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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital transmission systems – Digital networks – Quality and availability targets

Error performance parameters and objectives for international, constant bit rate synchronous digital paths

ITU-T Recommendation G.828

(Formerly CCITT Recommendation)

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ITU-T Recommendation G.828

Error performance parameters and objectives for international, constant bit rate synchronous digital paths

Summary

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. This Recommendation is based upon a block-based measurement concept using error detection codes inherent to the path under test; the block repetition rate being in accordance with SDH technology. This simplifies in-service measurements. The events, parameters and objectives are defined accordingly. In addition to path performance assessment, tandem connection monitoring is covered.

It is not required to apply this Recommendation to SDH paths using equipment designed prior to the date of adoption of this version of ITU-T Recommendation G.828 (March 2000).

Source

ITU-T Recommendation G.828 was prepared by ITU-T Study Group 13 (1997-2000) and approved under the WTSC Resolution 1 procedure on 10 March 2000.

Keywords

Background Block Error (BBE), block-based concept, Error Detection Codes (EDC), error performance objectives, error performance parameters, Errored Second (ES), In-Service Measurements (ISM), Severely Errored Period (SEP), Severely Errored Second (SES), synchronous digital path, Tandem Connection Monitoring (TCM).

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 Conference (WTSC), 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 WTSC 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.

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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.

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ITU-T Recommendation G.828

Error performance parameters and objectives for international, constant bit rate synchronous digital paths

1 Scope

This Recommendation specifies error performance events, parameters and objectives for synchronous digital paths. Subclauses 1.1 to 1.3 give further details.

1.1 Application of this Recommendation

This Recommendation is applicable to international, constant bit rate digital paths based on Synchronous Digital Hierarchies. 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. This Recommendation is generic in that it defines the parameters and objectives for paths independent of the physical transport network providing the paths.

Compliance with the performance specification of this Recommendation will, in most cases, also ensure that subtending connections will meet the requirements laid out in ITU-T Recommendations G.821 (N × 64 kbit/s) [5] and G.826 [6]. Therefore, this Recommendation is the only Recommendation required for designing the error performance of synchronous digital paths (see Note). In accordance with the definition of a digital path, path end points may be located at user's premises.

NOTE – It is not required to apply this Recommendation to SDH paths using equipment designed prior to the adoption of this Recommendation in March 2000. Performance events and objectives for paths using equipment designed prior to this date are given in ITU-T G.826.

Paths are used to support services such as circuit switched, packet switched and leased circuit services. The quality of such services, as well as the performance of the network elements belonging to the service layer, is outside of the scope of this Recommendation. However, G.828-based paths can carry ATM traffic. Synchronous digital paths meeting the objectives of this Recommendation will enable the ATM traffic to meet I.356 [9].

The error performance objectives are applicable to each direction of the path independently. The values apply end-to-end over a 27 500 km Hypothetical Reference Path (see Figure 3) which may include optical fibre, digital radio relay, metallic cable and satellite transmission systems. The performance of multiplex and cross-connect functions employing ATM techniques is not included in these values.

The parameter definitions are block-based with the block repetition rate in accordance with SDH technology, making in-service measurement convenient. In addition to in-service measurements, compliance with this Recommendation can be assessed using out-of-service measurements or estimated by measures compatible with this Recommendation as those specified in Annex B.

The objectives given in this Recommendation are long-term objectives to be met over an evaluation period of typically 30 consecutive days (one month). Shorter measurement periods required for maintenance and bringing-into-service are covered in ITU-T Recommendation M.2101 [10].

1.2 Transport network layers

This Recommendation specifies the error performance of synchronous digital paths in a given transport network layer. Two cases are considered:

1) End-to-end Synchronous Digital Hierarchy (SDH) transport.

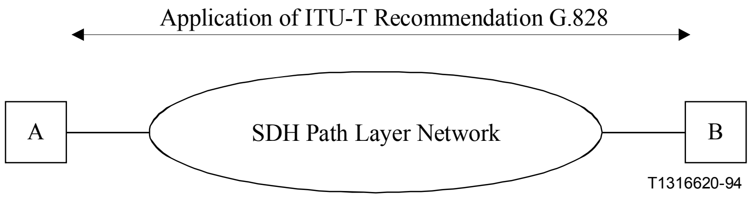
2) SDH paths forming the physical layer portions of ATM connections.

See 1.2.1 and 1.2.2 for details.

NOTE – For the purpose of this Recommendation, SDH transport includes other SDH type systems such as the Synchronous Optical Network (SONET).

1.2.1 SDH transport networks

In the context of this Recommendation, an SDH digital path is a trail carrying an SDH payload and associated overhead through the layered transport network between the path terminating equipment (see Figure 1). ITU–T Recommendation M.2101 [10] provides Bringing into-Service (BIS) and maintenance requirements which ensure that G.828 objectives are met.

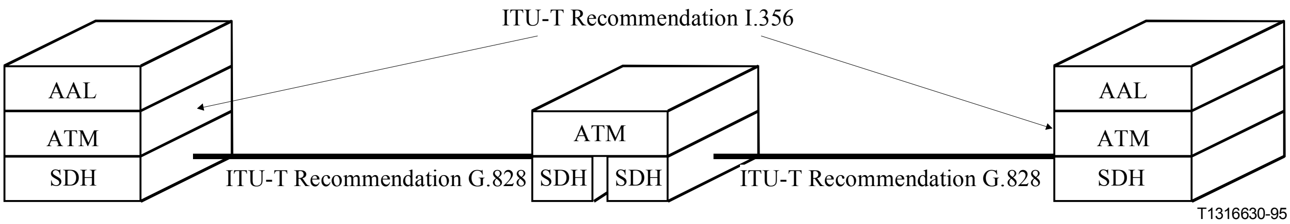


NOTE – A and B are path end points located at the terminations as defined in ITU-T Recommendation G.783 [2].

Figure 1/G.828 – Application of ITU-T Recommendation G.828 for an end-to-end SDH path

1.2.2 ATM connections

Where the path forms the physical part of an ATM connection (see Figure 2), the overall end-to-end performance of the ATM connection is defined by ITU-T Recommendation I.356 [9]. In this case, this Recommendation can be applied with an appropriate allocation to the performance between the path end points terminated by the physical layer of ATM cross-connects or switches (see Recommendation I.321 [8]). ATM transmission paths in the physical layer correspond to a stream of cells mapped into SDH frame structures.



AAL ATM Adapatation Layer
ATM ATM Layer
SDH SDH Layer

Figure 2/G.828 – Architectural relationship between ITU-T Recommendations G.828 and I.356 [9]

1.3 Allocation of end-to-end performance

Allocations of end-to-end performance of synchronous digital paths are derived using the rules laid out in 6.2, which are length and complexity based. Detailed allocations of G.828 performance to the individual components (lines, sections, multiplexers and cross-connects, etc.) are outside the scope of this Recommendation, but when such allocations are performed, the requirements of 6.2 with regard to national and international allocations should be met.

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; all 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.

[1] ITU-T Recommendation G.707 (1996), *Network node interface for the synchronous digital hierarchy (SDH)*.

[2] ITU-T Recommendation G.783 (1997), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks*.

[3] ITU-T Recommendation G.784 (1999), *Synchronous digital hierarchy (SDH) management*.

[4] ITU-T Recommendation G.803 (2000), *Architecture of transport networks based on the synchronous digital hierarchy (SDH)*.

[5] ITU-T Recommendation G.821 (1996), *Error performance of an international digital connection operating at a bit rate below the primary rate and forming part of an integrated services digital network*.

[6] ITU-T Recommendation G.826 (1999), *Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate*.

[7] ITU-T Recommendation G.827 (2000), *Availability parameters and objectives for path elements of international constant bit rate digital paths at or above the primary rate*.

[8] CCITT Recommendation I.321 (1991), *B-ISDN Protocol reference model and its application*.

[9] ITU-T Recommendation I.356 (2000), *B-ISDN ATM layer cell transfer performance*.

[10] ITU-T Recommendation M.2101 (2000), *Performance limits for bringing-into-service and maintenance of international SDH paths and multiplex sections*.

3 Definitions and abbreviations

3.1 Abbreviations

This Recommendation uses the following abbreviations:

AAL ATM Adaptation Layer

AIS Alarm Indication Signal

ATM Asynchronous Transfer Mode

AU Administrative Unit

BBE Background Block Error

BBER	Background Block Error Ratio
BIP	Bit Interleaved Parity
B-ISDN	Broadband ISDN
CBR	Constant Bit Rate
CSES	Consecutive Severely Errored Seconds
EB	Errored Block
EDC	Error Detection Code
ES	Errored Second
ESR	Errored Second Ratio
HP	Higher order Path
HPTC	Higher order Path Tandem Connection
HRP	Hypothetical Reference Path
IG	International Gateway
ISDN	Integrated Services Digital Network
ISM	In-Service Monitoring
LOF	Loss of Frame Alignment
LOM	Loss of Multiframe Alignment
LOP	Loss of Pointer
LOS	Loss of Signal
LP	Lower order Path
LPTC	Lower order Path Tandem Connection
LTC	Loss of Tandem Connection Monitoring
N-ISDN	Narrow-Band ISDN
OOS	Out-Of-Service
PEP	Path End Point
PLM	Payload Label Mismatch
RDI	Remote Defect Indication
REI	Remote Error Indication
RS	Regenerator Section
SDH	Synchronous Digital Hierarchy
SEP	Severely Errored Period
SEPI	Severely Errored Period Intensity
SES	Severely Errored Second
SESR	Severely Errored Second Ratio
SONET	Synchronous Optical Network
STM	Synchronous Transport Module
S UNEQ	Supervisory Unequipped

TC	Tandem Connection
TCM	Tandem Connection Monitoring
TIM	Trace Identifier Mismatch
TU	Tributary Unit
UNEQ	Unequipped
VC	Virtual Container

3.2 Terms and Definitions

This Recommendation defines the following terms:

3.2.1 hypothetical reference path: A Hypothetical Reference Path (HRP) is defined as the whole means of digital transmission of a digital signal of a specified rate, including the path overhead, between equipment at which the signal originates and terminates. An end-to-end Hypothetical Reference Path spans a distance of 27 500 km.

3.2.2 SDH digital path: An SDH digital path is a trail carrying an SDH payload and associated overhead through the layered transport network between the path terminating equipment. A digital path may be bidirectional or unidirectional and may comprise both customer owned portions and network operator owned portions.

3.2.3 Generic definition of the block: This ITU-T Recommendation is based upon the error performance measurement of blocks consistent with a synchronous digital hierarchy frame. This clause offers a generic definition of the term "block" as follows:

A block is a set of consecutive bits associated with the path; each bit belongs to one and only one block. Consecutive bits may not be contiguous in time.

3.2.4 Error performance events

3.2.4.1 errored block (EB): A block in which one or more bits are in error.

3.2.4.2 errored second (ES): A one second period with one or more errored blocks or at least one defect (see Note 1).

3.2.4.3 severely errored second (SES): A one-second period which contains ≥30% errored blocks or at least one defect. SES is a subset of ES. (See Notes 1 and 2.)

NOTE 1 – The defects and related performance criteria are listed in Annex B.

NOTE 2 – To simplify measurement processes, the defect is used in the definition of SES instead of defining SES directly in terms of severe errors affecting the path. While this approach simplifies the measurement of SES, it should be noted that there may exist error patterns of severe intensity that would not trigger a defect as defined in Annex B. Thus, these would not be considered as an SES under this definition. If in the future such severe user-affecting events were found, this definition will have to be studied again.

3.2.4.4 background block error (BBE): An errored block not occurring as part of an SES.

3.2.5 Error performance parameters

Error performance should only be evaluated whilst the path is in the available state. For a definition of the entry/exit criteria for the unavailable state see ITU-T Recommendation G.827 [7] and Annex A.

3.2.5.1 errored second ratio (ESR): The ratio of ES in available time to total seconds in available time during a fixed measurement interval.

3.2.5.2 severely errored second ratio (SESR): The ratio of SES in available time to total seconds in available time during a fixed measurement interval.

3.2.5.3 background block error ratio (BBER): The ratio of BBE in available time to total blocks in available time during a fixed measurement interval. The count of total blocks excludes all blocks during SESs.

3.2.6 Additional error performance event / performance parameter

The support of this event/of this parameter and its related functionalities within one network operator's domain is a network operator option. If implemented, the following definitions apply:

3.2.6.1 severely errored period (SEP): A sequence of between 3 to 9 consecutive SES. The sequence is terminated by a second which is not a SES. (See Note 1.)

NOTE 1 – The Severely Errored Period (SEP) event is identical to the CSES event contained in ITU-T Recommendation G.784 [3] on condition that the lower threshold is fixed at three consecutive SESs.

3.2.6.2 Severely Errored Period Intensity (SEPI): The number of SEP events in available time, divided by the total available time in seconds. (See Notes 2, 3 and 4.)

NOTE 2 – The SEPI parameter has a unit of (1/s). This is to enable the SEPI objective to be easily translated to the equivalent number of SEP events over a specific measurement interval. It should be noted that the SEP event has no significance over a time interval of less than three seconds.

NOTE 3 – Ongoing studies of the SEP event and the SEPI parameter shall prove their usefulness in complementing the SESR parameter. Any objectives for the SEPI parameter (presently under study) shall empirically demonstrate this value.

NOTE 4 – The impact of SEP/SEPI on customer services has to be investigated.

4 Measurement of the block

4.1 In-service monitoring

Each block is monitored by means of an inherent (Bit Interleaved Parity) Error Detection Code (EDC). The EDC bits are physically separated from the block to which they apply. It is not normally possible to determine whether a block or its controlling EDC bits are in error. If there is a discrepancy between the EDC and its controlled block, it is always assumed that the controlled block is in error.

No specific EDC is given in this generic definition but it is recommended that for in-service monitoring purposes, future designs should be equipped with an EDC capability such that the probability to detect an error event is ≥ 90% assuming Poisson error distribution.

Estimation of errored blocks on an in-service basis is dependent upon the path configuration and the EDC choice. Annex B describes how in-service estimates of errored blocks can be obtained from the ISM facilities of the SDH network fabric.

4.2 Out-of-service measurements

Out-of-service measurements shall also be block-based. It is expected that the out-of-service error detection capability will be superior to the in-service capability described in 4.1.

5 Performance monitoring at the near end and far end of a path

By monitoring SES events for both directions at a single path end point, a network provider is able to determine the unavailable state of the path (see Annex A). In some cases, it is also possible to monitor the full set of error performance parameters in both directions from one end of the path. Specific in-service indicators for deriving far end performance of a path are listed in Annex B.

6 Error performance objectives

6.1 End-to-end objectives

Table 1 specifies the end-to-end objectives for a 27 500 km HRP in terms of the parameters defined in 3.2.5. The actual objectives applicable to a real path are derived from Table 1 using the allocation principles detailed in 6.2. Each direction of the path shall independently satisfy the allocated objectives for all parameters. In other words, a path fails to satisfy this Recommendation if any parameter exceeds the allocated objective in either direction at the end of the given evaluation period. The objectives given in this ITU-T Recommendation are understood to be long-term objectives to be met over an evaluation period of typically 30 consecutive days (1 month)[1].

Table 1/G.828 – End-to-end error performance objectives for a 27 500 km international synchronous digital HRP

Bit rate (kbit/s)	Path type	Blocks/s	ESR	SESR	BBER	SEPI
1 664	VC-11, TC-11	2 000	0.01	0.002	5×10^{-5}	(Note 3)
2 240	VC-12, TC-12	2 000	0.01	0.002	5×10^{-5}	(Note 3)
6 848	VC-2, TC-2	2 000	0.01	0.002	5×10^{-5}	(Note 3)
48 960	VC-3, TC-3	8 000	0.02	0.002	5×10^{-5}	(Note 3)
150 336	VC-4, TC-4	8 000	0.04	0.002	1×10^{-4}	(Note 3)
601 344	VC-4-4c, TC-4-4c	8 000	(Note 1)	0.002	1×10^{-4}	(Note 3)
2 405 376	VC-4-16c, TC-4-16c	8 000	(Note 1)	0.002	1×10^{-4}	(Note 3)
9 621 504	VC-4-64c, TC-4-64c	8 000	(Note 1)	0.002	1×10^{-3} (Note 2)	(Note 3)

NOTE 1 – ESR objectives tend to lose significance for applications at high bit rates and are therefore not specified for paths operating at bit rates above 160 Mbit/s. Nevertheless, it is recognized that the observed performance of synchronous digital paths is error-free for long periods of time even at Gbit/s rates; and that significant ESR indicates a degraded transmission system. Therefore, for maintenance purposes ES monitoring should be implemented within any error performance measuring devices operating at these rates.

NOTE 2 – This BBER objective corresponds to a equivalent bit error ratio of 8.3×10^{-10}, an improvement over the bit error ratio of 5.3×10^{-9} for the VC-4 rate. Equivalent Bit Error Ratio is valuable as a rate-independent indication of error performance, as BBER objectives cannot remain constant as block sizes increase.

NOTE 3 – SEPI objectives require further study.

Synchronous digital paths operating at bit rates covered by this Recommendation are carried by transmission systems (digital sections) operating at higher bit rates. Such systems must meet their allocations of the end-to-end objectives for the highest bit rate paths which are foreseen to be carried. Meeting the allocated objectives for this highest bit rate path should be sufficient to ensure that all paths through the system are achieving their objective. For example, in SDH, an STM-1 section may

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[1] In cases (e.g. paths transported via radio-relay or satellite systems) where a one month evaluation period may not permit accurate statistical estimation, a longer evaluation period (up to one year) may be used for design purposes.

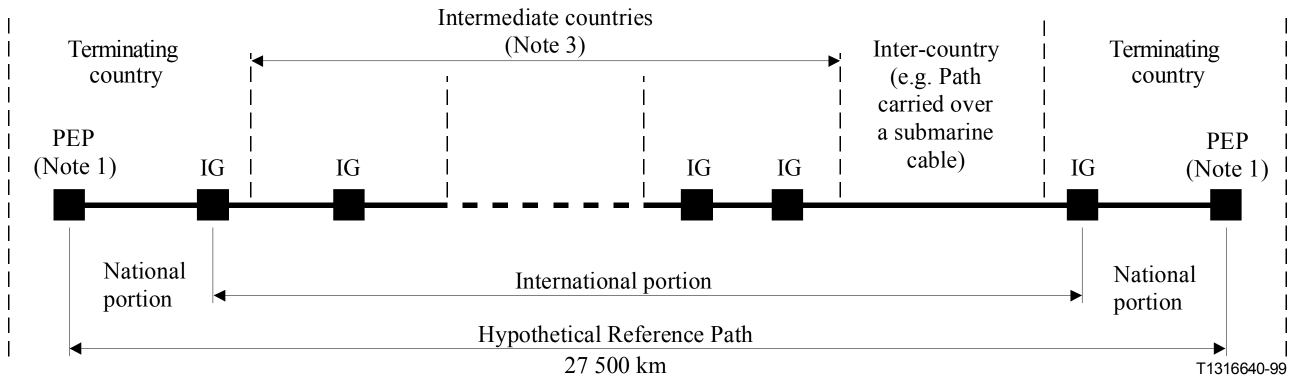
carry a VC-4 path and therefore the STM-1 section should be designed such that it will ensure that the objectives as specified in this Recommendation for the bit rate corresponding to a VC-4 path are met.

NOTE 1 – Digital sections are defined for higher bit rates. In addition to this subclause, guidance on evaluating the performance of digital sections can be found in a Recommendation dealing with section performance events.

NOTE 2 – Objectives are allocated in this Recommendation to the national and international portions of a path. In the above example, if the STM-1 section does not form a complete national or international portion, the corresponding national/international allocation must be subdivided to determine the appropriate allocation for the digital section. This is outside the scope of this Recommendation.

6.2 Apportionment of end-to-end objectives

The apportionment methodology in this subclause specifies the levels of performance expected from the national and international portions of an HRP. Further subdivision of these objectives is beyond the scope of this Recommendation. (See Figure 3.)



NOTE 1 – If a path is considered to terminate at the IG, only the international portion allocation applies.
NOTE 2 – One or two International Gateways (entry or exit) may be defined per intermediate country.
NOTE 3 – Four intermediate countries are assumed.

Figure 3/G.828 – Hypothetical Reference Path

For the purposes of this Recommendation the boundary between the national and international portions is defined to be at an International Gateway which usually corresponds to a cross-connect, a higher-order multiplexer or a switch (N-ISDN or B-ISDN). IGs are always terrestrially based equipment physically resident in the terminating (or intermediate) country. Higher-order paths (relative to the HRP under consideration) may be used between IGs. Such paths receive only the allocation corresponding to the international portion between the IGs. In intermediate countries, the IGs are only located in order to calculate the overall length of the international portion of the path in order to deduce the overall allocation.

The following allocation methodology applies to each parameter defined in 3.2.5 and takes into account both the length and complexity of the international path. All paths should be engineered to meet their allocated objectives as described in 6.2.1 and 6.2.2. If the overall allocation exceeds 100%, then the performance of the path may not fulfil the objectives of Table 1. Network Operators should note that if performance could be improved in practical implementations to be superior to allocated objectives, the occurrence of paths exceeding the objectives of Table 1 can be minimized.

6.2.1 Allocation to the national portion of the end-to-end path

Each national portion is allocated a fixed block allowance of 17.5% of the end-to-end objective. Furthermore, a distance based allocation is added to the block allowance. The actual route length between the PEP and IG should first be calculated if known. The air route distance between the PEP and IG should also be determined and multiplied by an appropriate routing factor. This routing factor is specified as follows:

- If the air route distance is < 1 000 km, the routing factor is 1.5;
- If the air route distance is ≥ 1 000 km and < 1 200 km, the calculated route length is taken to be 1 500 km;
- If the air route distance is ≥ 1 200 km, the routing factor is 1.25.

When both actual and calculated route lengths are known, the smaller value is retained. This distance should be rounded up to the nearest 100 km. An allocation of 0.2% per 100 km is then applied to the resulting distance. The two national portions are allocated a minimum of 500 km (i.e. 1%) each.

NOTE – If a path comprises portions that are privately owned (private in this context means that the network portion is customer owned and not available to the public), end-to-end performance objectives apply to the portion situated between the two Network Terminating Equipment (NTE). Between the NTE and the Terminal Equipment (TE), no specific requirements are given. However, careful attention should be paid concerning this portion because overall performance depends on it. Appendix II contains details for the case of Leased Circuits.

While the performance sub-allocation of the 17.5% national portion block allowance is beyond the scope of this Recommendation, it is the expectation that such a sub-allocation would be done by national standards bodies or regulators in an equitable manner. When making such sub-allocation, the national standards bodies or regulators are urged to take into consideration the empirical evidence that most of the error impairments can occur in that part of the path nearest to its end point.

When a national portion includes a satellite hop, a total allowance of 42% of the end-to-end objectives in Table 1 is allocated to this national portion. The 42% allowance completely replaces both the distance-based allowance and the 17.5% block allowance otherwise given to national portions.

6.2.2 Allocation to the international portion of the end-to-end path

The international portion is allocated a block allowance of 2% per intermediate country plus 1% for each terminating country. Furthermore, a distance based allocation is added to the block allowance. As the international path may pass through intermediate countries, the actual route length between consecutive IGs (one or two for each intermediate country) should be added to calculate the overall length of the international portion. The air route distance between consecutive IGs should also be determined and multiplied by an appropriate routing factor. This routing factor is specified as follows for each element between IGs:

- If the air route distance between two IGs is < 1 000 km, the routing factor is 1.5;
- If the air route distance is ≥ 1 000 km and < 1 200 km, the calculated route length is taken to be 1 500 km;
- If the air route distance between two IGs is ≥ 1 200 km, the routing factor is 1.25.

When both actual and calculated route lengths are known, the smaller value is retained for each element between IGs for the calculation of the overall length of the international portion. This overall distance should be rounded up to the nearest 100 km but shall not exceed 26 500 km. An allocation of 0.2% per 100 km is then applied to the resulting distance.

Independent of the distance spanned, any satellite hop in the international portion receives a 35% allocation of the objectives in Table 1. The 35% allowance completely replaces all distance-based and block allowances otherwise given to parts of the international portion spanned by the satellite hop.

ANNEX A

Criteria for entry to and exit from the unavailable state

A.1 Criteria for a single direction

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 10 consecutive non-SES events. These ten seconds are considered to be part of available time. SEP indicates a severe condition, which does not result in unavailability. Figure A.1 illustrates the definition of criteria for transition to/from the unavailable state, including the relationship with SEP.

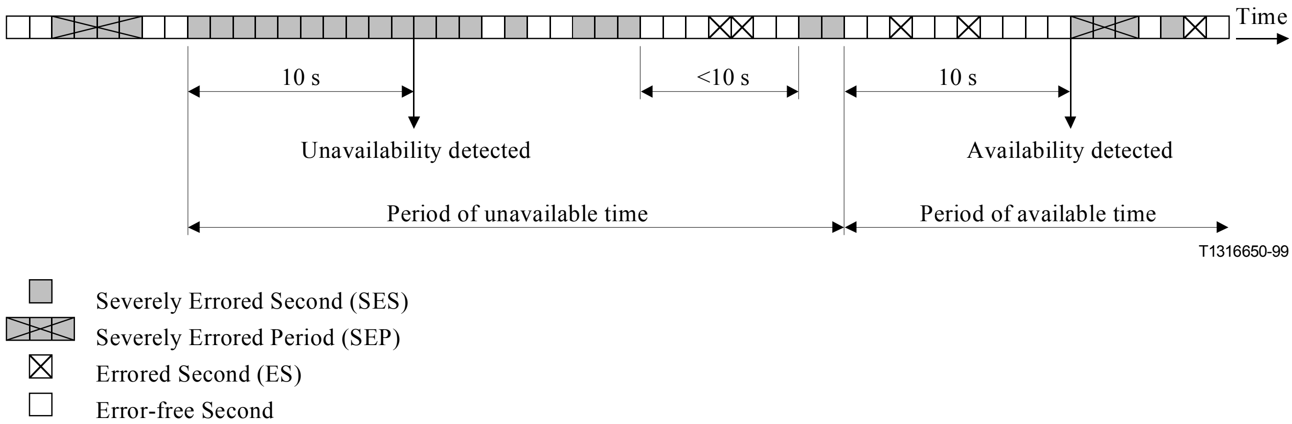


Figure A.1/G.828 – Example of unavailability determination

A.2 Criterion for a bidirectional path

A bidirectional path is in the unavailable state if either one or both directions are in the unavailable state. This is shown in Figure A.2.

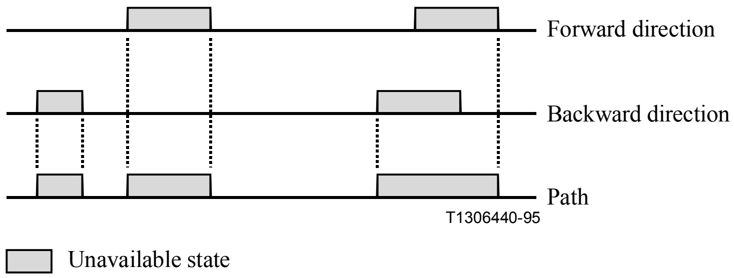


Figure A.2/G.828 – Example of the unavailable state of a path

A.3 Criterion for a unidirectional path

The criterion for a unidirectional path is defined in A.1 above.

A.4 Consequences on error performance measurements

When a bidirectional path is in the unavailable state, ES, SES and BBE counts may be collected in both directions and may be helpful in the analysis of the trouble. However, it is recommended that these ES, SES and BBE counts are not included in estimates of ESR, SESR and BBER performance (see 3.2.5).

Some existing systems may not support the above requirement. For these systems, the performance of a bidirectional path can be approximated by evaluating the parameters in each direction, independently of the state of availability of the other direction. It should be noted that this approximation method may result in a worse estimate of performance in the event that only one direction of a bidirectional path becomes unavailable.

NOTE – This is not an issue for unidirectional paths.

ANNEX B

Relationship between path performance monitoring and the block-based parameters

B.1 General

In addition to path performance monitoring, this Annex covers Tandem Connection Monitoring (TCM) as shown in Tables B.1 to B.4. VC-n and TC-n trails are equivalent from a performance perspective. The established rules for VC-n apply also to TC-n. Further details are given in ITU-T Recommendations G.707 [1], G.783 [2] and G.803 [4].

B.1.1 Converting BIP measurements into errored blocks

Subclause 3.2.4 describes error performance events used in defining performance parameters. The method of converting BIP measurements into errored blocks is described below.

Since this ITU-T Recommendation defines a block as consecutive bits associated with a path, each BIP-n (Bit Interleaved Parity, order "n") in the SDH path overhead pertains to a single defined block. For the purpose of this annex, a BIP-n corresponds to a G.828 block. The BIP-n is NOT interpreted as checking "n" separate interleaved parity check blocks. If any of the "n" separate parity checks fails, the block is assumed to be in error.

NOTE – It shall be noted that BIP-2 does not satisfy the error detection probability of ≥90%.

B.1.2 Block size for monitoring SDH paths

The number of bits per block for in-service performance monitoring of SDH Paths, as specified in ITU-T Recommendation G.707 [1], are given in Table B.1. Paths operating at VC-11, VC-12 or VC-2 rates use 500 µsec measurement blocks, i.e. 2 000 blocks per second.

Table B.1/G.828 – Block sizes for synchronous digital path performance monitoring

Bit rate (kbit/s)	Path type	SDH block size used in G.828	EDC
1 664	VC-11, TC-11	832 bits	BIP-2
2 240	VC-12, TC-12	1 120 bits	BIP-2
6 848	VC-2, TC-2	3 424 bits	BIP-2
48 960	VC-3, TC-3	6 120 bits	BIP-8
150 336	VC-4, TC-4	18 792 bits	BIP-8
601 344	VC-4-4c, TC-4-4c	75 168 bits	BIP-8
2 405 376	VC-4-16c, TC-4-16c	300 672 bits	BIP-8
9 621 504	VC-4-64c, TC-4-64c	1 202 688 bits	BIP-8

B.1.3 Anomalies

In-service anomaly conditions are used to determine the error performance of an SDH path when the path is not in a defect state. The following anomaly is defined:

a_1 an EB as indicated by an EDC. (See B.1.1)

B.1.4 Defects

In-service defect conditions defined in ITU-T Recommendations G.707 [1] and G.783 [2] are used to determine the change of performance state which may occur on a path. Tables B.2 and B.3 show the defects used in this Recommendation.

Table B.2/G.828 – Defects resulting in a near-end Severely Errored Second

<table>
<tr><th colspan="3">Near end defects (Notes 5, 6 and 7)</th><th rowspan="2">Kind of path</th></tr>
<tr><th>Path termination</th><th>Non-Intrusive Monitor</th><th>Tandem Connection</th></tr>
<tr><td>LP UNEQ (Note 3)</td><td>LP UNEQ (Notes 3 and 4)</td><td>LPTC UNEQ (Note 3)</td><td rowspan="8">Applicable to lower order paths and lower order tandem connections</td></tr>
<tr><td>LP TIM</td><td>LP TIM</td><td>LPTC TIM</td></tr>
<tr><td>–</td><td>–</td><td>LPTC LTC</td></tr>
<tr><td>–</td><td>LP VC AIS (Note 2)</td><td>–</td></tr>
<tr><td>TU LOP</td><td>TU LOP</td><td>TU LOP</td></tr>
<tr><td>TU AIS</td><td>TU AIS</td><td>TU AIS</td></tr>
<tr><td>HP LOM (Note 1)</td><td>HP LOM (Note 1)</td><td>HP LOM (Note 1)</td></tr>
<tr><td>HP PLM</td><td>HP PLM</td><td>HP PLM</td></tr>
<tr><td>HP UNEQ (Note 3)</td><td>HP UNEQ (Notes 3 and 4)</td><td>HPTC UNEQ (Note 3)</td><td rowspan="6">Applicable to higher order paths and higher order tandem connections</td></tr>
<tr><td>HP TIM</td><td>HP TIM</td><td>HPTC TIM</td></tr>
<tr><td>–</td><td>–</td><td>HPTC LTC</td></tr>
<tr><td>–</td><td>HP VC AIS (Note 2)</td><td>–</td></tr>
<tr><td>AU LOP</td><td>AU LOP</td><td>AU LOP</td></tr>
<tr><td>AU AIS</td><td>AU AIS</td><td>AU AIS</td></tr>
</table>

Table B.2/G.828 – Defects resulting in a near-end Severely Errored Second *(concluded)*

NOTE 1 – This defect is not related to VC-3.
NOTE 2 – VC AIS defect applies to monitoring a path at an intermediate point by means of non-intrusive monitoring.
NOTE 3 – Paths not actually completed, e.g. during path set-up, will contain the unequipped VC-n signal.
NOTE 4 – Two types of non-intrusive monitor functions are defined in ITU-T Recommendation G.783. The original (version 1) type detect the UNEQ defect when an unequipped or a supervisory-unequipped VC signal is received. The advanced (version 2) type detects the UNEQ condition as type 1 but validates this condition by means of checking the content of the trace identifier; the receipt of a supervisory-unequipped VC signal will not result in an UNEQ defect. Neither will the receipt of a supervisory-unequipped VC signal result in the contribution of UNEQ condition to performance monitoring; if the supervisory-unequipped VC signal was not the expected signal, TIM defect will contribute to performance monitoring instead.
NOTE 5 – The above defects are path defects only. Section defects such as MS AIS, RS TIM, STM LOF and STM LOS give rise to an AIS defect in the path layers.
NOTE 6 – When a near-end SES is caused by a near-end defect as defined above, the far-end performance event counters are not incremented, i.e. an error-free period is assumed. When a near-end SES results from ≥30% errored blocks, the far-end performance evaluation continues during the near-end SES. This approach does not allow reliable evaluation of Far-End data if the Near-End SES is caused by a defect. It should be noted in particular, that the evaluation of Far-End events (such as SES or Unavailability) can be inaccurate in the case where Far-End SESs occur in coincidence with Near-End SESs caused by a defect. Such inaccuracies cannot be avoided, but are negligible in practice because of the low probability of the occurrence of such phenomena.
NOTE 7 – Refer to ITU-T Recommendation G.783 for defects contributing to performance monitoring in each trail termination sink function.

Table B.3/G.828 – Defects resulting in a far-end Severely Errored Second

Far end defects			Kind of path
Path termination	**Non-Intrusive Monitor**	**Tandem Connection**	
LP RDI	LP RDI	LPTC TC RDI	Applicable to lower order paths and lower order tandem connections
HP RDI	HP RDI	HPTC TC RDI	Applicable to higher order paths and higher order tandem connections

B.2 Estimation of the performance parameters

For SDH transmission paths, the full set of performance parameters shall be estimated using the following events:

ES: An ES is observed when, during one second, at least one anomaly a_1, or one defect according to Tables B.2 and B.3 occurs. For the ES event, the actual count of EBs is irrelevant, it is only the fact that an EB has occurred in a second which is significant.

SES: An SES is observed when, during one second, at least 30% EBs – derived from anomaly a_1 or one defect according to Tables B.2 and B.3 occur (see Table B.4).

BBE: A BBE is observed when an anomaly a_1 occurs in a block not being part of an SES.

NOTE – The errored block threshold resulting in an SES is shown in Table B.4 for each SDH path type.

Table B.4/G.828 – Threshold for the declaration of a severely errored second

Bit rate (kbit/s)	Path type	Threshold for SES (Number of Errored Blocks/s)
1 664	VC-11, TC-11	600
2 240	VC-12, TC-12	600
6 848	VC-2, TC-2	600
48 960	VC-3, TC-3	2 400
150 336	VC-4, TC-4	2 400
601 344	VC-4-4c, TC-4-4c	2 400
2 405 376	VC-4-16c, TC-4-16c	2 400
9 621 504	VC-4-64c, TC-4-64c	2 400

B.3 Estimation of performance events at the far end of a path

The following indications available at the near end or at an intermediate point along the path/tandem connection are used to estimate the performance events (occurring at the far end) for the reverse direction:

- Higher and lower order path/tandem connection RDI and REI (ITU-T Recommendation G.707 [1]).
- Higher or lower order path/tandem connection REIs are anomalies which are used to determine the occurrence of ES, BBE and SES at the far end.
- Higher or lower order path/tandem connection RDIs are defects which estimate the occurrence of SES at the far end.

APPENDIX I

Flow chart illustrating the recognition of anomalies

Notes to Figures I.1 and I.2:

NOTE 1 – The determination of unavailability time introduces a delay of 10 seconds. This delay should be considered when counting BBE, ES and SES.

NOTE 2 – cES, cSES, cSEP and cBBE represent counts of ES, SES, SEP and BBE respectively. These counts are reset at the start of a measurement period.

NOTE 3 – EB is the count of errored blocks within an ES whilst %EB represents the proportion of errored blocks within an ES compared to the number of blocks per second.

NOTE 4 – G.828 parameters can be evaluated during, or at the end of, a measurement period P as follows, taking into account Unavailable Seconds (UAS):

BBER = cBBE/[(P-UAS – cSES) · blocks/second]

ESR = cES/(P-UAS)

SESR = cSES/(P-UAS)

SEPI = cSEP/(P-UAS)

NOTE 5 – In the simplified diagrams, no action is taken if the path is in the unavailable state. This is because the diagram does not consider the transition between availability states when, in fact, event counters must be modified retrospectively. In practice, the status of a second (i.e. error-free, ES or SES) must always be determined before a test is made on the status of path availability. In other words, error events are always detected regardless of whether the path is available or not – only the *counting* of events is inhibited during unavailability periods for the purposes of long-term performance monitoring. This process is reflected in the flow chart although consequent actions on changes of availability state are not.

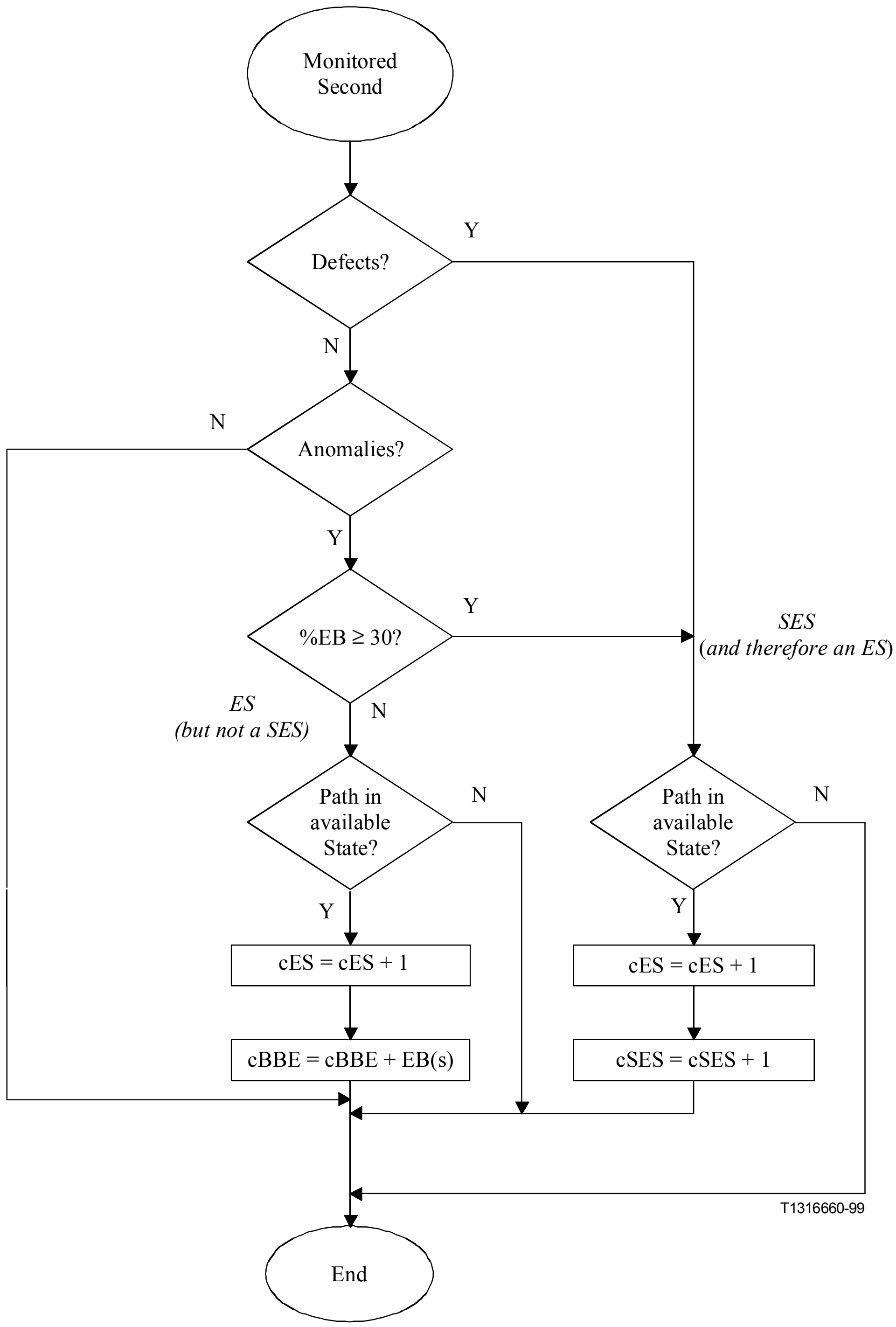


Figure I.1/G.828 – Recognition of anomalies, defects, errored blocks, ES, SES and BBE

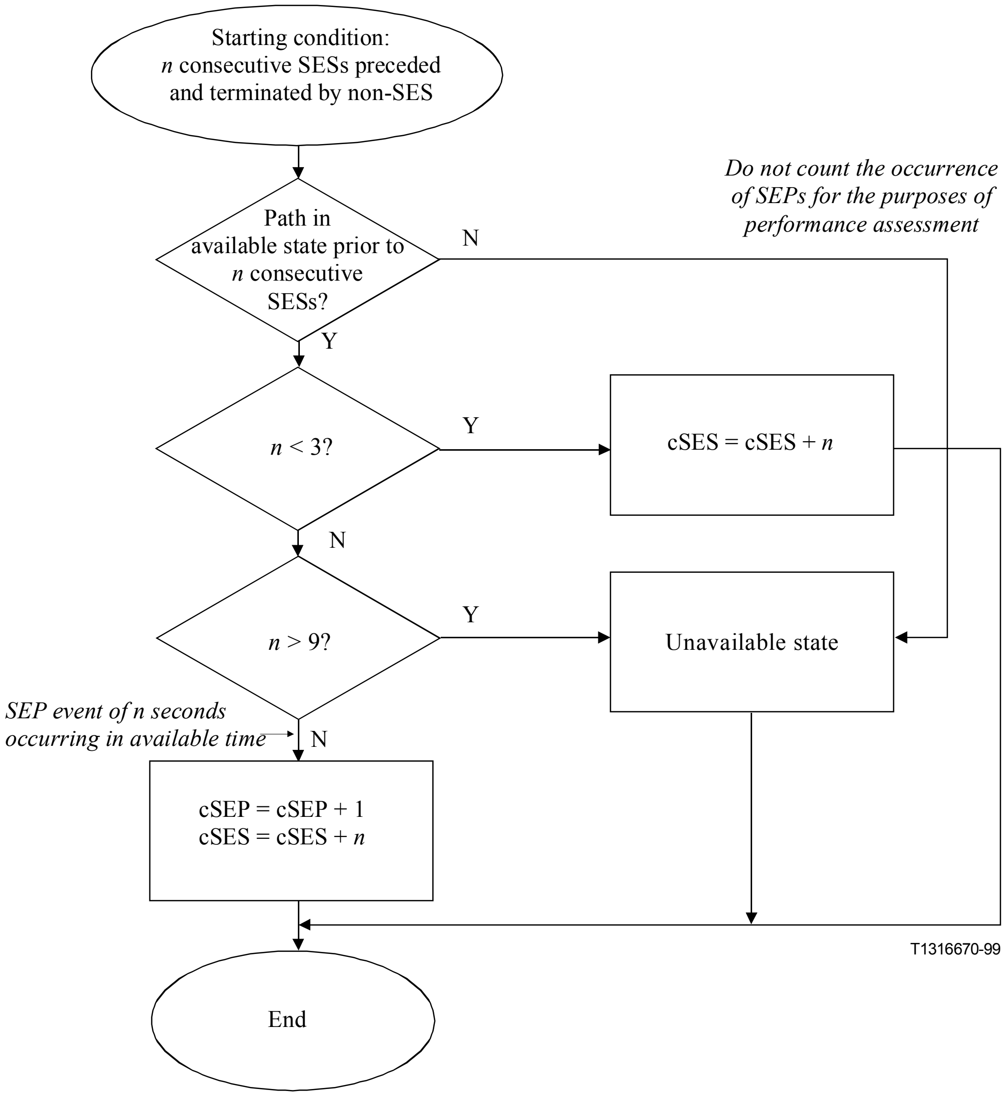


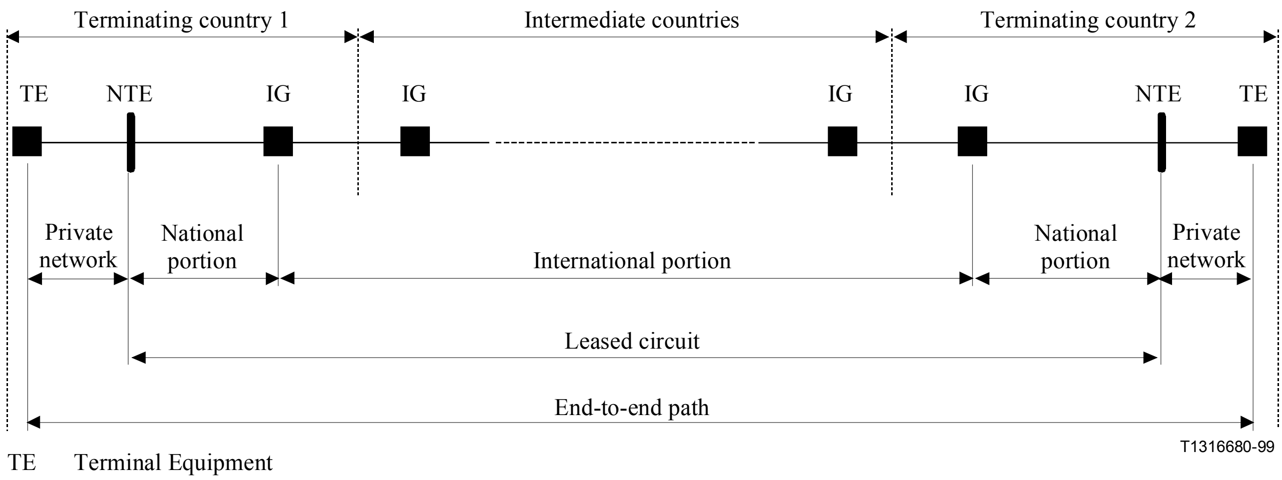
Figure I.2/G.828 – Recognition of SEP

APPENDIX II

Applicability of ITU-T Recommendation G.828 to non-public networks

Figure II.1 depicts a typical leased circuit situation where a path is composed of three independent networks: Two private networks at both path ends and a public network connecting them where the public network provides a leased circuit to connect the two private networks.

However, the problem is not restricted to the case shown in the figure but is of more general nature. For instance, similar considerations are applicable in cases where the public network operator has no access to the path end point.



TE Terminal Equipment
NTE Network Terminating Equipment
IG International Gateway

Figure II.1/G.828 – Digital path composed of two private networks and a leased circuit provided by a public network operator

Taking into account that a public operator can only control the public network from NTE to NTE (Network Terminating Equipment), no performance objectives can be given for the portion between NTE and TE. Nevertheless, transmission performance between NTEs may be estimated e.g. by using non-intrusive monitoring.

It may also be that the public network operator provides the connection by other means than a leased circuit.

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