INTERNATIONAL TELECOMMUNICATION UNION

ITU-T G.820/I.351/Y.1501

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TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

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Digital networks – Quality and availability targets

SERIES I: INTEGRATED SERVICES DIGITAL NETWORK

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ITU-T Recommendation G.820/I.351/Y.1501

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ITU-T Recommendation G.820/I.351/Y.1501

Relationships among ISDN, IP-based network and physical layer performance Recommendations

Summary

This Recommendation defines relationships among a set of existing ITU-T Recommendations that collectively provide the basis for the specification and apportionment of performance in narrow-band and broadband ISDNs, Internet Protocol (IP)-based networks, and digital layers of transport networks, as well as jitter, wander, and network synchronization and timing performance. These Recommendations are intended to be used in describing performance between the measurement points that delimit and apportion international ISDNs, IP-based networks, and digital layers of transport networks.

Source

ITU-T Recommendation G.820/I.351/Y.1501 was approved on 29 July 2004 by ITU-T Study Group 13 (2001-2004) under the ITU-T Recommendation A.8 procedure.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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

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

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

ITU-T Recommendation G.820/I.351/Y.1501

Relationships among ISDN, IP-based network and physical layer performance Recommendations

1 Scope

This Recommendation describes relationships among the following ITU-T Recommendations: G.781, G.783, G.798, G.803, G.810, G.811, G.812, G.813, G.821, G.822, G.823, G.824, G.825, G.826, G.827, G.828, G.829, G.921, G.8201, G.8251, I.350, I.352, I.353, I.354, I.355, I.356, I.357, I.358, I.359, I.381, Y.1530, Y.1540, Y.1541, Y.1560 and Y.1561. Collectively, these Recommendations provide the basis for the specification and apportionment of performance in narrow-band and broadband ISDNs, Internet Protocol (IP)-based networks, and digital layers of transport networks. They include jitter, wander, and network synchronization and timing performance. These Recommendations are intended to be used in describing performance between the measurement points that delimit and apportion international ISDNs, IP-based networks, and digital layers of transport networks.

The relevant Recommendations and their relationships are illustrated in Figure 1. The 3 × 3 performance description framework defined in ITU-T Rec. I.350 is used to illustrate the relationships among particular Recommendations. Three protocol-independent telecommunication functions are identified in the matrix: access, user information transfer, and disengagement. These general functions correspond to specified aspects of ISDN, IP-based network, and transport network digital layer services conforming to ITU-T standardized protocols[1]. Each function is considered with respect to three general performance concerns (or "performance criteria"): speed, accuracy, and dependability. These express, respectively, the delay or rate, degree of correctness, and degree of certainty with which the function is performed. Recommendations shown within the matrix define sets of protocol-specific parameters ("primary parameters") that describe performance relative to each function and criterion. An associated model provides a basis for describing overall service availability. A specified availability function compares the values for a subset of the primary parameters with corresponding outage thresholds to classify the services as "available" (no service outage) or "unavailable" (service outage) during scheduled service time. Figure 1 presents the Recommendations that specify availability functions and define availability parameters associated with ISDN, IP-based network, and transport network digital layer services. Recommendations concerning jitter, wander, and timing and synchronization performance of digital networks are illustrated in Figure 1 by their relationships to the complementary aspects of network level jitter, wander, and synchronization performance and related timing equipment performance.

This Recommendation is organized as follows. The scope of the Recommendation is provided in clause 1. A list of abbreviations is provided in clause 2. The general scope and content of each Recommendation illustrated in Figure 1 is described in clause 3[2]. Annex A contains information on the history of the G-series physical layer error performance Recommendations. An index listing key concepts and associated Recommendations is also provided.

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[1] For B-ISDN, these general functions include multiparty and multipoint connection types.

[2] The most recent editions of draft and approved Recommendations should be consulted.

General performance aspects of ISDNs, IP-based networks and digital layers of transport networks
I.350 (QoS/Network performance framework in digital networks, including ISDNs) I.353 (Reference events for defining ISDN performance parameters)

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ISDN, IP-based network and transport network digital layer performance			
Criterion / Function	Speed	Accuracy	Dependability
Access	I.352 (N-ISDN – CBR) I.354 (N-ISDN – PKT) I.358 (B-ISDN) Y.1530 (IP) Y.1560 (TCP)	I.354 (N-ISDN – PKT) I.358 (B-ISDN) I.359 (N-ISDN – CBR) Y.1530 (IP) Y.1560 (TCP)	I.354 (N-ISDN – PKT) I.358 (B-ISDN) I.359 (N-ISDN – CBR) Y.1530 (IP) Y.1560 (TCP)
Information transfer	I.354 (N-ISDN – PKT) I.356 (ATM) I.381 (AAL) Y.1540 (IP) Y.1541 (IP) Y.1561 (MPLS)	G.821 (CBR) G.826 (CBR) G.828 (CBR) G.829 (CBR) G.921 (CBR) G.8201 (OTN) I.354 (N-ISDN – PKT) I.356 (ATM) I.381 (AAL) Y.1540 (IP) Y.1541 (IP) Y.1561 (MPLS)	I.354 (N-ISDN – PKT) I.356 (ATM) Y.1540 (IP) I.381 (AAL) Y.1541 (IP) Y.1561 (MPLS)
Disengagement	I.352 (N-ISDN – CBR) I.354 (N-ISDN – PKT) I.358 (B-ISDN) Y.1530 (IP) Y.1560 (TCP)	I.354 (N-ISDN – PKT) I.358 (B-ISDN) I.359 (N-ISDN – CBR) Y.1530 (IP) Y.1560 (TCP)	I.354 (N-ISDN – PKT) I.358 (B-ISDN) I.359 (N-ISDN – CBR) Y.1530 (IP) Y.1560 (TCP)

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Availability
G.827 (B-ISDN – CBR) I.355 (N-ISDN – CBR & PKT) I.357 (ATM) Y.1540 (IP) Y.1541 (IP)

Timing and synchronization performance	
Network level jitter, wander, and synchronization	Equipment jitter, wander and timing
G.803 (Network Synchronization Architecture) G.810 (Terminology) G.822 (Slips) G.823 (Jitter/Wander – 2048 kbit/s Hierarchy) G.824 (Jitter/Wander – 1544 kbit/s Hierarchy) G.825 (Jitter/Wander – SDH) G.8251 (Jitter/Wander – OTN)	G.781 (Synchronization Distribution Layer and Network Synchronization Layer Atomic Functions) G.783 (Jitter/Wander – SDH Equipment) G.798 (OTN CBR Client Asynchronous Mapper Buffer Hysteresis) G.810 (Terminology) G.811 (Primary Reference Clock) G.812 (Synchronization Supply Unit) G.813 (SDH Equipment Clock) G.921 (Jitter – 2048 kbit/s Hierarchy) G.8251 (Jitter/Wander – OTN Equipment and ODUk Clock)

Figure 1/G.820/I.351/Y.1501 – Relationships among ISDN, IP and transport network digital layer performance Recommendations

2 Abbreviations

This Recommendation uses the following abbreviations:

AAL	ATM Adaptation Layer
ATM	Asynchronous Transfer Mode
B-ISDN	Broadband ISDN
CBR	Constant Bit Rate
EDC	Error Detection Code
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISDN	Integrated Services Digital Network
kbit/s	kilobit/second
LSP	Label Switched Path
MRTIE	Maximum Relative Time Interval Error
MTIE	Maximum Time Interval Error
MPLS	Multi-Protocol Label Switching
N-ISDN	Narrow-band ISDN
NP	Network Performance
ODUk	Optical Channel Data Unit k
ODC	ODUk Clock
OTN	Optical Transport Network
PDH	Plesiochronous Digital Hierarchy
PKT	Packet Mode
PRC	Primary Reference Clock
PVC	Permanent Virtual Connection
QoS	Quality of Service
SDH	Synchronous Digital Hierarchy
SEC	SDH Equipment Clock
SSM	Synchronization Status Message
SSU	Synchronization Supply Unit
STM	Synchronous Transport Module
TCP	Transmission Control Protocol
TDEV	Time Deviation
VC	Virtual Channel
VCC	Virtual Channel Connection
VPC	Virtual Path Connection

3 General scope and content of performance Recommendations

The general scope and content of each of the ISDN, IP, and transport network digital layer performance Recommendations identified in Figure 1 is summarized below. For ease of reference, the Recommendations are listed alphanumerically.

3.1 ITU-T Rec. G.781 – Synchronization layer functions (1999)

This Recommendation specifies mainly the SSM selection algorithm which is applicable to clocks of SDH equipments (ITU-T Rec. G.813). It specifies the synchronization interfaces, the Quality Level of clock sources, the SSM (Synchronization Status Message), the SDH clock selection process, some rules to prevent timing loops in SDH networks and all synchronization distribution basic functions that are required to describe a digital transmission equipment's synchronization functionality.

This Recommendation specifies 3 different options. "Option I" applies to SDH networks optimized for the 2048 kbit/s hierarchy. "Option II" applies to SDH networks optimized for the 1544 kbit/s hierarchy that includes the rates 1544 kbit/s, 6312 kbit/s, and 44 736 kbit/s. "Option III" applies to SDH networks optimized for the 1544 kbit/s hierarchy that includes the rates 1544 kbit/s, 6312 kbit/s, 33 064 kbit/s, 44 736 kbit/s, and 97 728 kbit/s.

3.2 ITU-T Rec. G.783 – Characteristics of Synchronous Digital Hierarchy (SDH) equipment functional blocks (2004)

This Recommendation covers general equipment requirements for SDH equipment. It specifically contains jitter and wander requirements in clauses 9.3 and 15. This includes jitter transfer, jitter tolerance and jitter generation for SDH regenerators, mappers, and demappers, and also wander specifications for SDH mappers and demappers. The jitter requirements for SDH regenerators ensure that the SDH jitter network limits are met. The jitter and wander requirements for SDH mappers and demappers help ensure that the jitter and wander requirements for PDH clients are met.

3.3 ITU-T Rec. G.798 – Characteristics of optical transport network hierarchy equipment functional blocks (2004)

This Recommendation covers the functional requirements of Optical Transport Network functionality within equipment. It uses the specification methodology defined in ITU-T Rec. G.806 for transport network equipment and is based on the architecture of optical transport networks defined in ITU-T Rec. G.872 and the interfaces defined in ITU-T Rec. G.709/Y.1331. The portion of ITU-T Rec. G.798 that is relevant to jitter and wander performance (i.e., relevant to the network performance specifications and objectives for which corresponding Recommendations are summarized in ITU-T Rec. G.820/I.351/Y.1501) is the specification of the maximum buffer hysteresis for the asynchronous mapper.

The requirement on maximum buffer hysteresis for the asynchronous mapper or multiplexer applies to asynchronous mapping of CBRx clients into ODUk (via the ODUkP/CBRx-a_A_So atomic function) and asynchronous multiplexing of ODUj clients into ODUk (k > j, via the ODUkP/ODUi[j]_A_So atomic function). The main purpose of the requirement on maximum buffer hysteresis for the asynchronous mapper or multiplexer is to limit the long-term wander on CBRx clients.

3.4 ITU-T Rec. G.803 – Architecture of transport networks based on the Synchronous Digital Hierarchy (SDH) (2000)

Clause 8 of this Recommendation gives the rules that must be applied to build a synchronization network so that the requirements of synchronization interfaces are met. It specifies the synchronization network architecture, the clock synchronization modes, the synchronization network reference chain that gives the maximum number of clocks a synchronization signal can pass through, the synchronization strategy, how to deal with network evolution, and network robustness. It provides methods to prevent timing loops between SSUs, and also between SECs by use of the SSM. ITU-T Rec. G.803 also provides information on payload jitter and wander, pointer simulations and jitter at SDH/PDH boundaries, and PDH/SDH interworking.

3.5 ITU-T Rec. G.810 – Definitions and terminology for synchronization networks (1996)[3]

This Recommendation provides definitions and terms for describing network timing, jitter, and synchronization performance. These definitions and terms are used in ITU-T Recs G.781, G.783, G.798, G.803, G.811, G.812, G.813, G.822, G.823, G.824, G.825, G.8251 and G.921.

3.6 ITU-T Rec. G.811 – Timing characteristics of primary reference clocks (1997)

This Recommendation defines specifications for the Primary Reference Clock (PRC). The specifications utilize G.810 parameters and terminology. Key parameters are frequency accuracy, MTIE, TDEV, phase discontinuity, and peak-to-peak jitter.

The specifications apply to PRC jitter and wander performance. This Recommendation provides part of the basis for the slip performance objectives in ITU-T Rec. G.822 and the wander reference models in ITU-T Recs G.823 and G.824.

3.7 ITU-T Rec. G.812 – Timing requirements of slave clocks suitable for use as node clocks in synchronization networks (2004)

This Recommendation defines specifications for slave clocks (i.e., timing equipment synchronization supply units). The specifications utilize G.810 parameters and terminology. Key parameters are frequency accuracy, pull-in, pull-out, and hold-in ranges, MTIE, TDEV, phase discontinuity, and peak-to-peak jitter. Six clock types are defined, designated Type I through VI, respectively.

The specifications apply to slave clock jitter, wander, transient, and holdover performance. Clock types I, V and VI are intended for PDH networks of the 2048 kbit/s hierarchy and SDH networks optimized for this hierarchy. Clock types II, III and IV are intended for PDH networks of the 1544 kbit/s hierarchy and SDH networks optimized for this hierarchy.

3.8 ITU-T Rec. G.813 – Timing characteristics of SDH equipment slave clocks (SEC) (2003)

This Recommendation defines specifications for SDH equipment clocks. The specifications utilize G.810 parameters and terminology. Key parameters are frequency accuracy, pull-in, pull-out, and hold-in ranges, MTIE, TDEV, and peak-to-peak jitter. Two Options for the SDH Equipment Clock are defined, designated Option 1 and Option 2, respectively.

The specifications apply to SDH Equipment Clock jitter, wander, transient, and holdover performance. Option 1 applies to SDH networks optimized for the 2048 kbit/s hierarchy and Option 2 applies to SDH networks optimized for the particular 1544 kbit/s hierarchy that includes the rates 1544 kbit/s, 6312 kbit/s, and 44 736 kbit/s.

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[3] See also Corrigendum 1, 10-2001.

3.9 ITU-T Rec. G.821 – Error performance of an international digital connection operating at a bit rate below the primary rate and forming part of an ISDN (2002)

This Recommendation defines error performance parameters and objectives for international digital connections operating below the primary rate of the digital hierarchy, using equipment designed prior to the adoption of revised ITU-T Rec. G.826 on 14 December 2002. The objectives given are independent of the physical network supporting the connection. This Recommendation is based upon bit error and bit error ratio measurements. The events, parameters and objectives are defined accordingly. Annex A/G.821 deals with the definition of availability of the connection.

3.10 ITU-T Rec. G.822 – Controlled slip rate objectives on an international digital connection (1988)

ITU-T Rec. G.822 defines parameters and objectives for describing network controlled slip performance. The parameter definitions utilize G.810 terminology. Key parameters are the mean slip rate and its associated proportion of time.

The parameters and objectives apply to specified portions of an international digital connection. This Recommendation provides a basis for Option 1 and Option 2 network wander limits in ITU-T Rec. G.813.

3.11 ITU-T Rec. G.823 – The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy (2000)

This Recommendation defines specifications for jitter and wander performance for networks based on the 2048 kbit/s hierarchy. The specifications utilize G.810 parameters and terminology. Key parameters are peak-to-peak jitter and associated measurement filter bandwidths, MTIE, MRTIE, TDEV, and sinusoidal tolerance.

The specifications apply to jitter and wander tolerance and network limits for PDH traffic interfaces and synchronization interfaces, for networks based on the 2048 kbit/s hierarchy.

3.12 ITU-T Rec. G.824 – The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy (2000)

This Recommendation defines specifications for jitter and wander performance for networks based on the 1544 kbit/s hierarchy. The specifications utilize G.810 parameters and terminology. Key parameters are peak-to-peak jitter and associated measurement filter bandwidths, MTIE, MRTIE, TDEV, and sinusoidal tolerance.

The specifications apply to jitter and wander tolerance and network limits for PDH traffic interfaces and synchronization interfaces, for networks based on the 1544 kbit/s hierarchy. This Recommendation provides input to the Option 2 wander budget and network wander limits in ITU-T Rec. G.813.

3.13 ITU-T Rec. G.825 – The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH) (2000)[4]

This Recommendation defines specifications for jitter and wander performance for SDH networks. The specifications utilize G.810 parameters and terminology. Key parameters are peak-to-peak jitter and associated measurement filter bandwidths, and sinusoidal tolerance (for wander limits, which utilize MTIE, MRTIE, and TDEV parameters). ITU-T Rec. G.825 references ITU-T Recs G.823 and G.824.

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[4] See also Erratum 1, 08-2001.

The specifications apply to jitter and wander tolerance and network limits for SDH interfaces. ITU-T Rec. G.825 references ITU-T Recs G.783, G.812 and G.813 for jitter and wander generation and transfer requirements. ITU-T Rec. G.825 provides part of the basis for the Option 1 SEC bandwidth specification in ITU-T Rec. G.813.

3.14 ITU-T Rec. G.826 – End-to-end error performance parameters and objectives for international, constant bit-rate digital paths and connections (2002)

This Recommendation defines end-to-end error performance parameters and objectives for international digital paths which operate at or above the primary rate, and for international digital connections which operate below the primary rate, of the digital hierarchy. The objectives given are independent of the physical network supporting the path or connection.

For digital paths which operate at or above the primary rate, this Recommendation is based upon a block-based measurement concept using error detection codes inherent to the path under test. This supports in-service measurements.

For digital connections which operate below the primary rate of the digital hierarchy, this Recommendation is based upon bit error and bit error ratio measurements. This approach does not support in-service measurements.

Annex A/G.826 deals with the definition of availability of the path or connection. Annexes B, C and D give specific information concerning PDH, SDH and cell-based transmission paths.

The ITU-T Rec. G.826 requirements for digital connections apply to connections using equipment designed after the adoption of revised ITU-T Rec. G.826 on 14 December 2002. It is not required to apply this Recommendation to connections using equipment designed prior to that date.

This Recommendation deals with the performance of PDH paths, and of those SDH paths using equipment designed prior to the adoption of ITU-T Rec. G.828 in March 2000.

3.15 ITU-T Rec. G.827 – Availability performance parameters and objectives for end-to-end international constant bit-rate digital paths (2003)

This Recommendation defines network performance parameters and objectives for the path elements and end-to-end availability of international constant bit rate digital paths. These parameters are independent of the type of physical network supporting the end-to-end path, e.g., optical fibre, radio relay or satellite. Guidance is included on methods for improving availability and calculating the end-to-end availability of a combination of network elements.

3.16 ITU-T Rec. G.828 – Error performance parameters and objectives for international, constant bit-rate synchronous digital paths (2000)[5]

This Recommendation defines error performance parameters and objectives for international synchronous digital paths. While this Recommendation specifically addresses objectives for international digital paths, the allocation principles can be applied to the design of error performance for national or private synchronous digital paths. The objectives given are independent of the physical network supporting the path. The Recommendation is based upon a block-based measurement concept using error detection codes inherent to the path under test. The block repetition rate is in accordance with SDH technology. The events, parameters and objectives are defined accordingly. In addition to path performance assessment, tandem connection monitoring is covered.

ITU-T Rec. G.828 is the only Recommendation required for designing the error performance of synchronous digital paths using equipment installed after the adoption of ITU-T Rec. G.828 in

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[5] See also Corrigendum 1, 07-2001.

March 2000. In accordance with the definition of a digital path, path end points may be located at user's premises.

Paths are used to support services such as circuit switched, packet switched and leased circuit services. ITU-T Rec. G.828-based paths can carry ATM traffic. Synchronous digital paths meeting the objectives of ITU-T Rec. G.828 will enable the ATM traffic to meet ITU-T Rec. I.356.

3.17 ITU-T Rec. G.829 – Error performance events for SDH multiplex and regenerator sections (2002)

This Recommendation defines error performance events and block structures for SDH multiplex and regenerator sections (see ITU-T Recs G.707/Y.1322 and G.708 for reference). SDH equipment functional blocks and SDH management are defined in ITU-T Recs G.783 and G.784. Observing the definitions given in this Recommendation shall ensure that error performance assessment on SDH multiplex and regenerator sections yields compatible results. Definition of events in this Recommendation is based on the same basic concept as in ITU-T Rec. G.828.

The events defined for regenerator sections apply to microwave radio and satellite systems only.

Performance monitoring of SDH sections is not mandatory. If implemented, the specifications of this Recommendation apply.

3.18 ITU-T Rec. G.921 – Digital sections based on the 2048 kbit/s hierarchy (1988)

This Recommendation specifies characteristics of digital sections based on the 2048 kbit/s hierarchy. The performance specifications in ITU-T Rec. G.921 (i.e., the portions of ITU-T Rec. G.921 that are relevant to ITU-T Rec. G.820/I.351/Y.1501) include requirements for jitter, error, and availability performance. The jitter specifications utilize G.810 parameters and terminology; key parameters are peak-to-peak jitter and associated measurement filter bandwidths. The error performance specifications refer to ITU-T Rec. G.821 for the performance objectives for the end-to-end connection of which the digital section in question is part. ITU-T Rec. G.921 specifies the allocation of the objective for the end-to-end connection given to the digital section. The error performance specifications utilize events and parameters defined in ITU-T Rec. G.821. The jitter specifications apply to a single regenerator section of the 2048 kbit/s hierarchy. They include output jitter in the absence of input jitter (i.e., jitter generation for a single regenerator), jitter tolerance (ITU-T Rec. G.823 is referenced for these requirements), and jitter transfer. The error performance specifications apply to digital sections of the 2048 kbit/s hierarchy.

3.19 ITU-T Rec. G.8201 – Error performance parameters and objectives for multi-operator international paths within the Optical Transport Network (OTN) (2003)

This Recommendation defines error performance parameters and objectives for international ODUk paths transported by the Optical Transport Network (OTN) as described in ITU-T Rec. G.709/Y.1331. While this Recommendation specifically addresses objectives for international ODUk paths, the allocation principles can be applied to the design of error performance for national or private ODUk paths. This Recommendation is based upon a block-based measurement concept using error detection code (EDC) and EDC usage inherent to the path under test; the block repetition rate being in accordance with OTN technology in accordance with ITU-T Rec. G.709/Y.1331. This simplifies in-service measurements. The events, parameters and objectives are defined accordingly. In addition to path performance assessment, tandem connection monitoring is covered.

3.20 ITU-T Rec. G.8251 – The control of jitter and wander within the Optical Transport Network (OTN) (2001)[6]

This Recommendation defines specifications for jitter and wander performance for the Optical Transport Network (OTN). The specifications cover network limits, jitter tolerance of network interfaces, jitter generation, and jitter transfer. The specifications utilize G.810 parameters and terminology. Key parameters are peak-to-peak jitter and associated measurement filter bandwidths, sinusoidal jitter tolerance, maximum bandwidth and gain peaking for jitter transfer, and frequency accuracy, pull-in range, and pull-out range for relevant ODUk clocks. Annex A/G.8251 defines four ODUk clocks: ODCa for the asynchronous mapper, ODCb for the bit-synchronous mapper, ODCr for the 3R regenerator, and ODCp for the demapper or demultiplexer.

The specifications in the main body apply to jitter and wander tolerance for OTN and client interfaces, and OTN network limits. The specifications in Annex A apply to the ODCa, ODCb, ODCr, and ODCp clocks. The OTN timing and jitter specifications do not distinguish between Option 1 and Option 2 networks; the specifications apply without regard to whether an SDH client is Option 1 or Option 2.

3.21 ITU-T Rec. I.350 – General aspects of quality of service and network performance in digital networks, including ISDNs (1993)

This Recommendation defines Quality of Service (QoS) and Network Performance (NP) principles; illustrates how the QoS and NP concepts are applied in digital networks including ISDNs (providing both narrow-band and broadband capabilities); describes the features of, and the relationships between, these concepts; indicates and classifies performance concerns for which parameters may be needed; and identifies generic performance parameters.

3.22 ITU-T Rec. I.352 – Network performance objectives for connection processing delays in an ISDN (1993)

This Recommendation defines speed parameters and objectives for describing N-ISDN circuit mode access and disengagement performance. Key parameters are call set-up delay and call clearing delay. The parameters and objectives apply to specified portions of an international end-to-end circuit mode connection. This Recommendation provides a basis for N-ISDN circuit mode availability performance specified in ITU-T Rec. I.355.

3.23 ITU-T Rec. I.353 – Reference events for defining ISDN and B-ISDN performance parameters (1996)

This Recommendation defines the measurement points and performance-significant reference events that are used in ITU-T Recs I.352, I.354, I.355, I.356, I.357, I.358 and I.359 to define performance parameters for international ISDN services.

3.24 ITU-T Rec. I.354 – Network performance objectives for packet-mode communication in an ISDN (1993)

This Recommendation defines speed, accuracy, and dependability parameters and objectives for describing N-ISDN packet-mode access, information transfer, and disengagement performance. Key parameters are call set-up delay, call set-up denial probability, errored packet ratio, packet loss ratio, and call clearing delay. The parameters and objectives apply to specified portions of an international end-to-end packet mode connection. This Recommendation provides a basis for N-ISDN packet-mode availability performance specified in ITU-T Rec. I.355.

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6 See also Corrigendum 1, 06-2002 and Amendment 1, 06-2002.

3.25 ITU-T Rec. I.355 – ISDN 64 kbit/s connection type availability performance (2000)

This Recommendation defines parameters and objectives for describing N-ISDN circuit mode and packet mode availability performance. The parameters are defined on the basis of G.821, I.352 and I.354 parameter thresholds. Key parameters are percent service availability and mean time between service outages. The parameters and objectives apply to specified portions of international end-to-end N-ISDN circuit mode and packet mode connections.

3.26 ITU-T Rec. I.356 – B-ISDN ATM layer cell transfer performance (2000)[7]

This Recommendation defines speed, accuracy, and dependability parameters and objectives for describing B-ISDN ATM information transfer performance. The key parameters include cell transfer delay, cell delay variation, cell error ratio, cell loss ratio, severely errored cell block ratio, frame transmission delay, and corrupted frame ratio. It includes adjusted parameter definitions that can be used when cell flows do not conform with the negotiated traffic contract. The parameters and objectives apply to specified portions of an end-to-end international B-ISDN ATM connection. Parameter values are grouped into five distinct QoS classes that users may request on a connection-by-connection basis. This Recommendation provides a basis for B-ISDN ATM availability performance specification in ITU-T Rec. I.357.

3.27 ITU-T Rec. I.357 – B-ISDN semi-permanent connection availability (2000)

This Recommendation defines network performance parameters, objectives and measurement methods for describing B-ISDN ATM semi-permanent connection availability. The specified parameters and objectives apply to international ATM semi-permanent connection[8] portions delimited by measurement points: National Portions, International Transit Portions and International Interoperator Portions. The objectives, which are worst-case values, are intended to assist providers in network planning by limiting the aggregate effect of network impairments, including congestion, equipment failures and transmission errors. Guidance on determining expected end-to-end performance is provided in Annex C/I.357.

A two-state availability model is defined along with criteria for entry into and exit from the unavailable state. An estimation procedure is also defined, providing a means of estimating availability performance using sampling techniques.

3.28 ITU-T Rec. I.358 – Call processing performance for switched Virtual Channel Connections (VCCs) in a B-ISDN (2003)

This Recommendation defines performance parameters and objectives for call processing in B-ISDNs for switched Virtual Channel Connections (VCCs). The B-ISDN call processing parameters defined in this Recommendation are applicable to point-to-point (Type 1) and point-to-multipoint (Type 2) connection topologies. The QoS relevant network performance objectives provided in this Recommendation are based on the general principles and generic performance parameters of ITU-T Rec. I.350. New performance-related aspects, associated with B-ISDN call processing functions providing access or disengagement, include the addition or release of a party to an existing B-ISDN connection. In a B-ISDN, a virtual connection can generally be either a Virtual Channel Connection (VCC) or a Virtual Path Connection (VPC). Since call processing capabilities are currently defined only for VCCs, a virtual connection within the context of this Recommendation is a VCC.

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[7] See also Amendment 1, 02-2004.

[8] Also known as permanent virtual connection or PVC.

3.29 ITU-T Rec. I.359 – Accuracy and dependability of ISDN 64 kbit/s circuit mode connection types (1999)

This Recommendation defines accuracy and dependability parameters for describing N-ISDN circuit mode access and disengagement performance. Key parameters are connection denial probability, incorrect call set-up probability, and premature disconnect probability. The parameters apply to specified portions of an international end-to-end 64 kbit/s circuit mode connection.

3.30 ITU-T Rec. I.381 – ATM Adaptation Layer (AAL) Performance (2001)

This Recommendation describes an approach for the performance description of AAL processes. It is motivated by the need, based on field experiences, to examine more carefully the performance aspects of some specific applications of ATM network technology. The approach presented here provides a unified framework for describing the performance of processes that depend upon AAL Type 1 (AAL-1), AAL Type 2 (AAL-2), AAL Type 3/4 (AAL-3/4), AAL Type 5 (AAL-5), or potentially other types of AAL, up to the point at which AAL layer actions have been completed. For each AAL, parameters that describe loss and delay performance are for further study. These parameters are related to relevant ATM cell transfer performance parameters from ITU-T Rec. I.356.

3.31 ITU-T Rec. Y.1530 – Call processing performance for voice service in hybrid IP networks (2004)

This Recommendation defines performance parameters and objectives for point-to-point call processing in voice service provided by hybrid IP networks. The parameter definitions are based on the principles and generic performance parameters defined in ITU-T Rec. I.350, and make use of relevant definitions from ISDN call processing performance Recommendations where appropriate.

3.32 ITU-T Rec. Y.1540 – Internet protocol data communication service – IP packet transfer and availability performance parameters (2002)[9]

This Recommendation defines parameters that may be used in specifying and assessing the speed, accuracy, dependability, and availability of Internet Protocol (IP) packet transfer of international IP data communication service. Connectionless transport is a distinguishing aspect of the IP service that is considered in ITU-T Rec. Y.1540. 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. The key parameters include IP packet transfer delay, IP packet delay variation, IP packet error ratio, IP packet loss ratio, spurious IP packet rate, and per cent IP service availability. Performance objectives for the parameters defined in ITU-T Rec. Y.1540 are specified in ITU-T Rec. Y.1541. Access and disengagement performance associated with IP service is addressed in ITU-T Rec. Y.1530.

3.33 ITU-T Rec. Y.1541 – Network performance objectives for IP-based services (2002)[10]

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

Appendix I/Y.1541 provides information about how ATM might support IP layer performance. Appendix II discusses alternatives for defining IP delay variation. Appendix III presents the Hypothetical Reference Paths against which the Y.1541 QoS objectives were tested for feasibility.

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[9] See also Amendment 1, 08-2003.

[10] See also Amendment 1, 08-2003; Appendix X, 11-2002; and Amendment 2 (02/04) – Appendix XI.

Appendix IV gives example computations of packet delay variation. Appendix V discusses issues that must be considered whenever IP measurements are made. Appendix VI addresses the applicability of the transfer capabilities defined in ITU-T Rec. Y.1221 in support of the Y.1541 IP QoS classes. It also specifies the relationship between Y.1221 transfer capabilities and IETF Differentiated Services Per Hop Behaviours consistent with what is specified in ITU-T Rec. Y.1221. Appendix VII discusses the packet transfer delay objective and how it relates to other Recommendations. Appendix VIII presents a Bibliography. Appendix IX discusses potential applications of IP Networks. Appendix X provides Speech Quality Calculations for Y.1541 Hypothetical Reference Paths. Appendix XI provides methods for estimating UNI-UNI performance from a set of QoS values contributed by Network Sections.

3.34 ITU-T Rec. Y.1560 – Parameters for TCP connection performance in the presence of middleboxes (2003)

This Recommendation describes end-to-end Transmission Control Protocol (TCP) performance in terms of speed, accuracy, and dependability in an IP-based network with middleboxes, which are network nodes terminating TCP connections.

3.35 ITU-T Rec. Y.1561 – Performance and availability parameters for MPLS networks (2004)

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. Two categories of MPLS networks are considered:

1) TE-LSP: Traffic Engineering Label Switched Path, or configured LSP. These are point-point paths.
2) LDP-based LSP: This includes point-to-point and multipoint-to-point LSPs.

Annex A

History of the G-series error performance Recommendations

A.1 Background on the content of Annex A

Because of the somewhat complex history of the G-series error performance Recommendations, clause A.2 and Table A.1 of this annex provide guidance to help users of these Recommendations to find the right standard for their application.

A.2 History of the G-series error performance Recommendations

ITU-T Rec. G.821 was adopted in 1980 and defined error performance parameters and objectives for ISDN connections operating at a bit rate of 64 kbit/s. Because it was the first Recommendation giving error performance objectives, it found wide application – even in some areas for which it was not developed. One of these applications was error performance evaluation at bit rates higher than 64 kbit/s.

In 1984, ITU-T Rec. G.921 was developed to define different section quality classes for digital sections based on the 2048 kbit/s hierarchy. The same targets were defined in ITU-T Rec. G.931 for digital sections on non-hierarchical 3152 kbit/s interface but no values for error and availability

parameters were indicated. These objectives were kept under study until the deletion of the Recommendation in 2002. In 1988, Annex D was added to ITU-T Rec. G.821, which indicated how to derive error performance data of 64 kbit/s connections taking into account measurements performed at higher bit rates. Practical experience showed, however, that this annex led in many cases to doubtful results.

Another problem discovered in practical use of ITU-T Rec. G.821 was the applicability of the Degraded Minute parameter (DM). In practice, this event was hardly detected and it was therefore deleted from the Recommendation.

In addition, it was a disadvantage of ITU-T Rec. G.821 that no signal overhead was available at the bit rates covered by the Recommendation. Because of this, in-service performance measurements were not possible.

With the beginning of the development of SDH and ATM transport networks, the inadequate performance requirements of ITU-T Rec. G.821 for higher bit rates came to light. Thus, it became obvious that a Recommendation was needed which dealt with error performance parameters and objectives for higher bit rates and which would allow in-service measurements. To fill this gap, ITU-T Rec. G.826 was developed and was adopted in 1993. It gives error performance parameters and objectives for constant bit rate digital paths operating at bit rates at and above the primary rate.

In 1996, ITU-T Rec. G.821 was restricted to bit rates below the primary rate and Annex D was deleted. On the other hand, the bit rate range between 64 kbit/s and the primary rate was to be covered by ITU-T Rec. G.821.

ITU-T Rec. G.826 makes use of different concepts to allow in-service measurements based on blocks of contiguous bits. To point to some inconsistency problems existing between ITU-T Recs G.821 and G.826, Appendix I to ITU-T Rec. G.821 was prepared.

In 2000, the new ITU-T Rec. G.828 was approved to meet the tighter requirements of synchronous digital paths supported by optical transport systems and to make sure that ATM traffic supported by these paths would meet the objectives of ITU-T Rec. I.356.

In 2002, ITU-T Rec. G.826 was extended to digital connections that operate below the primary rate. This extension made the allocation principles for digital connections consistent with those for digital paths, and improved the ESR objective for digital connections. At this point, ITU-T Rec. G.821 was restricted to digital connections using equipment designed prior to the adoption of revised ITU-T Rec. G.826 on 14 December 2002.

Finally, new ITU-T Rec. G.8201 for error and availability performance objectives of the optical transmission network (OTN) was completed in 2003.

Table A.1 gives an overview on the history of the Recommendations discussed here.

Table A.1/G.820/I.351/Y.1501 – History of the error performance Recommendations

<table>
<tr><th>Application \ Validity period</th><th>1980-1988</th><th>1988-1993</th><th>1993-1996</th><th>Since 1996</th><th>Since 2000</th><th>Since 2002</th><th>Since 2004</th></tr>
<tr><td>Digital connections
operating below the primary rate</td><td colspan="5">G.821</td><td colspan="2">G.826</td></tr>
<tr><td>Digital paths
operating at and above the primary rate
(PDH)</td><td>G.821</td><td>G.821 + Annex D</td><td colspan="5"></td></tr>
<tr><td>Digital paths
operating at and above the primary rate
(PDH, SDH, cell-based)</td><td colspan="2"></td><td>G.826</td><td colspan="4"></td></tr>
<tr><td>Digital paths
operating at and above the primary rate
(PDH, cell-based)</td><td colspan="4"></td><td colspan="3">G.826</td></tr>
<tr><td>Digital paths
operating at and above the primary rate
(SDH)</td><td colspan="4"></td><td colspan="3">G.828</td></tr>
<tr><td rowspan="2">PDH digital sections</td><td colspan="7">G.921</td></tr>
<tr><td colspan="5">G.931</td><td colspan="2"></td></tr>
<tr><td>SDH digital sections</td><td colspan="4"></td><td colspan="3">G.829</td></tr>
<tr><td>Error performance of the OTN</td><td colspan="6"></td><td>G.8201</td></tr>
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