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SERIES M: TMN AND NETWORK MAINTENANCE: INTERNATIONAL TRANSMISSION SYSTEMS, TELEPHONE CIRCUITS, TELEGRAPHY, FACSIMILE AND LEASED CIRCUITS

International transport network

Error performance limits and procedures for bringing-into-service and maintenance of multi-operator international paths and sections within an optical transport network

ITU-T Recommendation M.2401

ITU-T M-SERIES RECOMMENDATIONS

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ITU-T Recommendation M.2401

Error performance limits and procedures for bringing-into-service and maintenance of multi-operator international paths and sections within an optical transport network

Summary

This Recommendation gives error performance objectives, limits and procedures for bringing-into-service (BIS) and maintenance of multi-operator international ODUk Paths and OTUk Sections in an Optical Transport Network (OTN).

Source

ITU-T Recommendation M.2401 was approved by ITU-T Study Group 4 (2001-2004) under the ITU-T Recommendation A.8 procedure on 14 December 2003.

Keywords

Background block error, bringing-into-service, error detection code, error performance objectives, error performance parameters, forward error correction, in-service measurements, ODUk path monitoring, optical transport network, OTN maintenance, severely errored second.

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Error performance limits and procedures for bringing-into-service and maintenance of multi-operator international paths and sections within an optical transport network

1 Scope

This Recommendation gives error performance objectives, limits and procedures for bringing-into-service (BIS) and maintenance of multi-operator international ODUk paths and OTUk sections in an Optical Transport Network (OTN).

Note that possible consequences for the BIS and maintenance following from the use of an OTN as a server network for analog client signals is outside the scope of this Recommendation.

2 References

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

– ITU-T Recommendation G.709/Y.1331 (2003), *Interfaces for the Optical Transport Network (OTN)*.

– ITU-T Recommendation G.798 (2002), *Characteristics of optical transport network hierarchy equipment functional blocks*.

– ITU-T Recommendation G.874 (2001), *Management aspects of the optical transport network element*.

– ITU-T Recommendation G.7710/Y.1701 (2001), *Common equipment management function requirements*.

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

– ITU-T Recommendation M.20 (1992), *Maintenance philosophy for telecommunication networks*.

– ITU-T Recommendation M.60 (1993), *Maintenance terminology and definitions*.

– ITU-T Recommendation M.2110 (2002), *Bringing into service international multi-operator paths, sections and transmission systems*.

– ITU-T Recommendation M.2120 (2002), *International multi-operator paths, sections and transmission systems fault detection and localization procedures*.

3 Terms and definitions

General terms and definitions related to maintenance are provided in ITU-T Recs M.20 and M.60. Terms and definitions related to OTN performance assessment are given in ITU-T Rec. G.8201.

4 Abbreviations

This Recommendation uses the following abbreviations:

3R	Reamplification, Reshaping and Retiming
APO	Allocated Performance Objective
BBE	Background Block Error
BBER	Background Block Error Ratio
BDI	Backward Defect Indication
BEI	Backward Error Indication
BIP	Bit Interleaved Parity
BIS	Bringing-Into-Service
BISPO	Bringing-Into-Service Performance Objective
BOD	Backbone Operator Domain
DPL	Degraded Performance Level
DXC	Digital Crossconnect
EDC	Error Detection Code
EMF	Equipment Management Function
ES	Errored Second
ESR	Errored Second Ratio
FCE	FEC Corrected Errors
FEC	Forward Error Correction
HROP	Hypothetical Reference Optical Path
IOD	Inter-Operator Domain
ISM	In-Service Monitoring
LOD	Local Operator Domain
LT	Line Terminal
OCADM	Optical Add/Drop Multiplexer
OCh	Optical Channel
OCXC	Optical Crossconnect
OD	Operator Domains
ODUk	Optical Data Unit k, where k = 1, 2, 3
OG	Operator Gateway
OH	Overhead
OMS	Optical Multiplex Section
OPUk	Optical Payload Unit k, where k = 1, 2, 3
OS	Optical Section
OSM	Out-of-Service Measurement
OTN	Optical Transport Network

OTUk	Optical Transport Unit k, where k = 1, 2, 3
PO	Performance Objective
PRBS	Pseudo-Random Binary Sequence
ROD	Regional Operator Domain
SES	Severely Errored Second
SESR	Severely Errored Second Ratio
SLA	Service Level Agreement
STM	Synchronous Transport Module
TP	Test Period
UPL	Unacceptable Performance Level

5 Transport entities in the OTN

5.1 General introduction

Figure 1 provides a simplified view of the OTN information structure hierarchy. The client signal, together with associated overhead, is mapped into the payload area of an Optical Payload Unit k (OPUk). The OPUk, together with its overhead, is mapped into the payload area of an Optical Data Unit k (ODUk). The ODUk, together with its overhead, is mapped into the payload area of an Optical Transport Unit k (OTUk). The OTUk is transported over the optical carrier network by inserting it in an Optical Channel (OCh). This picture does not show the various layers of the optical carrier network as their details are not relevant for the purpose of this Recommendation.

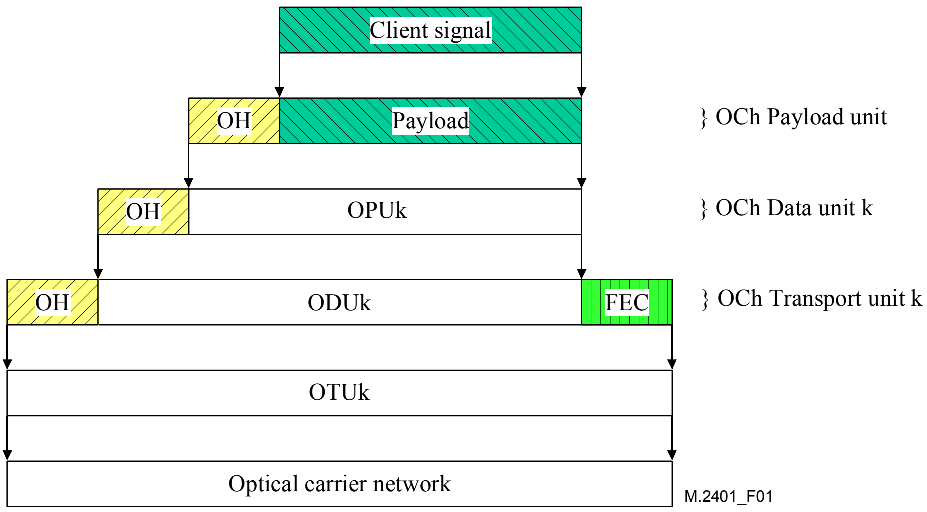


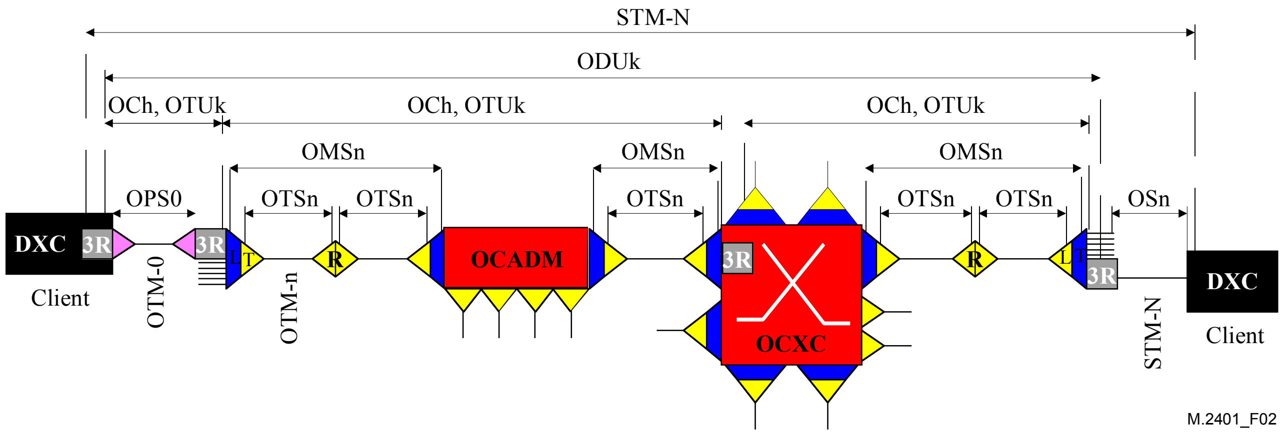
Figure 1/M.2401 – OTN signal structure

The ODUk and OTUk overhead (OH) bytes contain information used to check and to control the behaviour of the transport network. For the purpose of error performance monitoring, the Path Monitoring bytes in the ODUk OH and the Section Monitoring bytes in the OTUk OH are relevant: they contain amongst others Bit Interleaved Parity (BIP), Backward Error Indication (BEI) and Backward Defect Indication (BDI) information.

Note that the OPUk OH bytes do not contain error performance monitoring-related information.

The Forward Error Correction (FEC) bytes, which are part of the OTUk, serve the purpose of improving the error performance of the payload (in this case the ODUk together with its OH) under given optical transport conditions.

Figure 2 shows how these transport entities may be used in an example OTN. In this example, the client signal transported between the terminating Digital Crossconnects (DXCs) is an STM-N. This STM-N is carried on the concatenation of an SDH section (OSn) and the end-to-end connection in the OTN, the ODUk. The ODUk is carried on a concatenation of OTUks, each delimited by a 3R regeneration point. Each OTUk is associated with an optical wavelength by means of the OCh. A number of OChs are multiplexed into an Optical Multiplex Section n (OMSn), which spans the distance between the line-terminating equipment: LTs, OCADMs, OCXCs.



3R	Reamplification, Reshaping and Retiming	OSn	Optical Section Layer, level n
DXC	Digital Crossconnect	OTM-0	Optical Transport Module 0
OCADM	Optical Add/Drop Multiplexer	OTM-n	Optical Transport Module n
Och	Optical Channel	OTSn	Optical Transport Section n
OCXC	Optical Crossconnect	OTUk	Optical Transport Unit k
ODUk	Optical Data Unit k	R	Repeater
OMSn	Optical Multiplex Section n	STM-N	Synchronous Transport Module N
OPS0	Optical Physical Section 0		

Figure 2/M.2401 – Usage of transport entities in the OTN

5.2 Bidirectional transport entities and unidirectional monitoring

ITU-T Rec. G.709/Y.1331 defines the ODUk and the OTUk as bidirectional transport entities. ITU-T Rec. G.8201 defines error performance objectives for bidirectional ODUks. However, for the purposes of BIS and maintenance, both directions are treated as independent entities and all objectives set forth in this Recommendation shall be met by each direction independently of the condition of the other direction. Clause 8 provides further clarification on this issue.

6 Performance monitoring capabilities in the OTN

6.1 Optical impairments and digital error performance

While traversing an optical fibre or an optically transparent network element, an optical signal is subject to a number of physical phenomena which impair the quality of the signal. Typical examples are attenuation, polarization mode dispersion, chromatic dispersion, four-wave mixing and various scattering phenomena. This Recommendation does not elaborate on the details of these phenomena and the mechanisms through which they might affect the quality of the transport services provided by the optical signal. From the perspective of a client, it is sufficient to recognize that such impact may exist. The way in which this impact may be perceived, detected and quantified depends on the nature of the client signal. As the scope of this Recommendation is limited to digital client signals as standardized in ITU-T Rec. G.709/Y.1331, it uses the digital error performance of the ODUk and OTUk layer signals as a means to assess the quality of the transport services provided by an OTN.

6.2 Monitored layer signals

This Recommendation sets objectives and limits for the path (ODUk) and the section (OTUk). The rationale is:

- The ODUk is the end-to-end connection in the OTN. Monitoring is needed because its performance is the performance of the OTN as perceived by the client.
- The OTUk is the connection between two 3R regeneration points in the network. 3R regeneration is needed because the current state of technology does not permit the construction of a worldwide transparent optical transport network. At a 3R regeneration point the optical signal is converted to an electrical signal, subsequently it is reshaped and retimed such that it conforms to the applicable pulse mask and jitter requirements, and converted again to optical format (O-E-O conversion). Monitoring is needed to support maintenance of the optical connections formed by 3R regeneration spans.

ODUk Tandem Connection (ODUkT):

- The ODUkT is specifically created to enable the monitoring of the performance of a part of a path without affecting the end-to-end monitoring of that path. Applications are: monitoring of an Operator Domain (see clause 9), and monitoring of a transport service provided by a subcontractor within an Operator Domain. Such monitoring might be needed to verify compliance with the applicable Service Level Agreement (SLA).

6.3 ODUk and OTUk overhead

In order to be able to assess the error performance of the transport service provided by the OTN without being dependent on *a priori* knowledge of the client signal, the ODUk and OTUk layers provide error performance information themselves. This is accomplished by means of an error detection code (EDC) scheme. In the OTN, the EDC is a BIP-8 code.

At the transmit end, the parity information over the payload signal is calculated. This information is transmitted together with the payload signal, in the applicable OH bytes. At the receive end, the parity information is extracted. Simultaneously, at the receive end, the parity information over the payload signal is recalculated. The received parity information and the recalculated parity information are compared. Any errors incurred during the transport, be it in the payload signal or in the parity information, will be detected by a difference between the received and the calculated parity information. The nature of the used parity scheme does not allow all possible error patterns to be detected; however, for the purpose of assessing the quality of the transport the detecting capability is adequate.

For the ODUk, the following OH information is available to assess its performance:

- BIP-8: This is a one byte Error Detection Code (EDC) signal. Each ODUk BIP-8 is computed over the bits in the OPUk area of ODUk frame i (the block), and inserted in the ODUk Path Monitoring BIP-8 overhead location in the ODUk frame i + 2.
- BDI: This is a single bit Backward Defect Indication (BDI) signal. It conveys in the upstream direction the signal fail status detected in the path termination sink function.
- BEI: This is a four-bit Backward Error Indication (BEI) signal. It conveys in the upstream direction the count of interleaved-bit blocks that have been detected in error by the corresponding ODUk path monitoring sink using the BIP-8 EDC. This count has nine legal values, namely 0-8.

For the ODUkT and the OTUk, similar OH information is available.

Further details about these OH signals, like their locations in the OH bytes area are given in ITU-T Rec. G.709/Y.1331.

In order to improve the error performance of an OTUk signal under given optical transport conditions, ITU-T Rec. G.709/Y.1331 defines Forward Error Correction (FEC) schemes. The use of a FEC is not mandatory; however, when it is used, the FEC decoder provides additional error information in the form of FEC Corrected Errors (FCE).

6.4 In-Service Monitoring and Out-of-Service Measurement

The use of the OH as described in 6.3 enables the assessment of the error performance of a transport service without affecting the client signal, i.e., simultaneously with the performance assessment the service may be used for life traffic. This method is called In-Service Monitoring (ISM). It may be clear that this method can be used only if one has access to the error performance information from the equipment providing the transport service.

If this is not possible, or not preferred, the performance of a transport service may be assessed by using a known test pattern, e.g., a Pseudo-Random Binary Sequence (PRBS) of known properties as the client signal, and performing a bit-by-bit check of this signal at the receiving end. This method is called Out-of-Service Measurement (OSM).

7 Error performance events and parameters

7.1 Severely Errored Seconds and Background Block Errors

If the transport is not error free, this will be detected through the occurrence of a difference between the received and the calculated BIP-8 parity information. In such case, the transport atomic function which is responsible for the comparison will indicate that a block error occurred. While also taking into account the defect status of the signal of interest, these block errors will be processed further in the Equipment Management Function (EMF), leading to the detection of Severely Errored Second (SES) and Background Block Error (BBE) performance events, which are considered to be essential for BIS and maintenance.

In general, the detection criteria for these events are:

- a SES occurs when in a second more than 15% of the blocks is errored or a defect is detected;
- a BBE occurs when an errored block is detected in a second which is not a SES.

The detection criteria are formally defined in clause 7/G.8201.

ITU-T Recs G.7710/Y.1701 and G.874 provide details on the processing inside the EMF.

From the events, the following performance parameters are derived:

- Severely Errored Second Ratio (SESR): The ratio of the number of SESs to the total number of seconds in the observation interval in available time.
- Background Block Error Ratio (BBER): The ratio of the number of BBEs to the total number of blocks in the observation interval in available time.

The Errored Second (ES) event, and the related parameter Errored Second Ratio (ESR), which are used for PDH and SDH transport error performance characterization, are not considered to be useful for performance assessment in the OTN. Due to the high bit rate transport and the physical properties of the optical transport, almost every second might exhibit at least one error before correction by the FEC. After the correction by FEC, there will be either no ESs, or so many that counting them does not provide information which is useful for BIS or maintenance purposes.

7.2 FEC Corrected Errors

An OTN system, which uses a Forward Error Correction method to improve the error performance behaviour under given optical transport conditions, may provide an additional parameter: the number of FEC Corrected Errors (FCE) in each second. This parameter is only available for OTUk sections, not for ODUk paths.

8 Availability

According to 4.5/G.8201, the error performance of a path shall only be evaluated whilst the path is in the available state. The reason is that error performance is a parameter which characterizes the service provided by the path. When the service is not available, this characteristic is irrelevant.

In line with this general principle, the evaluation of the error performance shall be based on the numbers of events which happened during available time.

Annex A/G.8201 further stipulates that a bidirectional service between A and B is only available if both of the two constituent unidirectional services (A to B, and B to A) are available. The reason is that a client is not very much interested in the detailed performance of one direction if the other direction is completely broken.

This Recommendation has a different approach because it is dealing with BIS and maintenance. Maintenance consists of identifying, localizing and correcting failures which affect the performance of a path. In order to be able to carry out these tasks efficiently, the view of an operator working on failures affecting one direction of a bidirectional path should not be obscured by possible unavailability of the other direction.

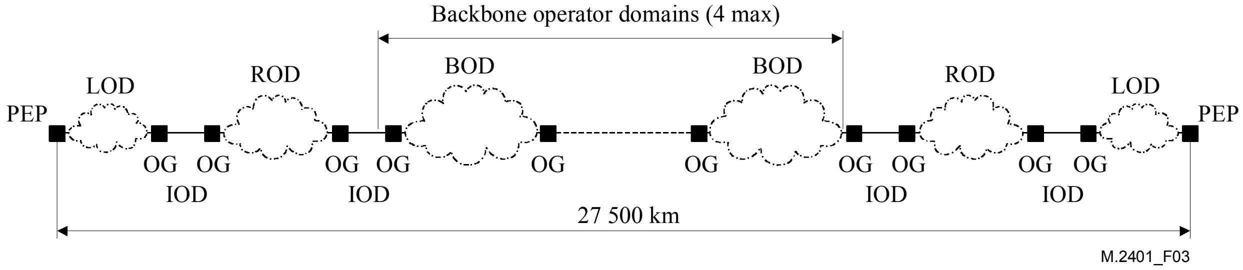
For this reason, this Recommendation uses only the criteria for a single direction from ITU-T Rec. G.8201, and not the criterion for a bidirectional path.

The criteria for a single direction are: "A period of unavailable time begins at the onset of ten consecutive SES events. These ten seconds are considered to be part of unavailable time. A new period of available time begins at the onset of ten consecutive non-SES events. These ten seconds are considered to be part of available time.".

Hence, in order to evaluate the error performance of a transport entity against the objectives put forward in clause 10, each direction shall be evaluated while disregarding the behaviour of the other direction, and the counting of events for a direction shall only be inhibited when that direction is unavailable.

9 Network reference model

This clause introduces the notion of the ODUk Hypothetical Reference Optical Path (HROP). This is a 27 500 km long path, spanning a total of at most eight operator domains as depicted in Figure 3.



BOD	Backbone Operator Domain	OG	Operator Gateway
IOD	Inter-Operator Domain	PEP	Path End Point
LOD	Local Operator Domain	ROD	Regional Operator Domain

Figure 3/M.2401 – The hypothetical reference optical path

From this model, four types of domains can be distinguished: the Local Operator Domain (LOD), the Regional Operator Domain (ROD), the Backbone Operator Domain (BOD), and the Inter-Operator Domain (IOD). The boundary between the domains is called an Operator Gateway (OG). Four BODs and two pairs of LOD-ROD are used for a total of at most eight operator domains.

10 Error performance objectives

10.1 Error performance objectives for the HROP

The end-to-end performance objectives for the ODUk HROP, and the rules to derive from it the objectives for a real path, are chosen such that a path, brought into service and maintained in accordance with this Recommendation, will meet the long-term performance objectives of ITU-T Rec. G.8201. Table 1 gives end-to-end performance objectives for the ODUk HROP. The SESR and BBER values are 50% of the G.8201 values in order to provide some marging for maintenance purposes.

Table 1/M.2401 – Performance objectives for the ODUk HROP

Path type	Bit rate	Number of blocks per second	SESR	BBER
ODU1	2.5 Gbit/s	20 420	10^{-3}	2×10^{-5}
ODU2	10 Gbit/s	82 025	10^{-3}	5×10^{-6}
ODU3	40 Gbit/s	329 492	10^{-3}	1.25×10^{-6}

10.2 Error performance objectives for the domains of a real path

For the four types of domains, the following block allocations, expressed as a percentage of the performance objective for the HROP, apply:

- a block allocation of 5% for a BOD;
- a block allocation of 5% for a ROD;
- a block allocation of 7.5% for a LOD;
- a block allocation of 0.1% for an IOD.

An additional distance-based allocation is also given to each domain, except for the IOD. This distance-based allocation is 0.2% per 100 km based on the real length. If the real length is not known, the product of the air route distance and a routing factor has to be used.

The routing factor is specified as follows for each operator domain (between OGs):

- if the air route distance between two OGs is <1000 km, the routing factor is 1.5;
- if the air route distance is ≥1000 km and <1200 km, the calculated route length is taken to be 1500 km;
- if the air route distance between two OGs is ≥1200 km, the routing factor is 1.25.

The distance-based allocation is added to the block allocation to yield the total allocation for an operator domain, the so-called Path Allocation.

NOTE – A single operator may span several domains, such as one LOD, one ROD and one BOD. In this case, the allocation to the operator is the sum of the various domain allocations.

10.3 Error performance objectives for the section

Table 2 gives performance objectives for the OTUk section.

Table 2/M.2401 – Performance objectives for the OTUk section

Path type	Bit rate	Number of blocks per second	SESR	BBER
OTU1	2.5 Gbit/s	20 420	FFS	FFS
OTU2	10 Gbit/s	82 025	FFS	FFS
OTU3	40 Gbit/s	329 492	FFS	FFS
NOTE – FFS: For further study.				

Note that the FCE parameter might be useful for maintenance of OTUk sections. However, due to the implementation specific behaviour of this parameter, no objectives or limits are specified.

11 Performance limits – General considerations

11.1 Relationship between performance limits and performance objectives

The limits in this Recommendation are to be used to indicate the need for actions during bringing-into-service and maintenance. A network maintained to these limits should meet the performance objectives specified in ITU-T Rec. G.8201.

The particular parameters measured, the measurement duration, and the limits used for the procedures need not be identical to those used in the specification of these performance objectives as long as they result in network performance which meets these objectives. For example, the error performance objectives refer to long periods, such as one month. However, practical considerations demand that maintenance and BIS limits be based on shorter measurement intervals.

Statistical fluctuations in the occurrence of anomalies and defects mean that one cannot be certain that the long-term objectives are met. The limits on the numbers of events and the duration of measurements attempt to ensure that OTN sections or paths exhibiting unacceptable or degraded performance can be detected. The only way to ensure that an OTN section or path meets network performance objectives is to evaluate continuous measurement over a long period (i.e., months).

11.2 Types of limits

Limits are needed for several maintenance functions as defined in ITU-T Rec. M.20. This Recommendation provides methods for calculation of path limits for three of these functions:

– bringing-into-service;

– keeping the network operational (maintenance);

– system restoration.

Limits for commissioning (installation and acceptance) of OTN sections are not provided in ITU-T Recommendations.

11.2.1 BIS tests/limits

BIS tests are done by measurements using a PRBS between digital terminating points. When a particular path/section is brought into service, the collection of anomalies and defects for the BIS tests shall be done at the actual termination points of this path/section. See ITU-T Rec. M.2110 for further information.

Tests results should be compared to the BIS limits, calculated according to the method given in this Recommendation.

11.2.2 Maintenance limits

Once entities have been placed into service, supervision of the network requires additional limits, as described in ITU-T Rec. M.20. This supervision is done by in-service performance monitoring. The supervision process involves analysing anomalies and defects detected by maintenance entities to determine if the performance level is normal, degraded, or unacceptable. Thus, degraded and unacceptable performance limits are required.

11.2.3 System restoration limit

The limits used after intervention (repair) are equal to the BIS limits.

12 Bringing-into-service procedures and limits

The BIS testing procedures, including how to deal with any period of unavailability during the tests, are defined in ITU-T Rec. M.2110. These procedures use limits, called S_{15}, S_2, and S_{24}, according to the duration of the tests (15 minutes, 2 hours, or 24 hours).

These limits are derived from the PO given in Table 1 by means of calculating the Allocated Performance Objective (APO), taking into account the measurement period and the allocation according to 10.2. The Bringing-Into-Service Performance Objective (BISPO) is derived from the APO. This BISPO is chosen to be a factor 2[1] more stringent than the APO. This factor is called the ageing marging. Subsequently, the BISPO is used to calculate the limits.

12.1 Calculation of the BIS limits

This clause defines the method for the calculation of the BIS limits.

Step a: Identification of the PO:

1) Identify the bit rate of the path.
2) Read the PO for BBE and SES for the appropriate bit rate from Table 1, denote these as PO_{bbe} and PO_{ses} (note that these are expressed as ratios).

Step b: Calculation of path allocation:

3) Identify all domains for the entire path; let N be the number of Operator Domains (OD).
4) Label the ODs as OD_1 to OD_N.
5) Identify the length, *d*, of each ODn. The length, *d*, is either the actual path length or, if not known, calculated according to the rules in 10.2.
6) Read the allocation, a_n%, (as a percentage of end-to-end PO) for OD_n from 10.2. Note that these allocations are maximum values; more stringent values can be used by bilateral or multilateral agreement.
7) Calculate the allocation for the Inter-Operator Domains: $a_{IOD} = (N - 1) \times 0.1\%$.
8) Calculate A, the path allocation: $A = a_1 + a_2 + .. + a_n + a_{IOD}$ (note that A is a percentage).

Step c: Calculation of APO:

9) Determine the required Test Period, (TP) where TP is 15 minutes, 2 hours or 24 hours. Express TP in seconds, e.g., TP = 900 seconds for a 15-minute test.
10) Calculate the APO count for SES, converting percentage to ratio:

    $APO_{ses} = (A \div 100) \times PO_{ses} \times TP$

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[1] This is a preliminary value; it might need revision when more error performance data, related to the operation of OTNs, becomes available.

11) Calculate the APO count for BBE, converting percentage to ratio (N_b is the number of blocks per second as given in Table 2):

$APO_{bbe} = (A \div 100) \times PO_{bbe} \times TP \times N_b$

Step d: Calculation of BISPO and S values:

12) Calculate the BISPO counts:

$$BISPO_{ses} = \frac{APO_{ses}}{2} \;;\; BISPO_{bbe} = \frac{APO_{bbe}}{2}$$

13) Calculate S values:

$D_{ses} = 2\sqrt{BISPO_{ses}}$

$S_{ses} = BISPO_{ses} - D_{ses}$

$D_{bbe} = 2\sqrt{BISPO_{bbe}}$

$S_{bbe} = BISPO_{bbe} - D_{bbe}$

14) Round all S values to the nearest integer value ≥ 0.

13 Performance levels and limits for maintenance

Once entities have been placed into service, they will be subject to the supervision processes, as described in ITU-T Rec. M.20. According to this Recommendation, an entity can be in a limited number of predefined conditions depending on its performance. These conditions are called performance levels, and are the Unacceptable Performance Level (UPL), the Degraded Performance Level (DPL) and the Acceptable Performance Level. The boundaries between the performance levels are called performance limits. Refer to ITU-T Rec. M.2120 for further information on the use of these limits.

13.1 Calculation of limits for maintenance

The maintenance performance limits are a function of the APO and the applicable measurement period and are calculated as follows:

– UP limit $\geq$ 10 × APO where TP = 900 seconds;

– DP limit = 0.75 × APO where TP = 86 400 seconds.

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