void.

[i.3] IETF RFC 2330: "Framework for IP Performance Metrics". V. Paxson, G. Almes, J. Mahdavi, M. Mathis. May 1998.

[i.4] IETF RFC 2678: "IPPM Metrics for Measuring Connectivity". J. Mahdavi, V. Paxson. September 1999.

[i.5] IETF RFC 2679: "A One-way Delay Metric for IPPM". G. Almes, S. Kalidindi, M. Zekauskas. September 1999.

[i.6] IETF RFC 2680: "A One-way Packet Loss Metric for IPPM". G. Almes, S. Kalidindi, M. Zekauskas. September 1999.

[i.7] IETF RFC 2681: "A Round-trip Delay Metric for IPPM". G. Almes, S. Kalidindi, M. Zekauskas. September 1999.

[i.8] IETF RFC 3148: "A Framework for Defining Empirical Bulk Transfer Capacity Metrics". M. Mathis, M. Allman. July 2001.

[i.9] IETF RFC 3357: "One-way Loss Pattern Sample Metrics". R. Koodli, R. Ravikanth. August 2002.

[i.10] IETF RFC 3393: "IP Packet Delay Variation Metric for IP Performance Metrics (IPPM)". C. Demichelis, P. Chimento. November 2002.

[i.11] Void.

[i.12] Void.

[i.13] Void.

[i.14] IETF RFC 4656: "A One-way Active Measurement Protocol (OWAMP)". S. Shalunov, B. Teitelbaum, A. Karp, J. Boote, M. Zekauskas. September 2006.

[i.15] IETF RFC 4737: "Packet Reordering Metrics". A. Morton, L. Ciavattone, G. Ramachandran, S. Shalunov, J. Perser. November 2006.

[i.16] Void.

[i.17] Void.

[i.18] IETF RFC 5101: "Specification of the IPFIX Protocol for the Exchange of IP Traffic Flow Information". B. Claise, S. Bryant, S. Leinen, T. Deitz, B.Trammell. January 2008.

[i.19] IPFIX Architecture. N.Brownlee et Al. Internet-Draft, work in progress.

[i.20] IETF RFC 5102: "IPFIX Information Model". J. Quittek et Al. January 2008.

[i.21] "IPFIX Applicability Statement". T. Zseby, E. Boschi, N.Brownlee, B. Claise. Internet-Draft, work in progress.

[i.22] ITU-T Recommendation G.114 (05/03): "One-way transmission time".

[i.23] ITU-T Recommendation G.1020 (07/06): "Performance parameter definitions for quality of speech and other voiceband applications utilizing IP networks".

[i.24] IETF RFC 3917: "Requirements for IP Flow Information Export". J. Quittek, T. Zseby, B. Claise, S. Zander. October 2004.

[i.25] Void.

[i.26] Void.

[i.27] Void.

[i.28] Void.

[i.29] "Reporting Metrics: Different Points of View", A. Morton, G. Ramachandran, G. Maguluri, work in progress, draft-morton-ippm-reporting-metrics-02.

NOTE: http://tools.ietf.org/html/draft-morton-ippm-reporting-metrics-02, and the derived presentation "Reporting Metrics: Different Points of View" presented by Al Morton on IETF66 July 2006, http://www3.ietf.org/proceedings/06jul/slides/ippm-2.pdf .

[i.30] IETF RFC 3611: "RTP Control Protocol Extended Reports (RTCP XR)", T. Friedman, R. Caceres, A. Clark. November 2003.

[i.31] IETF RFC 5136: "Defining Network Capacity", P. Chimento, J. Ishac. February 2008.

[i.32] IETF RFC 2581: "TCP Congestion Control", M. Allman, V. Paxson, W. Stevens. April 1999.

[i.33] IETF RFC 5357: "A Two-Way Active Measurement Protocol (TWAMP)", K. Hedayat, R. Krzanowski, A. Morton, K. Yum, J. Babiarz. October 2008.

[i.34] IETF RFC 1122: "Requirements for Internet Hosts - Communication Layers", R. Braden ed. October 1989.

[i.35] IETF RFC 3550: "User Accounts for UCSB On-Line System".

[i.36] IETF RFC 1633: "Integrated Services in the Internet Architecture: an Overview".

[i.37] IETF RFC 2216: "Network Element Service Specification Template".

[i.38] ITU-T Recommendation I.380: "Internet protocol data communication service - IP packet transfer and availability performance parameters".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in RFC 2330 [i.3], ITU-T Recommendation G.1020 [i.23] and RFC 2680 [i.6] apply.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

T, t Time
T_{max} Time threshold
dT Time difference

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ASON	Automatically Switched Optical Network
ATM	Asynchronous Transfer Mode
BTC	Bulk transport Capacity
DNS	Domain Name System
ESD	End System Delay
FTP	File Transfer Protocol
HTTP	HyperText Transfer Protocol
ICMP	Internet Control Message Protocol
IETF	Internet Engineering Task Force
IPDV	IP Packet Dealy Variation
IPFIX	IP Flow Information eXport
IPLR	IP Packet Loss Ratio
IPPM	IP Performance Metrics
IPTD	IP Packet Transfer Delay
ITU-T	International Telecommunication Union - Telecommunication standardisation sector
MIB	Management Information Base
NSE	Network Section Ensemble
OP	Observation Point
OWAMP	One Way Active Measurement Protocol
OWD	One Way Delay
PDV	Packet Delay Variation
PIA	Percent IP service Availability
PON	Passive Optical Network
PSAMP	Packet SAMPling
QoS	Quality of Service
RFC	Request For Comments
RTCP	Real Time Control Protocol
RTD	Round Trip Delay
RTP	Real-Time Transport Protocol
RTT	Round Trip Time
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
TCP	Transmission Control Protocol
TWAMP	Two-Way Active Measurement Protocol
UTC	Coordinated Universal Time
VoIP	Voice over IP

4 Performance Metrics Definitions and Measurement Methods

This clause provides common definitions for network performance metrics. These definitions are based, whenever possible, on existing definitions proposed by other relevant standard bodies such as IETF or ITU-T. Note that the different definitions of similar metrics are in most cases compatible, that is, semantically equivalent or easily convertible into one another.

For each metric, passive and active measurement methods are defined. Note that we chose to focus on commonly used measurement methods rather than on standards; when a standard exists, a reference is provided as well. Note also that throughout this text we refer for each metric to active and passive measurements in the following way:

- **Active measurements**

  Active measurement methods inject traffic into the network and compute traffic metrics based on monitoring the injected traffic or the response to the injected traffic. Active test traffic may perturb other traffic already present on the network; therefore its scheduling and volume should be carefully configured. One can distinguish active monitoring systems based on the position of sender and receiver and the observed traffic; this is specified in detail for the considered metrics in the following text.

- **Passive measurements**

  Passive measurements provide information about traffic in the observed network by capturing all or a selected subset of the IP packets traversing a monitoring point. Since no test traffic is generated, passive measurements can only be applied when the traffic of interest is already present on the network. The physical deployment of monitoring probes in the network can be realised in different ways, depending on the metrics of interest, but also on the network technology, e.g. via a physical line splitter, via a normal client connection in broadcast networks, or via a dedicated monitoring port on a switch or router.

4.1 One Way Delay vs. IP Packet Transfer Delay

Delay is used to measure the expected time for an IP packet to traverse the network from one host to another. Delay is applicable to QoS for latency-sensitive protocols. The IETF and ITU-T metrics for measuring delay are essentially compatible, though there are minor differences; the details of these metrics are given in this clause.

4.1.1 IETF Definition

RFC 2679 [i.5] distinguishes between a "singleton analytic metric", called Type-P-One-way-Delay, and a "sample", called Type-P-One-way-Delay-Poisson-Stream. The singleton is introduced to measure a single observation of one-way delay, while the sample is used to measure a sequence of singleton delays measured at times taken from a Poisson process. Based on these samples, several statistics are defined, such as Type-P-One-way-Delay-Percentile, Type-P-One-way-Delay-Median, Type-P-One-way-Delay-Minimum, and Type-P-One-way-Delay-Inverse-Percentile.

Since the value of many of these metrics depends on the type of the IP packet used to perform the measurements, IPPM metrics definitions include the generic notion of "a packet of type P", which should be further specified when making actual measurements.

RFC 2679 [i.5] defines:

*"For a real number dT, >>the *Type-P-One-way-Delay* from Src to Dst at T is dT<< means that Src sent the first bit of a Type-P packet to Dst at wire-time* T and that Dst received the last bit of that packet at wire-time T+dT."*

The notion of wire time is introduced in RFC 2330 [i.3] in order to take into account the additional delay derived from the use of Internet hosts to perform the measurements. Wire time is defined with reference to an Internet host H observing an Internet link L at a particular location. More precisely, for a given packet P, the "wire arrival time" of P at H on L is the first time (see note) T at which the first bit of P has appeared at H's observational position on L. On the other side, For a given packet P, the 'wire exit time' of P at H on L is the first time T at which all the bits of P have appeared at H's observational position on L. Wire time delay is defined as the time between the first wire arrival time, the moment in which the first bit of the packet leaves the network interface of the source and the subsequent wire exit time at the remote end, the moment at which it has arrived completely at the network interface of the destination host.

NOTE: An IP packet might arrive at the destination Dst more than once, due to retransmission.

An upper bound for the expected packet delivery is taken into account (this threshold should also be reported):

"If the packet fails to arrive within a reasonable period of time, the one-way delay is taken to be undefined (informally, infinite)."