



ATIS-1000076

ATIS Standard on -

**Reliability and Quality of Service Enablers –
PSTN Transition to IP Packet Networks**



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Reliability and Quality of Service Enablers – PSTN Transition to IP Packet Networks

Alliance for Telecommunications Industry Solutions

Approved February 13, 2017

Abstract

This ATIS Standard provides a comprehensive list of standards, technical requirements, and technical reports that have already been developed in areas of IP packet reliability, priority, and Quality of Service (QoS). The goal is to demonstrate that IP packet networks and services are subjected to a similar level of depth and rigor as the PSTN on issues related to reliability, priority, and QoS.

Foreword

The Alliance for Telecommunication Industry Solutions (ATIS) serves the public through improved understanding between providers, customers, and manufacturers. The Packet Technologies and Systems Committee (PTSC) develops and recommends standards and technical reports related to services, architectures, and signaling, in addition to related subjects under consideration in other North American and international standards bodies. PTSC coordinates and develops standards and technical reports relevant to telecommunications networks in the U.S., reviews and prepares contributions on such matters for submission to U.S. ITU-T and U.S. ITU-R Study Groups or other standards organizations, and reviews for acceptability or per contra the positions of other countries in related standards development and takes or recommends appropriate actions.

The mandatory requirements are designated by the word *shall* and recommendations by the word *should*. Where both a mandatory requirement and a recommendation are specified for the same criterion, the recommendation represents a goal currently identifiable as having distinct compatibility or performance advantages. The word *may* denotes an optional capability that could augment the standard. The standard is fully functional without the incorporation of this optional capability.

Suggestions for improvement of this document are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions, PTSC, 1200 G Street NW, Suite 500, Washington, DC 20005.

At the time of consensus on this document, PTSC, which was responsible for its development, had the following leadership:

- M. Dolly, PTSC Chair (AT&T)
- V. Shaikh, PTSC Vice Chair (Applied Communication Sciences)
- P. Tarapore, Technical Editor (AT&T)

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1 Scope & Purpose

The Alliance for Telecommunications Industry Solutions (ATIS) Public Switched Telephone Network (PSTN) Transition Focus Group Report [ATIS-I-0000034] indicated several potential issues for the reliability and Quality of Service (QoS) aspects associated with the transition to IP-based packet networks and services. As stated in the Packet Technologies and Systems Committee (PTSC) Issue 129:

“There is a need to further review the reliability and QoS aspects within the PSTN Transition Focus Group Report. This report focuses on availability and robustness requirements and a strong requirement for ETS service reliability. In addition, there are no metrics or quantitative assessment methods specified. There are vague references to QoS parameters and a strong requirement for interconnection/interface QoS. In addition, there are no metrics or quantitative assessment methods specified.”

Accordingly, the purpose of this ATIS Standard is to provide a comprehensive list of standards, technical requirements, and technical reports that have already been developed in areas of Internet Protocol (IP) packet reliability, priority, and QoS. The goal is to demonstrate that IP packet networks and services are subjected to a similar level of depth and rigor as the PSTN on issues related to reliability, priority, and QoS.

Standards, technical requirements, and technical reports related to IP packet network and service reliability, priority, and QoS are enumerated in this ATIS Standard. These documents provide an extensive set of metrics, classification schemes, and measurement parameters associated with IP packet network and service reliability, priority, and QoS. The list is comprehensive but by its very nature it presents a snapshot in time; new documents continue to be developed. The goal of this document is to demonstrate significant efforts undertaken by the telecommunications industry to deliver reliable services with desired levels of priority and QoS over packet networks.

The standards and documents listed here include work from several ATIS Committees, International Telecommunications Union Telecommunication Sector (ITU-T) Study Groups, and the Internet Engineering Task Force (IETF) and the 3rd Generation Partnership Project (3GPP).

2 References

The following standards contain provisions which, through reference in this text, constitute provisions of this ATIS Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this ATIS Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

2.1 Normative References

ATIS-0100003, *User Plane Priority Levels for IP Networks and Services*.¹

ATIS-0100006, *Service Restoration Priority Levels for IP Networks*.¹

¹ This document is available from the Alliance for Telecommunications Industry Solutions (ATIS) at: < <https://www.atis.org/docstore/> >.

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ATIS-0100008, *Defects per Million (DPM) Metric for Transaction Services such as VoIP*.¹

ATIS-0100009, *Overview of Standards in Support of Emergency Telecommunications Service (ETS)*.¹

ATIS-0100011, *Priority for NS/EP Services in NGN/IP Environment – Role of TSP*.¹

ATIS-0100012, *Standard Outage Classification*.¹

ATIS-0100020, *Availability Metric for IP-Based Networks and Services*.¹

ATIS-0100021, *Analysis of FCC-Reportable Service Outage Data Version 2*.¹

ATIS-0100022, *Priority Classification Levels for Next Generation Networks*.¹

ATIS-0100025, *A Methodology for Estimating the Availability of Access IP Routers in Terms of Customer Facing Line Card Availability*.¹

ATIS-0100028, *Network Resiliency Planning for Enterprise Customers*.¹

ATIS-0100030, *Mean Time Between Outages – A Generalized Metric for Assessing Production Failure Rates in Telecommunications Network Elements*.¹

ATIS-0100032, *Relation Between ITU-T (Y.1541/Y.1221) and 3GPP UMTS/LTE QoS Classes*.¹

ATIS-0100035, *Telepresence Quality of Experience and Quality of Service*.¹

ATIS-0100037, *Impact Weighted MTBF – A Metric for Assessing Reliability of Hierarchical Systems*.¹

ATIS-0100038, *Analysis of Large DS3 FCC Reportable Outages*.¹

ATIS-1000011, *ETS Packet Priority for IP NNI Interfaces – Use of Existing Diffserv per Hop Behaviors*.¹

ATIS-1000020, *ETS Packet Priority for IP NNI Interfaces – Requirements for a Separate Expedited Forwarding Mechanism*.¹

ATIS-1000070, *Emergency Telecommunications Service (ETS) Roadmap*

ITU-T Recommendation G.1091, *QoE Requirements for Telepresence Services*.²

ITU-T Recommendation J.147, *Objective picture quality measurement method by use of in-service test signals*.²

ITU-T Recommendation J.148, *Requirements for an objective perceptual multimedia quality model*.²

ITU-T Recommendation J.241, *Quality of service ranking and measurement methods for digital video services delivered over broadband IP networks*.²

ITU-T Recommendation J.244, *Full reference and reduced reference calibration methods for video transmission systems with constant misalignment of spatial and temporal domains with constant gain and offset*.²

ITU-T Recommendation J.246, *Perceptual visual quality measurement techniques for multimedia services over digital cable television networks in the presence of a reduced bandwidth reference*.²

ITU-T Recommendation J.247, *Objective perceptual multimedia video quality measurement in the presence of a full reference*.²

ITU-T Recommendation J.248, *Requirements for operational monitoring of video-to-audio delay in the distribution of television programs*.²

ITU-T Recommendation J.249, *Perceptual video quality measurement techniques for digital cable television in the presence of a reduced reference*.²

ITU-T Recommendation J.260, *Requirements for preferential telecommunications over IPCablecom networks*.²

ITU-T Recommendation J.261, *Framework for implementing preferential telecommunications in IPCablecom and IPCablecom2 networks*.²

ITU-T Recommendation J.262, *Specifications for authentication in preferential telecommunications over IPCablecom2 networks*.²

ITU-T Recommendation J.263, *Specification for priority in preferential telecommunications over IPCablecom2 networks*.²

ITU-T Recommendation J.340, *Reference algorithm for computing peak signal to noise ratio of a processed video sequence with compensation for constant spatial shifts, constant temporal shift, and constant luminance gain and offset*.²

ITU-T Recommendation J.341 (2011), *Objective perceptual multimedia video quality measurement of HDTV for digital cable television in the presence of a full reference*.²

ITU-T Recommendation J.342 (2011), *Objective multimedia video quality measurement of HDTV for digital cable television in the presence of a reduced reference signal*.²

² Available from the ITU-T at: < <http://www.itu.int/ITU-T/recommendations/index.aspx> >.

ITU-T Recommendations J.343.1-6, *Hybrid perceptual bitstream video quality assessment family of Recommendations*.²

ITU-T Recommendation P.913, *Methods for the subjective assessment of video quality, audio quality and audiovisual quality of Internet video and distribution quality television in any environment*.²

ITU-T Recommendation P.1201, *Parametric non-intrusive assessment of audiovisual media streaming quality - Higher resolution application area*.²

ITU-T Recommendation P.1202, *Parametric non-intrusive bitstream assessment of video media streaming quality*.²

ITU-T Recommendation Y.1540, *Internet protocol data communication service – IP packet transfer and availability performance parameters*.²

ITU-T Recommendation Y.1561, *Performance and availability parameters for MPLS networks*.²

ITU-T Recommendation Y.1541, *Network performance objectives for IP-based services*.²

ITU-T Recommendation Y.1542, *Framework for achieving end-to-end IP performance objectives*.²

ITU-T Recommendation Y.1561, *Performance and availability parameters for MPLS networks*.²

ITU-T Recommendation Y.1566, *Quality of service mapping and interconnection between Ethernet, Internet protocol and multiprotocol label switching networks*.²

ITU-T Recommendation Y.2171, *Admission control priority levels in Next Generation Networks*.²

ITU-T Recommendation Y.2172, *Service restoration priority levels in Next Generation Networks*.²

ITU-T Recommendation Y.2174, *Distributed RACF architecture for MPLS networks*.²

IETF RFC 2597, *Assured Forwarding PHB Group*.³

IETF RFC 3246, *An Expedited Forwarding Per Hop Behavior (PHB)*.³

IETF RFC 3260, *New Terminology and Clarifications for DiffServe*.³

IETF RFC 3564, *Requirements for Support of Differentiated Services-aware MPLS Traffic Engineering*.³

IETF RFC 5865, *A Differentiated Services Code Point (DSCP) for Capacity-Admitted Traffic*.³

3GPP TS 23-203, *Policy and Charging Control Architecture*.⁴

3GPP TS 22-153, *Multimedia Priority Service*.⁴

2.2 Informative References

ATIS-I-0000034, *PSTN Transition Focus Group Assessment and Recommendations*.¹

3 Acronyms & Abbreviations

3GPP	Third Generation Partnership Project
AF	Assured Forwarding
ATIS	Alliance for Telecommunications Industry Solutions
BRR	Bit-Rate Reduction
CAC	Call Admission Control
CIF	Common Intermediate Format
DPM	Defects Per Million
DS	Differentiated Services (DiffServe)

³ Available from the IETF at: < <https://tools.ietf.org/> >.

⁴ Available from 3GPP at: < <http://www.3gpp.org/specifications> >.

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DSCP	DiffServe Code Point
DS-TE	DiffServe Aware MPLS Traffic Engineering
EF	Expedited Forwarding
ETS	Emergency Telecommunications Service
EVC	Ethernet Virtual Connections
FR	Full Reference
GBR	Guaranteed Bit Rate
GETS	Government Emergency Telecommunications Service
HD	High Definition
HDTV	High Definition Television
IANA	Internet Assigned Numbers Authority
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPTV	Internet Protocol Television
ITU-T	International Telecommunications Union Telecommunication Standardization Sector
IW-MTBF	Impact Weighted Mean Time Between Failure
LCD	Liquid Crystal Display
LDP	Label Distribution Protocol
LSP	Label Switched Path
LTE	Long Term Evolution
MOS	Mean Opinion Score
MPLS	Multi Protocol Label Switching
MTBF	Mean Time Between Failure
MTBO	Mean Time Between Outage
NGN	Next Generation Network
NMS	Network Management System
NNI	Network-to-Network Interface
NORS	Network Outage Reporting System
NRSC	Network Reliability Steering Committee
OTT	Over The Top
PCEF	Policy Charging Enforcement Function
PD-FE	Policy Decision Functional Entity
PHB	Per Hop Behavior

PSNR	Peak Signal to Noise Ratio
PSTN	Public Switched Telecommunications Network
QCI	QoS Class Identifier
QCIF	Quarter Common Intermediate Format
QoE	Quality of Experience
QoS	Quality of Service
RACF	Resource Admission Control Function
RNC	Radio Network Controllers
RR	Reduced Reference
SLA	Service Level Agreement
TDM	Time Division Multiplexing
TE-LSP	Traffic Engineering Label Switched Path
TRC-FE	Transport Resource Control Functional Entity
TSP	Telecommunications Service Priority
UMTS	Universal Mobile Telecommunications System
VoIP	Voice over IP
VGA	Video Graphics Array
VPN	Virtual Private Network
VQEG	Video Quality Experts Group
WRR	Weighted Round Robin

4 PSTN Transition to IP Packet Networks – An Introduction

The PSTN Transition work is characterized by the following Problem Statement [ATIS-I-0000034]:

“The infrastructure of the Public Switched Telecommunications Network (PSTN) has been transitioning from TDM (time division multiplex) technology to IP (Internet Protocol). The TDM network that consists of a telecommunications service provider providing a single-purpose voice connection to the consumer is being replaced by an IP network where a voice application (Voice over IP [VoIP]) is transported over a multi-purpose broadband connection.

IP is significantly different from TDM. The existing processes and regulations associated with the PSTN are based on a TDM network. As the network transitions to IP, it is important for the industry to evaluate the impact of this transition and make changes and recommendations where necessary.”

Briefly stated, IP networks have become ubiquitous; they allow significantly more flexibility for network operators to provide innovative services over wired and wireless technologies. Thus IP networks convey all types of communications applications in the form of packets that are transported (routed) to their destinations by IP routers. The point to note is that all application types are transported as IP packets; in the early days of the Internet, all packets were “equal” in terms of criticality and importance. That thinking has evolved as there is growing awareness that certain types of communications are deemed to be more important than others. For that reason, the telecommunications industry has started to adopt technologies based on industry standards that

provide a higher degree of priority, reliability, and QoS to specific classes of telecommunications traffic over others. Examples of traffic classes include the following:

- Emergency Telecommunications Service (ETS) – Government Emergency Telecommunications Service (GETS), Wireless Priority Services (WPS), and National Security/Emergency Preparedness Next Generation GETS (NS/EP NGN-GETS) are all facets of the USA instantiation of the international standard for ETS [E.107]. In addition to high degrees of reliability and QoS, this class of service is also given the highest priority for admission control, priority when admitted, and restoration. Several industry standards have been developed for this purpose.
- Voice over IP (VoIP) – The entire set of PSTN Voice calls are slated to be completely transported over IP networks. The telecommunications industry has adopted many capabilities and standards to ensure that reliability and QoS for VoIP services is similar to those experienced over the PSTN.
- “Private Network Services” – Typically, network operators provide a suite of services to specific entities such as large corporations and Federal, State, and Local Governments. The range of services include VoIP, Data, and Video communications. Depending on the required contracts between the operator and the entity, these services often are segregated from the rest of the operator’s traffic in the form of Virtual Private Networks (VPN). The agreed upon assurances include requirements for reliability and QoS.
- Special Services – Specific service offerings to the general population and business/government communities include Internet Protocol Television (IPTV), Mobility services, Telepresence, etc. IP networks allow the creation and distribution of such services over a single network; often with specified degrees/assurances of reliability and QoS.
- Internet Traffic – General “Best Effort” traffic that does not require any assurance of reliability and QoS fits into this class. Any type of traffic that does not require specific assurances from the network operator fits into this class. Examples include Web surfing, email, Over-the-Top (OTT) video⁵ requests (e.g., YouTube), etc.

The above set of traffic classes are representative of the types of traffic delivered by network operators. Each class has certain requirements for reliability and QoS; in addition, priority assurances are also specified for critical traffic classes for certain types of network functions such as admission control and restoration.

At the same time, network operators need to ensure that network and network element reliability and QoS also conform to certain requirements. Standards specifications have been developed to assist network operators and equipment suppliers to ensure minimum acceptable levels of equipment reliability such that element and network-wide availability and QoS can be achieved.

The objective of this document is to provide an in-depth and comprehensive overview of reliability, QoS, and priority standards that have been developed for the purpose of supporting IP network operators to achieve desired goals and Service Level Agreements at service, equipment, and network levels. These standards demonstrate that the resulting expectations for IP network/service reliability/availability and QoS are comparable to those achieved by the PSTN. QoS standards are described in clause 6. Reliability standards are described in clause 7. Priority standards are described in clause 8.

5 Quality of Service Standards Overview for IP Packet Networks

IP-based Quality of Service standardization was initially proposed in ATIS Committee T1A1. The focus was on determining a set of performance ranges for services offered over IP-based packet networks. Some development work was initiated in T1A1; however the bulk of the standards effort was eventually completed in the ITU-T under Study Groups 13 and 12. Follow up performance measurement work is undergoing in the ITU-T Study Group 12 as well as in the IETF under the IP Performance Metrics (ippm) Working Group.

Under the ATIS Network Performance, Reliability and Quality of Service Committee (PRQC), Quality of Service work focused on potential alignment between wireline and wireless service performance classes and an initial development of telepresence QoS requirements.

⁵ Note that OTT video accounts for the majority of “Best Effort” ISP traffic requests.

A representative set of standards and recommendations from these three Standards bodies are presented below.

5.1 ITU-T Standards

ITU-T standards are summarized as follows.

1. ITU-T Recommendation Y.1541, *Network performance objectives for IP-based services*:
 - a. 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.
 - b. Notes: The objectives are organized in sets called network QoS classes that can be matched with well-designed customer equipment to satisfactorily support a wide range of IP-based services and applications such as conversational telephony, multimedia conferencing, reliable data exchange using TCP, and digital television. Six performance classes are defined covering these services and specifying a range of performance measures for each class. These performance measures are IP Transfer Delay, Delay Variation, Packet Loss Ratio, and Error Rate. The performance objective for each measure is specified by means of an Upper Bound. Two additional provisional classes have also been specified to support newer high speed IP services such as IPTV; the performance ranges are deemed to be provisional pending further evaluation of network data and delivery experiences. The applicability of these performance metrics and measure ranges are carefully explained in several detailed clauses and appendices in this document.
2. ITU-T Recommendation Y.1542, *Framework for achieving end-to-end IP performance objectives*:
 - a. Summary: ITU-T Recommendation Y.1542 considers various approaches toward achieving end-to-end (UNI-UNI) IP network performance objectives. Detailed examples are provided as to how some approaches might work in practice, including how service providers might handle cases where the aggregated impairments exceed those specified in a requested QoS class (such as those of ITU-T Recommendation Y.1541). The advantages and disadvantages of each approach are summarized.
 - b. Notes: This Recommendation provides a methodology for satisfying the end-to-end performance objectives defined in ITU-T Recommendation Y.1541 over paths involving multiple network operators, and in some cases, unusual topologies and distances. The guidance provided here is intended to accelerate the planning, deployment, and management of networks and systems that can interoperate with a clear goal of supporting the end-to-end performance objectives detailed in Y.1541.
3. ITU-T Recommendation Y.1561, *Performance and availability parameters for MPLS networks*:
 - a. Summary: This Recommendation defines parameters that may be used in specifying and assessing the performance of speed, accuracy, dependability, and availability of packet transfer over a Label Switched Path on a Multi-Protocol Label Switching (MPLS) network. The defined parameters apply to end-to-end, point-to-point, and multipoint-to-point Label Switched Path (LSP) and to any MPLS domain that provides or contributes to the provision of packet transfer services.
 - b. Notes: This Recommendation provides the basis for deriving performance and availability for services over MPLS networks. Two categories of MPLS networks are considered:
 - i. TE-LSP: Traffic Engineering Label Switched Path, or configured LSP. These are point-point paths.
 - ii. Label Distribution Protocol (LDP)-based LSP: This includes point-to-point and multipoint to point LSPs.
4. ITU-T Recommendation Y.1566, *Quality of service mapping and interconnection between Ethernet, Internet protocol and multiprotocol label switching networks*:
 - a. Summary: ITU-T Recommendation Y.1566 simplifies technical Ethernet, Multiprotocol Label Switching (MPLS), and Internet Protocol (IP) QoS interconnection negotiations. Four ordinary classes and four auxiliary classes have been defined. This set of classes covers a wide range of transport service offerings.

- b. Notes: This Recommendation gives guidance on how to deal with issues resulting from differences in QoS deployments of interconnecting service providers, aiming at the preservation of the original intent of the service.
5. ITU-T Recommendation P.913, *Methods for the subjective assessment of video quality, audio quality and audiovisual quality of Internet video and distribution quality television in any environment*:
 - a. Summary: ITU-T Recommendation P.913 describes non-interactive subjective assessment methods for evaluating the one-way overall video quality, audio quality, and/or audiovisual quality for applications such as Internet video and distribution quality video. These methods can be used for several different purposes including, but not limited to, comparing the quality of multiple devices, comparing the performance of a device in multiple environments, and subjective assessment where the quality impact of the device and the audiovisual material is confounded.
 - b. Notes: A Recommendation for performing subjective assessments in test conditions less rigid than laboratory tests conducted according to P.910 or BT-500.
6. ITU-T Recommendation J.147, *Objective picture quality measurement method by use of in-service test signals (07/2002)*:
 - a. Summary: This Recommendation presents an objective picture quality measurement method by use of in-service test signals in a digital television network. This method is separated into three procedures:
 - Test signal generation at the transmission side using the invisible marker method.
 - Test signal detection at measurement points.
 - Picture quality measurement using the result of test signal detection. A practical implementation is described in Appendix I, whilst the parameters for generating in-service test signals and the performance of this method are described in Appendices II and III, respectively.
 - b. Notes: This Recommendation can be used to estimate picture quality by using invisible markers embedded into the video and calculating how well the markers are passed through the compression and/or transmission system.
7. ITU-T Recommendation J.148, *Requirements for an objective perceptual multimedia quality model (05/2003)*:
 - a. Summary: This Recommendation details the requirements for the development of an objective multimedia perceptual quality model. The requirements are set out for an auditory-visual model. The current requirements detail the form of the model, the focus for the multimedia modelling component, and the nature of the output necessary for the model to operate as a valuable assessment tool.
 - b. Notes: This Recommendation provides the requirements for an objective multimedia quality model including video only, audio only, and audiovisual quality modules.
8. ITU-T Recommendation J.241, *Quality of service ranking and measurement methods for digital video services delivered over broadband IP networks*:
 - a. Summary: This Recommendation specifies performance requirements and objective measuring methods of QoS for the delivery of digital video services over broadband IP networks. The specified performance requirements are based on an IP QoS ranking at various levels, from "excellent" to "out-of-service". They rely on the objective end-to-end measurement of the values of a small number of parameters on the delivered IP streams, performed at the consumer premises equipment and relayed back to the head end. The recommended objective measurement methods and parameters are known to influence the Quality of Service delivered to the user.
 - b. Notes: This Recommendation uses bitstream and other network parameters (e.g., packet loss ratio, network latency, jitter, throughput, etc.) to estimate the QoS of a video stream.
9. ITU-T Recommendation J.244, *Full reference and reduced reference calibration methods for video transmission systems with constant misalignment of spatial and temporal domains with constant gain and offset*:

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- a. Summary: ITU-T Recommendation J.244 specifies Full Reference (FR) and Reduced Reference (RR) calibration methods that report alignment shifts in both space and time of processed (e.g., compressed, transmitted, and decompressed) video sequences with respect to corresponding source video sequences. The methods also compute gain and offset of processed video sequences. The methods require that spatial and temporal shifts must be constant. Furthermore, the gain and offset must be constant. The methods in this Recommendation are applicable to:
- Reporting shifts that can be used to register source and processed video sequences in space and time, and
 - Reporting gains and offsets of video levels that can be used to calibrate processed video sequences with respect to the source.

Intended applications for these methods include, but are not limited to, assessing the operational readiness of video transmission systems that contain compression/transmission/decompression components, obtaining calibration estimates for correcting processed video sequences before measuring subjective or objective picture quality, and verifying that video transmission systems meet specified calibration requirements.

- b. Notes: This Recommendation is used to align input and output video streams in preparation for using an objective video quality method.

10. ITU-T Recommendation J.246, *Perceptual visual quality measurement techniques for multimedia services over digital cable television networks in the presence of a reduced bandwidth reference*:

- a. Summary: The term multimedia as defined in ITU-T Recommendation J.148 is the combination of multiple forms of media such as: video, audio, text, graphics, fax, and telephony in the communication of information. A three stage approach has been adopted to recommending objective assessment methods for multimedia. The first two stages will identify perceptual quality tools appropriate for measuring video and audio individually. The third stage will identify objective assessment methods for the combined audiovisual media. This Recommendation contains the first stage video only used in multimedia applications.

ITU-T Recommendation J.246 provides guidelines on the selection of appropriate objective perceptual video quality measurement methods when a reduced reference signal is available. The following are example applications that can use this Recommendation:

- Internet multimedia streaming.
 - Video telephony and conferencing over cable and other networks.
 - Progressive video television streams viewed on LCD monitors over cable networks including those transmitted over the Internet using Internet Protocol. (Video Graphics Array [VGA] was the maximum resolution in the validation test.)
 - Mobile video streaming over telecommunications networks.
 - Some forms of IPTV video payloads (VGA was the maximum resolution in this validation test).
 - Video quality monitoring at the receiver when side-channels are available.
- b. Notes: This Recommendation provides a reduced-reference method for objectively assessing the quality of video streams at resolutions of Quarter Common Intermediate Format (QCIF), Common Intermediate Format (CIF), and VGA.

11. ITU-T Recommendation J.247, *Objective perceptual multimedia video quality measurement in the presence of a full reference*:

- a. Summary: The term multimedia, as defined in ITU-T Recommendation J.148, is the combination of multiple forms of media such as video, audio, text, graphics, fax, and telephony in the communication of information. A three stage approach has been adopted to recommend objective assessment methods for multimedia. The first two stages identify perceptual quality tools appropriate for measuring video and audio individually. The third stage will identify objective assessment methods for the combined audiovisual media. This Recommendation contains the first stage – video only used in

multimedia applications.

ITU-T Recommendation J.247 provides guidelines on the selection of appropriate objective perceptual video quality measurement methods when a full reference signal is available. The following are example applications that can use this Recommendation:

- Internet multimedia streaming.
- Video telephony and conferencing over cable and other networks.
- Progressive video television streams viewed on LCD monitors over cable networks, including those transmitted over the Internet using Internet Protocol (VGA was the maximum resolution in the validation test).
- Mobile video streaming over telecommunications networks.
- Some forms of IPTV video payloads (VGA was the maximum resolution in this validation test).

- b. Notes: This Recommendation provides a full-reference method for objectively assessing the quality of video streams at resolutions of QCIF, CIF, and VGA.

12. ITU-T Recommendation J.248, *Requirements for operational monitoring of video-to-audio delay in the distribution of television programs*:

- a. Summary: Since the advent of digital television networks for program transmission, and the introduction of high-efficiency Bit-Rate Reduction (BRR) devices and of other types of digital image processing devices, audiences sometimes complain that the television programs they receive are out of "lip-sync". Lip-sync errors are generally due to the fact that audio and video are separately processed in the television chain, and processing delays are typically different for video than for the accompanying audio signal. ITU-T Recommendation J.248 analyzes the problem and provides guidance on means to measure lip-sync errors in the context of operational monitoring in television program transmission chains.
- b. Notes: Provides the requirements for handling lip-sync issues as well as offering research results showing the subjective quality degradation for lip-sync values (between –200 and 100 ms).

13. ITU-T Recommendation J.249, *Perceptual video quality measurement techniques for digital cable television in the presence of a reduced reference*:

- a. Summary: ITU-T Recommendation J.249 provides guidelines on the selection of appropriate objective perceptual video quality measurement methods when a reduced reference signal is available. The following are example applications that can use this Recommendation:
- Interlaced video television streams over cable networks including those transmitted over the Internet using Internet Protocol.
 - Some forms of IPTV video payloads.
 - Video quality monitoring at the receiver when side-channels are available.
 - Video quality monitoring at measurement nodes located between the point of transmission and the point of reception.
- b. Notes: Provides recommendations for objective video quality assessment of standard definition (525- and 625-line formats) video using a reduced-reference method.

14. ITU-T Recommendation J.340, *Reference algorithm for computing peak signal to noise ratio of a processed video sequence with compensation for constant spatial shifts, constant temporal shift, and constant luminance gain and offset*:

- a. Summary: Peak Signal to Noise Ratio (PSNR) is a useful benchmark for evaluating performance improvements of new objective perceptual video quality metrics. This PSNR calculation method in ITU-T Recommendation J.340 has the advantage of automatically determining the highest possible PSNR value for a given video sequence over the range of spatial and temporal shifts. Only one temporal shift is allowed for all frames in the entire processed video sequence (i.e., constant delay).

This Recommendation defines a Full Reference (FR) algorithm for computing both the calibration and

PSNR estimations for a processed video sequence: peak signal to noise ratio with compensation for constant spatial shifts, constant temporal shift, and constant luminance gain and offset (PSNRconst). Since the PSNRconst algorithm only examines the Y luminance channel (as defined by ITU-R Recommendation BT.601-6), distortions in the CB and CR chrominance channels will not be detected by the algorithm of this Recommendation. The intent of this Recommendation is to define and facilitate a standardized PSNR metric for use by industry and standard organizations. Reference code and test vectors have been included to assure accurate and consistent implementation of this PSNRconst metric.

- b. Notes: Provides a well-defined, standardized method for computing PSNR as well as offering methods for calibrating away constant spatial and temporal shifts and luminance gains and offsets.

15. ITU-T Recommendation J.341, *Objective perceptual multimedia video quality measurement of HDTV for digital cable television in the presence of a full reference*:

- a. Summary: ITU-T Recommendation J.341 provides an objective perceptual video quality measurement method for HDTV when a full reference signal is available. The following list shows example applications that can use this Recommendation:

- Potentially real-time, in-service quality monitoring at the source.
- Remote destination quality monitoring when a copy of the source is available at the point of measurement.
- Quality measurement for monitoring of a storage or transmission system that utilizes video compression and decompression techniques, either a single pass or a concatenation of such techniques.
- Lab testing of video systems.

This Recommendation includes an electronic attachment containing several short High Definition (HD) video sequences, their corresponding predicted Mean Opinion Scores (MOS), and the predicted MOS for five HD databases available via Video Quality Experts Group (VQEG).

- b. Notes: Provides a full reference method for objectively assessing the perceptual quality of HDTV.

16. ITU-T Recommendation J.342, *Objective multimedia video quality measurement of HDTV for digital cable television in the presence of a reduced reference signal*:

- a. Summary: ITU-T Recommendation J.342 provides an objective video quality measurement method for high definition television (HDTV) when a reduced reference signal is available. The following list shows example applications that can use this Recommendation:

- Interlaced video television streams over cable networks including those transmitted over the Internet using Internet Protocol.
- Video quality monitoring at the receiver when side-channels are available.
- Video quality monitoring at measurement nodes located between point of transmission and point of reception.

- b. Notes: Provides a reduced reference method for objectively assessing the perceptual quality of HDTV.

17. ITU-T Recommendation J.343, *J.343.1-6, Hybrid perceptual bitstream video quality assessment family of Recommendations*:

- a. Summary: This family of Hybrid perceptual bitstream Recommendations offers methods for 6 cases: No Reference, Reduced Reference, and Full Reference measurement methods for encrypted and non-encrypted video sequences. All of the methods utilize both IP bitstream data as well as the decoded video to estimate quality.
- b. Notes: The hybrid methods in this family of Recommendations offer useful ways to assess video quality by combining bitstream measurements and known parameters with perceptual information obtained from decoded video streams. These methods should be more flexible and/or more accurate than non-hybrid methods.

18. ITU-T Recommendation P.1201, *Parametric non-intrusive assessment of audiovisual media streaming quality - Higher resolution application area*:
 - a. Summary: The P.1201 family of Recommendations uses bitstream data to estimate audiovisual media streaming quality.
 - b. Notes: These methods should be able to provide monitoring of quality without access to the origin video stream. This family of bitstream methods is still adding additional methods.
19. ITU-T Recommendation P.1202, *Parametric non-intrusive bitstream assessment of video media streaming quality*:
 - a. Summary: The P.1202 family of Recommendations uses bitstream data to estimate video media streaming quality.
 - b. Notes: These methods should be able to provide monitoring of quality without access to the origin video stream. This family of bitstream methods is still adding additional methods.
20. ITU-T Recommendation G.1091, *QoE Requirements for Telepresence Services*:
 - a. Summary: Telepresence is an interactive audio-visual communications experience between remote locations, where the users enjoy a strong sense of realism and presence between participants by optimizing a variety of attributes such as audio and video quality, eye contact, gaze awareness, body language, spatial audio, coordinated environments, and natural image size. In this regard, delivering a high level of Quality of Experience (QoE) is an important factor. This Recommendation provides guidelines for achieving high QoE in Telepresence services. Firstly, a high level description of a Telepresence system is described, with an overview of the important use cases. This is then followed by defining specific audio and visual parameters, and other characteristics which are important from a QoE perspective. Where possible, specific values for these parameters necessary to achieve high QoE are recommended, along with references to associated test methodologies.
 - b. Notes: Provides technical requirements for a telepresence service including display, audio, color-space, and network aspects.

5.2 ATIS Standards

1. ATIS-0100032, *Relation Between ITU-T (Y.1541/Y.1221) and 3GPP UMTS/LTE QoS Classes*:
 - a. Abstract: This Technical Report addresses the relation between QoS classes defined in the ITU-T (Y.1541 performance classes) and the 3GPP (Universal Mobile Telecommunications System [UMTS] and LTE). It formally documents the mapping between the Y.1541 performance classes and the two 3GPP performance classes.
 - b. Notes: The document demonstrates that a rigorous mapping that fulfills the numerical performance objectives as currently defined for both domains is not possible; nor is it meaningful. The document points out that the ultimate industry goal of achieving true fixed/mobile network convergence will require some interworking mechanism which currently does not exist. This document lays the foundation for the development of quantitative methods for achieving this objective.
2. ATIS.0100035, *Telepresence Quality of Experience and Quality of Service*:
 - a. Abstract: This ATIS Standard evaluates and offers recommendations on the QoS and QoE aspects of telepresence. It further examines these QoS and QoE aspects for the development of interworking requirements to support desirable levels of telepresence quality.
 - b. Notes: Initial telepresence services were restricted to intra Service Provider (single administrative domain) offerings. The success of such offerings has led the industry to consider wider inter Service Provider offerings with potentially bilateral and multilateral agreements between Service Providers for ensuring service quality and delivery. This document establishes three fundamental requirements to support acceptable levels of telepresence QoS and QoE across inter Service Provider domains.

5.3 IETF Standards

IETF standards utilize Differentiated Services (DS) as a means of defining multiple classes of service for IP networks. IP packets are assigned the desired Diffserve Code Point (DSCP) – this enables packets to receive appropriate routing treatment in their path. IETF standards also provide a means to achieve end-to-end quality of service whereby the packets receive appropriate DSCPs and a prioritized path is identified through the network by means of Multi-Protocol Label Switching (MPLS). This higher level of QoS is designated as Diffserve-Aware MPLS Traffic Engineering (DS-TE). It should be noted that this level of classification offers a richer level of QoS than was available in the PSTN.

The main standards related to Diffserve classifications and DS-TE are as follows.

1. IETF RFC 3260, *New Terminology and Clarifications for DiffServe*:
 - a. Abstract: Differentiated services enhancements to the Internet Protocol are intended to enable scalable service discrimination in the Internet without the need for per-flow state and signaling at every hop. A variety of services may be built from a small, well-defined set of building blocks that are deployed in network nodes. The services may be either end-to-end or intra-domain; they include both those that can satisfy quantitative performance requirements (e.g., peak bandwidth) and those based on relative performance (e.g., "class" differentiation).
 - b. Notes: This is an update of the initial RFC defining the Diffserve architecture (RFC 2474). It concentrates on the forwarding path component for IP packets whereby differentiated services are realized by mapping the Diffserve Code Point (DSCP) contained in a field in the IP packet header to a particular forwarding treatment, or per-hop behavior (PHB), at each network node along its path. The DSCPs may be chosen from a set of mandatory values defined later in this document, from a set of recommended values to be defined in future documents, or may have purely local meaning. PHBs are expected to be implemented by employing a range of queue service and/or queue management disciplines on a network node's output interface queue: for example Weighted Round Robin (WRR) queue servicing or drop-preference queue management.
2. IETF RFC 2597, *Assured Forwarding PHB Group*:
 - a. Abstract: This document defines a general use Differentiated Services (DS) Per-Hop-Behavior (PHB) Group called Assured Forwarding (AF). The AF PHB group provides delivery of IP packets in four independently forwarded AF classes. Within each AF class, an IP packet can be assigned one of three different levels of drop precedence. A DS node does not reorder IP packets of the same micro flow if they belong to the same AF class.
 - b. Notes: This standard enables the delivery of selected types of IP packet services in a prioritized manner over other types of services. Four AF classes are defined, where each AF class is in each Differentiated Services (DS) node allocated a certain amount of forwarding resources (buffer space and bandwidth). Within each AF class, IP packets are marked (again by the customer or the provider DS domain) with one of three possible drop precedence values. In case of congestion, the drop precedence of a packet determines the relative importance of the packet within the AF class. A congested DS node tries to protect packets with a lower drop precedence value from being lost by preferably discarding packets with a higher drop precedence value.
 - c. Update: This RFC has since been "Updated" by RFC 3260 – see 1 above. However, this original RFC 2597 is presented here to emphasize the original set of Assured Forwarding PHBs.
3. IETF RFC 3246, *An Expedited Forwarding Per Hop Behavior (PHB)*:
 - a. Abstract: This document defines a PHB (per-hop behavior) called Expedited Forwarding (EF). The PHB is a basic building block in the Differentiated Services architecture. EF is intended to provide a building block for low delay, low jitter, and low loss services by ensuring that the EF aggregate is served at a certain configured rate.
 - b. Notes: The intent of the EF PHB is to provide a PHB in which suitably marked packets usually encounter short or empty queues. Furthermore, if queues remain short relative to the buffer space available, packet loss is also kept to a minimum. To ensure that queues encountered by EF packets are usually short, it is necessary to ensure that the service rate of EF packets on a given output interface exceeds their arrival rate at that interface over long and short time intervals, independent of the load of other (non-EF) traffic. This specification defines a PHB in which EF packets are

guaranteed to receive service at or above a configured rate and provides a means to quantify the accuracy with which this service rate is delivered over any time interval. It also provides a means to quantify the maximum delay and jitter that a packet may experience under bounded operating conditions.

4. IETF RFC 5865, *A Differentiated Services Code Point (DSCP) for Capacity-Admitted Traffic*:
 - a. Abstract: This document requests one Differentiated Services Code Point (DSCP) from the Internet Assigned Numbers Authority (IANA) for a class of real-time traffic. This traffic class conforms to the Expedited Forwarding Per-Hop Behavior. This traffic is also admitted by the network using a Call Admission Control (CAC) procedure involving authentication, authorization, and capacity admission. This differs from a real-time traffic class that conforms to the Expedited Forwarding Per-Hop Behavior but is not subject to capacity admission or very coarse capacity admission.
 - b. Notes: The intent of this RFC is to utilize a second EF DCSP for a higher priority class of real-time services. ETS falls under this category and service providers can use this DSCP to differentiate ETS from other types of traffic. This document is the culmination of a series of ATIS efforts to initiate protocol extensions in the IETF for the purpose of recognizing the high priority treatment of ETS.
5. IETF RFC 3564, *Requirements for Support of Differentiated Services-aware MPLS Traffic Engineering*:
 - a. Abstract: This document presents Service Provider requirements for support of Differentiated Services (Diff-Serv)-aware MPLS Traffic Engineering (DS-TE). Its objective is to provide guidance for the definition, selection, and specification of a technical solution addressing these requirements. Specification for this solution itself is outside the scope of this document. A problem statement is first provided. Then, the document describes example applications scenarios identified by Service Providers where existing MPLS Traffic Engineering mechanisms fall short and Diff-Serv-aware Traffic Engineering can address the needs. The detailed requirements that need to be addressed by the technical solution are also reviewed. Finally, the document identifies the evaluation criteria that should be considered for selection and definition of the technical solution.
 - b. Notes: In networks where optimization of transmission resources is sought, Diff-Serv mechanisms may be complemented by MPLS Traffic Engineering mechanisms which operate on an aggregate basis across all DiffServe classes of service. In this case, DiffServe and MPLS TE both provide their respective benefits. To achieve fine-grained optimization of transmission resources and further enhanced network performance and efficiency, it may be desirable to perform traffic engineering at a per-class level instead of at an aggregate level. By mapping the traffic from a given DiffServe class of service on a separate LSP, it allows this traffic to utilize resources available to the given class on both shortest paths and non-shortest paths, and follow paths that meet engineering constraints that are specific to the given class. This is what is referred to as "DiffServe-aware Traffic Engineering (DS-TE)".
 - c. Supporting RFCs: Several informational RFCs have been developed for the purpose of implementing DS-TE. These methods are specified in RFC 4125 (Maximum Allocation Model), RFC 4126 (Bandwidth Constraint Model), and RFC 4127 (Russian Dolls Model).

5.4 3GPP Standards

1. 3GPP TS 23-203, *Policy and Charging Control Architecture*:
 - a. Notes: The delivery of wireless services over end-to-end IP networks is described in the 3GPP series involving Long Term Evolution (LTE) Technical Specifications (TS). These documents provide detailed architectural descriptions and requirements for LTE services. QoS classifications for LTE are described in 3GPP Technical Specification TS 23.203, Version 14.1.0, *Policy and Charging Control Architecture*, (2016). This TS identifies nine QoS classes wherein each Service Data Flow is associated with exactly one QoS Class Identifier (QCI). Four standardized characteristics are associated with each QCI (Table 6.1.7):
 - Resource Type: Guaranteed Bit Rate (GBR) or Non-GBR.
 - Priority.
 - Packet Delay Budget.

- Packet Error Loss Rate.

The applicability of these QCI classes is restricted to the wireless domain between the User Element (UE) and the Policy Charging and Enforcement Function (PCEF). Standardized values for the four characteristics associated with each QCI are given in Table 6.1.7 of TS 23.203. The goal for standardizing these values is to ensure that applications/services mapped to that QCI receive the same minimum level of QoS in multi-vendor network deployments and in case of roaming.

6 Reliability Standards Overview for IP Packet Networks

6.1 ATIS Standards

The ATIS PRQC Committee recognized the need for evolving from the PSTN to IP Packet technology in 2001. Initial standards work focused on developing IP-based equivalents to the traditional PSTN reliability metrics of Availability and specifically, Defects per Million (DPM). Since then, many standards including American National Standards have been published in support of the reliability and availability aspects related to IP packet networks.

The ATIS Network Reliability Steering Committee (NRSC) has also progressed work in evaluating causes of network element outages in IP packet environments and has issued guidance on several processes and procedures similar to ones practiced in the PSTN environment.

These ATIS standards are summarized as follows.

1. ATIS-0100008, *Defects per Million (DPM) Metric for Transaction Services such as VoIP*:
 - a. Abstract: This standard defines a metric that can gauge the ability of an IP network to deliver transaction services in an acceptable manner. Transactions such as Voice over IP (VoIP) calls are either successfully completed as required, or they are considered to be defects. The DPM metric is defined as the ratio of all defective transactions to the total number of transactions attempted over a pre-determined period, normalized by a factor of one million.
 - b. Notes: This Standard extended the concept of DPM from the PSTN to transaction-based services such as VoIP. It allows Network Operators to continue the practice of tracking the availability of PSTN-based Voice Calls to calls made over IP networks. This document was also published as an American National Standard.
2. ATIS-1000070, *Emergency Telecommunications Service (ETS) Roadmap*:
 - a. Abstract: This Technical Report provides a roadmap view of the subtending suite of ATIS standards, technical reports, and requirements documents showing the applicability of particular standard specifications in the context of enabling deployment of the needed NS/EP priority related functions and capabilities supporting end-to-end priority communications in Next Generation Networks (NGNs). The ATIS set of standards includes national specific applications of 3GPP, IETF, and ITU-T specifications for the support of ETS. This document includes a roadmap of the dependent 3GPP, IETF, and ITU-T specifications and standards.
 - b. Notes: NS/EP NGN-GETS is the extension of the PSTN's GETS to the IP-based networks. NS/EP NGN-GETS was a major driver in the evolution of PSTN based service delivery over IP networks. As such, many initial IP-packet standards development revolved around the NGN-GETS concept. Applicable reliability, QoS, and priority standards circa 2008 are summarized in this document.
3. ATIS-0100011, *Priority for NS/EP Services in NGN/IP Environment – Role of TSP*:
 - a. Abstract: This document provides guidance regarding the applicability and usage of the Telecommunications Service Priority (TSP) codes for National Security/Emergency Preparedness (NS/EP) in an Next Generation Network (NGN)/IP environment.
 - b. Notes: Telecommunications Service Priority (TSP) applied to the GETS framework over the PSTN by ensuring that Voice circuits related to GETS received priority handling for provisioning and restoration/repair. A set of special TSP codes were assigned to GETS circuits. In the IP

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packet environment, manual provisioning and restoration/repair is replaced by automated systems that receive priority attributes to indicate their importance (e.g., ETS VoIP session) and hence, set up the sessions with automated restorations as necessary. This document reflects the automated nature of IP networks wherein the priorities applied are treated in automated systems with high priority attributes assigned for ETS. Traditional TSP codes do not apply in this environment.

4. ATIS-0100012, *Standard Outage Classification*:

- a. Abstract: Various systems exist for classifying outages in the communications industry. Several systems exist with the Federal Communications Commission as well. This standard provides a common single standard for outage cause definition.
- b. Notes: This document extends the industry's outage classification definitions from the PSTN era to today's IP network environments. In particular, the common language benefits vendors and service providers in packet technologies. It allows for comparable outage data collection throughout the industry and addresses classification of outages with respect to cause.

5. ATIS-0100020, *Availability Metric for IP-Based Networks and Services*:

- a. Abstract: This standard describes a metric that quantifies the impact on IP service availability due to an underlying network element outage. Currently, Network Management System (NMS) tools offer limited capabilities to collect necessary data for estimating this impact. The purpose of this metric is to encourage development of outage measurement capabilities and techniques.
- b. Notes: This document describes a metric that can be estimated by observing the fraction of service lost associated with any network element outage. The fractions described are in terms of IP packet technologies.

6. ATIS-0100021, *Analysis of FCC-Reportable Service Outage Data Version 2*:

- a. Abstract: This Technical Report provides methods (guidelines and algorithms) for the analysis of service outage data reported to the FCC in response to outage reporting requirements, which became effective in January 2005. These techniques are provided as an aid to the telecommunications industry including the individual reporting service providers and agencies and committees with access to the reports or data captured from the reports.
- b. Notes: The techniques outlined in this document extend the wireline PSTN outage reporting requirements by Service Providers to the FCC to all applicable technologies in packet environments such as wireless, cable, and satellite.

7. ATIS-0100025, *A Methodology for Estimating the Availability of Access IP Routers in Terms of Customer Facing Line Card Availability*:

- a. Abstract: This ATIS Standard proposes a methodology for estimating the availability of IP-based Access Routers in terms of lost customer-facing router line cards as a unit for access availability. The purpose is to stimulate interactions between service providers and equipment vendors and suppliers in the development of appropriate reliability/availability Service Level Agreements (SLAs).
- b. Notes: This methodology specifically focuses on IP Router customer-facing line cards as a unit of availability. The underlying assumption is that regardless of the failure of any network element, a customer-facing line card may be down thereby impacting service to customers. Tracking the down time of such Line Cards is therefore an attractive method for determining this estimation.

8. ATIS-0100028, *Network Resiliency Planning for Enterprise Customers*:

- a. Abstract: This ATIS Standard provides an overview of the network resiliency design process for Enterprise Customers. The design process examines a variety of resiliency options for all customer sites depending on site reliability requirements. The key metric driving this process is site availability. A service provider can then provide a range of resiliency options for connecting all customer sites together over the service provider's network.
- b. Notes: This document examines various techniques for estimating the availability of Enterprise Customer sites including Site Availability, Probability of Site Outage, and Mean Time to Failure of

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the Site. These metrics are examined in the framework of packet technologies and options for restoration, diversity planning, and disaster recovery are offered to Enterprise Customers such that appropriate planning and development of suitable Service Level Agreements can be developed between the Customer and the service provider.

9. ATIS-0100030, *Mean Time Between Outages – A Generalized Metric for Assessing Production Failure Rates in Telecommunications Network Elements*:
 - a. Abstract: The Mean Time Between Outages (MTBO) metric provides the frequency of all telecommunications network element failures (hardware and software) attributed to equipment supplier – including customer impacting short duration outages. By contrast the traditional Mean Time Between Failure (MTBF) metric only addresses total failures that lead to equipment replacement. The MTBO metric has been accepted as a key industry metric by the QuEST/TL9000 organization.
 - b. Notes: This document generalizes the metric introduced in *ATIS-0100025.2009* which was introduced for assessing access router availability in terms of downtime of customer-facing Line Cards. The generalized metric is shown to be applicable to any type of network element failure and provides illustrative examples for metric assessment of Software Controlled Devices (e.g., power amplifiers in UMTS eNodeB), Ethernet Virtual Connections (EVC), and Radio Network Controllers (RNC).
10. ATIS-0100037, *Impact Weighted MTBF – A Metric for Assessing Reliability of Hierarchical Systems*:
 - a. Abstract: The impact of failures in modern systems for voice and data transmission (e.g., IP Routers or a Radio Network Controller) as well as mobility and wire-line communication networks with hierarchical design increases progressively with the hierarchical level. The Impact Weighted Mean Time Between Failure (IW-MTBF) – a combination of MTBF values for all hierarchical levels of a given network element or network segment weighted for each level by its impact on failures – is proposed as a method for evaluating overall reliability of the hierarchical system during the design phase.
 - b. Notes: Network elements in IP environments are increasingly complex and typically, these elements are introduced into networks with insufficient testing and evaluation such that production failures result in significant impact on a service provider's customers. This metric is introduced to enable the critical assessment in the design phase of such complex hierarchical systems.
11. ATIS-0100038, *Analysis of Large DS3 FCC Reportable Outages*:
 - a. Abstract: This ATIS Standard discusses the investigative process and findings of the NRSC from its examination of large DS3 outages as identified in Network Outage Reporting System (NORS) reports for which the reason reportable was 1,350 DS3 minutes from January 2010 through September 2012.
 - b. Notes: Large DS3 outages are defined as outages in excess of 1,000 DS3s (or equivalents); the FCC noticed that the number of such reportable outages was on the rise. This document examines various causes for such outages in light of the increasing demand for bandwidth in IP environments and provides guidance for mitigating customer impacts.

6.2 Other Standards

IP-based availability standards developed in the ITU-T Study Group 13 include the following:

1. ITU-T Recommendation Y.1540, *Internet protocol data communication service – IP packet transfer and availability performance parameters*:
 - a. Abstract: ITU-T Recommendation Y.1540 defines parameters that may be used in specifying and assessing the performance of speed, accuracy, dependability, and availability of IP packet transfer of international Internet Protocol (IP) data communication services. The defined parameters apply to end-to-end, point-to-point IP service and to the network portions that provide, or contribute to the provision of, such service in accordance with the normative references specified in clause 2.

Connectionless transport is a distinguishing aspect of the IP service that is considered in this Recommendation.

- b. Notes: The main point of this Recommendation is deriving the basis for IP packet performance metrics. It also provides a basis for describing IP service availability.
2. ITU-T Recommendation Y.1561, *Performance and availability parameters for MPLS networks*:
 - a. Abstract: This Recommendation defines parameters that may be used in specifying and assessing the performance of speed, accuracy, dependability, and availability of packet transfer over a Label Switched Path on a Multi-Protocol Label Switching (MPLS) network. The defined parameters apply to end-to-end, point-to-point, and multipoint-to-point LSP and to any MPLS domain that provides, or contributes to the provision of, packet transfer services.
 - b. Notes: This Recommendation provides the basis for deriving performance and availability for services over MPLS networks. Two categories of MPLS networks are considered:
 - i. TE-LSP: Traffic Engineering Label Switched Path, or configured LSP. These are point-point paths.
 - ii. LDP-based LSP: This includes point-to-point and multipoint to point LSPs.

7 Priority Services Overview for IP Packet Networks

Emergency Telecommunications Service was the initial driver for development of IP-based priority standards in the ATIS PRQC and PTSC Committees. It was recognized that ETS support would require the highest available service capabilities in IP packet networks, just as the GETS service had the highest prioritization in the PSTN environment for call setup, signaling, provisioning, and restoration.

Accordingly, priority classification schemes were developed in ATIS PRQC, supporting requirements for IP Packet Networks were developed in ATIS PTSC, and IP packet protocol extensions were subsequently introduced and developed in the IETF.

7.1 ATIS Standards

ATIS standards are summarized as follows.

1. ATIS-0100003, *User Plane Priority Levels for IP Networks and Services*:
 - c. Abstract: This Technical Report was developed as a formal response to a request from the ATIS sub-committee PTSC SAC for guidance on user plane priority levels in IP networks. This TR proposes three levels of connection admission control priority for the user plane communications traffic in IP networks. It also proposes that all emergency communications (e.g., ETS and E911) be given the highest priority for call/session setup.
 - d. Notes: This was the initial document specifying highest available admission control priority level assignments for ETS in IP networks. This document was the basis for subsequent development of an ITU-T Recommendation.
2. ATIS-0100006, *Service Restoration Priority Levels for IP Networks*:
 - a. Abstract: This Technical Report proposes three levels of service restoration priority for traffic in IP networks. It also proposes that all emergency communications (e.g., ETS and E911) be included in the highest priority for service restoration. This report also provides guidance on restoration compliance with the Telecommunications Priority System as mandated by the Federal Communications Commission (FCC). The goal is to formalize restoration priority levels in IP networks such that appropriate signaling requirements can commence.
 - b. Notes: This document completes the development of priority level assignments – this time for restoration services. It was the basis for subsequent development of an ITU-T Recommendation.
3. ATIS-0100011, *Priority for NS/EP Services in NGN/IP Environment – Role of TSP*:

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- a. Abstract: This document provides guidance regarding the applicability and usage of the Telecommunications Service Priority (TSP) codes for National Security/Emergency Preparedness (NS/EP) in an Next Generation Network (NGN)/IP (Internet Protocol) environment.
 - b. Notes: Telecommunications Service Priority (TSP) applied to the GETS framework over the PSTN by ensuring that Voice circuits related to GETS received priority handling for provisioning and restoration/repair. A set of special TSP codes were assigned to GETS circuits. In the IP packet environment, manual provisioning and restoration/repair is replaced by automated systems that receive priority attributes to indicate their importance (e.g., ETS VoIP session) and hence, set up the sessions with automated restorations as necessary. This document reflects the automated nature of IP networks wherein the priorities applied are treated in automated systems with high priority attributes assigned for ETS. Traditional TSP codes do not apply in this environment.
4. ATIS-0100022, *Priority Classification Levels for Next Generation Networks*:
- a. Abstract: This standard formalizes a set of priority classification levels for admission control and service restoration in Next Generation Networks. The highest priority classification levels are reserved for Emergency Telecommunications Service.
 - b. Notes: This document formalizes earlier work as an American National Standard following the successful adoption of the stated priority classification levels in the ITU-T.
5. ATIS-1000011, *ETS Packet Priority for IP NNI Interfaces – Use of Existing Diffserv per Hop Behaviors*:
- a. Abstract: This Technical Report provides guidelines for the application of existing Differentiated Service (DiffServ) Per Hop Behaviors (PHB) and their associated DiffServ Code Points (DSCP) when Emergency Telecommunications Service (ETS) Voice over IP (VoIP) packets are transported in the media stream at Network-to-Network Interfaces (NNI). Given the current situation involving a single Expedited Forwarding DSCP for all real-time services, it is recommended that public carriers utilize a local/experimental DSCP to differentiate ETS VoIP traffic from other real-time traffic at NNI interfaces between carriers. The local/experiment DSCP assignment can be determined based on Service Level Agreements between the carriers.
 - b. Notes: This document was developed as an interim step toward assigning Local/Experimental DSCP given that there was only one Expedited Forwarding (EF) DSCP for real-time services. The single EF DSCP does not allow separation between Voice Calls of any kind – ETS Voice Calls would get the same treatment as other Voice Calls. This interim step allowed service providers to differentiate between ETS and other types of calls at the interfaces between their networks.
6. ATIS-1000020, *ETS Packet Priority for IP NNI Interfaces – Requirements for a Separate Expedited Forwarding Mechanism*:
- a. Abstract: This Technical Report (TR) provides the requirements for a separate Expedited Forwarding (EF) mechanism that can recognize a class of traffic for preferential treatment via a unique DiffServ Code Point (DSCP). This class of traffic includes Emergency Telecommunications Service (ETS) Voice over IP (VoIP) calls/sessions with the requirement of a pre-determined quantity of reserved bandwidth for ETS service.
 - b. Notes: This ATIS Standard developed the necessary requirements for the creation of a second EF DSCP in the IETF; the intent was to drive work in the IETF to recognize the differences between prioritized real-time services (e.g., ETS Voice Calls) over other types of real-time services.

7.2 ITU-T Standards

Work in the ITU-T Study Group 13 formalized the priority level descriptions from ATIS:

1. ITU-T Recommendation Y.2171, *Admission control priority levels in Next Generation Networks*:
 - a. Summary: This Recommendation proposes three levels for admission control priority for services seeking entry into Next Generation Networks. The admission control priority indicator is intended as a guidance in the development of appropriate signaling protocol extensions, and in the development of the necessary priority enabling mechanisms.

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- b. Notes: This document advanced the admission control priority concept into the ITU-T body of work with the same three priority classification levels defined in ATIS.
2. ITU-T Recommendation Y.2172, *Service restoration priority levels in Next Generation Networks:*
 - a. Summary: ITU-T Recommendation Y.2172 proposes three levels of restoration priority for services in Next Generation Networks. This indicator is intended as a guidance for the development of appropriate signaling protocol extensions and the restoration/re-route mechanisms.
 - b. Notes: This document advanced the service restoration priority concept into the ITU-T body of work with the same three priority classification levels defined in ATIS.
 3. ITU-T Recommendation Y.2174, *Distributed RACF architecture for MPLS networks:*
 - a. Summary: The architectural structure of a distributed Resource Admission and Control Function (RACF) is considered in this Recommendation. RACF is comprised of a Transport Resource Control Functional Entity (TRC-FE) and a Policy Decision Functional Entity (PD-FE). This Recommendation defines an architecture, which considers a distributed RACF resulting from a distributed TRC-FE, it specifies supporting requirements, and it describes the resource reservation process for this specific architecture.
 - b. Notes: This document advanced implementation mechanisms in MPLS based on service attributes such as admission control and restoration priority. While RACF as a concept was not widely accepted by industry, the MPLS capabilities for addressing priority schemes are recognized in this document.
 4. ITU-T Recommendation J.260, *Requirements for preferential telecommunications over IP-Cablecom networks:*
 - a. Summary: This Recommendation defines requirements for preferential telecommunications over IP-Cablecom networks. The essential aspects of preferential telecommunications over IP-Cablecom that this Recommendation covers can be grouped into two areas: prioritization and authentication. These two areas include capabilities to support telecommunications in IP-Cablecom that may require preferential treatment (e.g., Telecommunications for Disaster Relief and Emergency Telecommunications Service). The implementation of priority and authentication is necessary for the support of preferential telecommunications in IP-Cablecom networks.
 - b. Notes: This Recommendation provides requirements for preferential telecommunications over IP-Cablecom (e.g., Packet Cable) networks. Both priority and authentication are discussed. Approved in 2005, parts of this Recommendation may be out of date.
 5. ITU-T Recommendation J.261, *Framework for implementing preferential telecommunications in IP-Cablecom and IP-Cablecom2 networks:*
 - a. Summary: ITU-T Recommendation J.261 provides a framework for implementing preferential capabilities in IP-Cablecom and IP-Cablecom2 networks. The approach of this Recommendation is to define a framework for capabilities that can be utilized to meet the requirements in ITU-T Recommendation J.260 and forms the basis for detailed IP-Cablecom and IP-Cablecom2 Recommendations in support of preferential telecommunications.
 - b. Notes: The objective of this Recommendation is to provide a framework for the implementation of preferential telecommunications services within cable networks as described in [ITU-T J.160] and [ITU-T J.360]. This framework is one of a series (J.26x) of Recommendations addressing these services. The key aspects of preferential telecommunications services addressed in this framework are priority and authentication. The architectural differences in the two key aspects are addressed in terms of the logical functional entities defined in [ITU-T J.160] and [ITU-T J.360], respectively.
 6. ITU-T Recommendation J.262, *Specifications for authentication in preferential telecommunications over IP-Cablecom2 networks:*
 - a. Summary: ITU-T Recommendation J.262 is one of a series of Recommendations to enable support for preferential telecommunication services over IP-Cablecom networks. It defines the specifications for authentication in preferential telecommunications over IP-Cablecom2 networks. These specifications satisfy the requirements defined in ITU-T Recommendation J.260. The

essential aspects of preferential telecommunications over IPCablecom2 can be grouped into two areas: prioritization and authentication. This Recommendation defines specifications for authentication only. Authentication must be utilized to prevent unauthorized use of premium services and for emergency services in IPCablecom2 that may require preferential treatment (e.g., telecommunications for disaster relief and the emergency telecommunications service). User authentication is necessary to determine whether to authorize a request for preferential telecommunication services. This Recommendation covers only authentication and does not address which services the authenticated user is authorized to use.

- b. Notes: The objective of this Recommendation is to provide specifications for authentication in IPCablecom2 networks, e.g., [ITU-T J.360]. ITU-T J.262 is one of a series (J.26x) of Recommendations addressing preferential telecommunications services over Cable networks.
7. ITU-T Recommendation J.263, *Specification for priority in preferential telecommunications over IPCablecom2 networks:*
 - a. Summary: ITU-T Recommendation J.263 is one of a series of Recommendations to enable support for preferential telecommunication services over IPCablecom2 networks. It defines the specifications for priority for preferential telecommunication services over IPCablecom2 networks. These specifications satisfy the requirements defined in ITU-T Recommendation J.260. The essential aspects of preferential telecommunications over IPCablecom2 can be grouped into two areas: prioritization and authentication. This Recommendation provides specifications for prioritization only. Prioritization may be utilized for premium services and for emergency services in IPCablecom2 that may require preferential treatment (e.g., telecommunications for disaster relief and the emergency telecommunications service). The implementation of priority and authentication is necessary for the support of preferential telecommunications services in IPCablecom networks. This Recommendation only covers technical aspects for achieving prioritized treatment in IPCablecom2 networks.
 - b. Notes: The objective of this Recommendation is to provide specifications for priority in IPCablecom2 networks, e.g., [ITU-T J.360]. ITU-T J.262 is one of a series (J.26x) of Recommendations addressing preferential telecommunications services over Cable networks.

7.3 3GPP Standards

1. 3GPP TS 22-153, *Multimedia Priority Service:*

Notes: Multimedia priority service classifications for LTE are described in 3GPP Technical Specification TS 22-153, Version 14.4.0, *Multimedia Priority Service*, (2016). This TS establishes the need for priority levels to deliver calls or complete sessions of a high priority nature from mobile to mobile networks, mobile to fixed networks, and fixed to mobile networks. The priority level scheme is specified in Clause 5.5 as follows:

- The Service User shall be assigned one of "n" user priority levels. The priority levels are defined with 1 being the highest priority level and "n" being the lowest priority level.
- The 3GPP network shall be able to support at least 5 user priority levels.
- Assignment of priority levels is a matter of regional/national and operator policy.
- In case of interconnecting networks that have different priority levels, mappings between priority levels should be established.