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

Digital networks – Quality and availability targets

Availability parameters and objectives for path elements of international constant bit-rate digital paths at or above the primary rate

ITU-T Recommendation G.827

(Formerly CCITT Recommendation)

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ITU-T Recommendation G.827

Availability parameters and objectives for path elements of international constant bit-rate digital paths at or above the primary rate

Summary

This Recommendation defines network performance parameters, objectives and measurement methods for describing availability performance of international constant bit-rate digital paths at or above the primary rate. Performance objectives are specified for specific elements of the international path. Path elements are categorized according to their position in the path and their length. Guidance on determining expected end-to-end performance is provided in Annex A, and depends on the actual path topology. Measurement methods are also provided to enable estimation of path element performance using sampling techniques.

Source

ITU-T Recommendation G.827 was revised by ITU-T Study Group 13 (1997-2000) and approved under the WTSC Resolution 1 procedure on 10 March 2000.

Keywords

Availability, Availability Objectives, Availability Performance, Availability Ratio, Mean Time Between Digital Path Outages, Outage Intensity, Path Element, Unavailability Ratio.

FOREWORD

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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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Availability parameters and objectives for path elements of international constant bit-rate digital paths at or above the primary rate

1 Introduction

1.1 Purpose

The purpose of this Recommendation is to specify the availability parameters and objectives for Path Elements (PEs) of international constant bit-rate digital paths at or above the primary rate. This Recommendation should be used:

- by transmission network planners to determine the required measures and actions within the network (e.g. system reliability, maintenance organization, network protection techniques);
- by the organization responsible for the provision of a path to determine which additional end-to-end actions (such as end-to-end protection switching) are necessary to satisfy quality of service objectives;
- by network operators providing path core elements which make up an international digital path to ensure that availability requirements are met.

1.2 Scope

This Recommendation is applicable to path elements of international constant bit-rate digital paths at or above the primary rate. These paths may be based on the Plesiochronous Digital Hierarchy (PDH), the Synchronous Digital Hierarchy (SDH) or some other transport network such as cell-based. This Recommendation is generic in that it defines parameters and objectives independent of the physical transport network providing the paths.

Two types of paths are considered; paths between International Switching Centres (ISCs) which consist of an international portion only, and paths which extend beyond the ISC and consist of national and international portions. These paths are referred to as type "a" and type "b" respectively (see Figures 1 and 2). This Recommendation specifies objectives for the availability performance of each of these portions.

Both the national and international portions are made up of PEs. For the national portion of paths of type "b", this Recommendation specifies availability parameters and requirements for the portion as a whole – subdivision of requirements to the respective PEs making up the national portion is under the responsibility of the network operator. For the international portion of paths of both types, this Recommendation specifies availability parameters and requirements for the PEs making up the international portion. Note that the international measurement point is located on the international side of the ISC.

The end-to-end availability performance of an international digital path can be calculated from the arrangement of the constituent PEs and their associated objectives. Annex A gives guidance on evaluating end-to-end availability objectives. Note that the specification of required end-to-end performance, against which the calculated end-to-end performance may be judged as satisfactory or not, is outside the scope of this Recommendation. This specification may result from agreement with users of the path, or may be the subject of a separate Recommendation.

In some countries the network may be subdivided into parts which are under the responsibility of different network operators. The partitioning of the objectives between these parts is outside the scope of this Recommendation.

End-to-end objectives for path availability are the subject of another Recommendation currently under development.

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 G.826 (1999), *Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate*.

[2] ITU-T M.20 (1992), *Maintenance philosophy for telecommunication networks*.

[3] ITU-T M.1010 (1988), *Constitution and nomenclature of international leased circuits*.

3 Abbreviations

This Recommendation uses the following abbreviations:

AR Availability Ratio

CP Customer Premises

FS Frontier Station

IB International Border

ICPCE Inter-Country Path Core Element

IG International Gateway

IPCE International Path Core Element

ISC International Switching Centre

Mo Mean Time Between Digital Path Outages

NPCE National Path Core Element

NPE National Path Element

OI Outage Intensity

PAE Path Access Element

PDH Plesiochronous Digital Hierarchy

PE Path Element

PEP Path End Point

PSE Path Switching Element

SDH Synchronous Digital Hierarchy

SES Severely Errored Second

SIE Short Interruption Event

TIC Terminal International Centre

UR Unavailability Ratio

4 Definition of paths, path elements and path element categories

4.1 Path

A path is a transport entity responsible for the integrity of client network information transfer.

Paths are terminated at each end by a Path End Point (PEP). For paths of type "a", the exact location of the PEP is for further study, but is on the international side of the ISC. For paths of type "b", the PEP is located at the Customer Premises (CP).

4.2 Path element

A PE is a portion of a path resulting from partitioning for the purpose of availability management.

NOTE – In this Recommendation, paths are partitioned on the basis of geographical rather than architectural considerations. PEs are therefore considered to be logical elements of a path whose boundaries are not necessarily at the network level (i.e. bit rate) of the path under consideration. For example, on a 2 Mbit/s path, an international boundary might only exist physically at 140 Mbit/s. In such situations, the constituent 2 Mbit/s signal at the international boundary can only be observed using additional equipment which passively analyses the embedded signal structure. However, availability performance may still be monitored using mechanisms at the layer of the supporting path.

The physical realization and topology of the PEs are under the responsibility of each network operator.

4.3 Path element categories

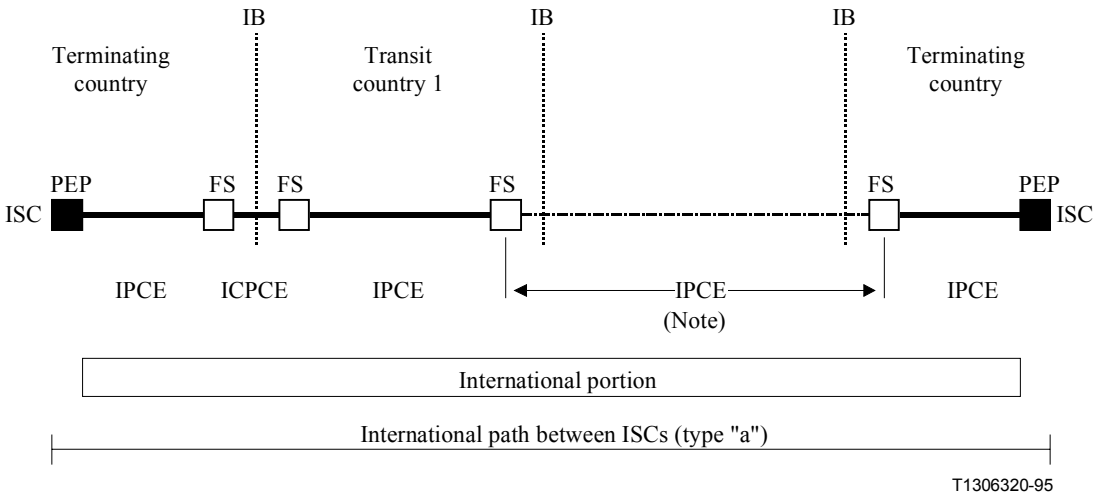
PEs are categorized according to their location in the network and their length. Further dimensioning on the basis of the level of availability performance is for further study.

4.3.1 Network location

Paths may traverse different portions of networks having significantly different availability performance characteristics. For the purpose of this Recommendation, three different portions are distinguished:

- Inter-Country Path Core Element (ICPCE).
- International Path Core Element (IPCE).
- National Path Element (NPE).

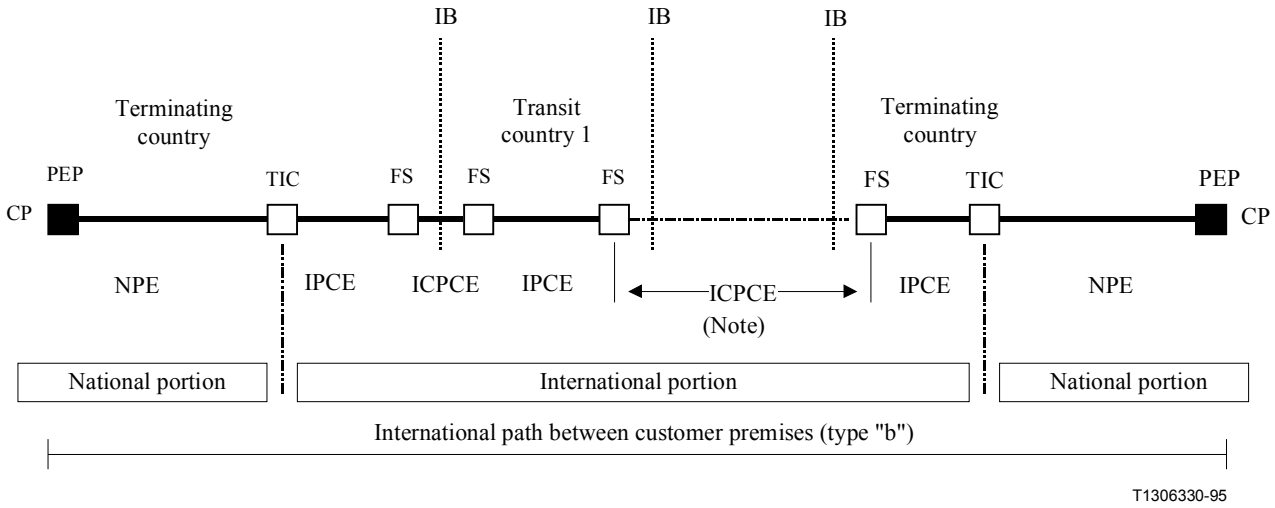
Figures 1 and 2 show the conceptual location of these PEs. Note that the NPE, which constitutes the national portion, is only applicable to paths of type "b". The international portion is made up of a combination of ICPCEs and IPCEs.



FS	Frontier Station	IPCE	International Path Core Element
IB	International Border	ISC	International Switching Centre
ICPCE	Inter-Country Path Core Element	PEP	Path End Point

NOTE – This ICPCE crosses two international borders and is typically supported by a satellite or under sea transmission system.

Figure 1/G.827 – Conceptual location of the elements of an international path between ISCs



CP	Customer Premises	IPCE	International Path Core Element
FS	Frontier Station	NPE	National Path Element
IB	International Border	PEP	Path End Point
ICPCE	Inter-Country Path Core Element	TIC	Terminal International Centre

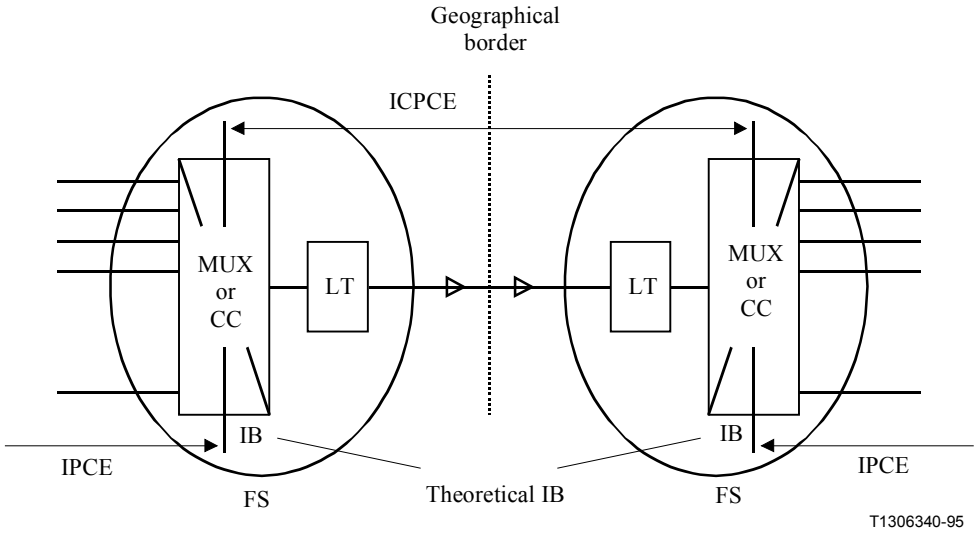
NOTE – This ICPCE crosses two international borders and is typically supported by a satellite or under sea transmission system.

Figure 2/G.827 – Conceptual location of the elements of an international path between customer premises

4.3.1.1 Inter-country path core element

The ICPCE is the PE carried on the highest order digital path across the geographical border between two countries. The ICPCE is the link between networks in different countries, considered as subnetworks.

This element is limited by the Frontier Stations (FSs) where the highest order inter-country path may be terminated. When the highest order inter-country path is not terminated in the FS, the ICPCE is limited by the supporting inter-country section access point. An example of an ICPCE is given in Figure 3.



CC	Cross Connect	IPCE	International Path Core Element
FS	Frontier Station	LT	Line Terminal
IB	International Border	MUX	Multiplexer
ICPCE	Inter-Country Path Core Element		

Figure 3/G.827 – Example of an inter-country path core element

An ICPCE may be transported on a satellite, terrestrial or undersea cable transmission system. In the case of a satellite transmission system, the FS is considered to be located in the earth station.

4.3.1.2 International path core element

The IPCE is the PE used in the core network of an operator.

The boundary of this element depends on its application; for a transit country, this element is limited by the two FSs. For a terminating country, this element is limited by the International Gateway (IG) and the FS. In particular:

- in a type "a" path, this element is delimited by the ISC and the FS;
- in a type "b" path, this element is limited by the Terminal International Centre (TIC), which corresponds to the end of the international portion, and the FS. The TIC is defined in ITU-T M.1010. (Note that the ISC and TIC may be in the same location.)

4.3.1.3 National path element

The NPE is a PE used in a terminating country to connect the international portion and the PEP for type "b" paths only. Although the NPE includes both the Path Access Element (PAE) and the National Path Core Element (NPCE), this Recommendation provides only a national objective applicable to the NPE. Suballocation of this requirement to the PAE and NPCE is outside the scope of this Recommendation.

4.3.2 Length

PE length categories are defined by the following rules:

- $500.(i - 1) \leq L < 500.i$ where i = 1, 2, ..., 20 (4-1)
- $L \geq 10\ 000$ km (4-2)

Formula (4-1) specifies 20 length categories, in 500 km intervals, in the range 0 to less than 10 000 km. Each category is represented by variable "i", which is used in Formulae (6-1) and (6-2) to determine the availability performance objectives for a PE of length L. PEs with lengths greater than, or equal to, 10 000 km are specified by Formula (4-2), and relevant availability performance objectives are also determined by Formulae (6-1) and (6-2).

Except for PEs carried on undersea cables, the length L refers to the actual route length, or the air-route distance multiplied by a routing factor, whichever is less. For a PE carried on an undersea cable, the actual route length is used.

The routing factor is specified as follows:

- If the air-route distance is less than 1 000 km, the routing factor is 1.5.
- If the air-route distance is in the range 1 000 km to 1 200 km, the calculated length is taken to be 1 500 km.
- If the air-route distance is greater than 1 200 km, the routing factor is 1.25.

4.3.3 Performance level

The specification of level of performance is for further study.

5 Definition of parameters

5.1 General

Each direction of a path can be in one of two states, available time, or unavailable time. The criteria determining the transition between the two states are as follows.

A period of unavailable time begins at the onset of 10 consecutive Severely Errored Second (SES) events. These 10 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 (a non-SES event is a second that is an ES but not an SES or is error free). These 10 seconds are considered to be part of available time. For the definition of SES, refer to ITU-T G.826. Figure 4 illustrates the transitions between the availability states.

A path is available if, and only if, both directions are available.

NOTE – For a path to enter the unavailable state, either direction must be unavailable. Thus, if both directions are subject to overlapping consecutive SES events such that neither direction becomes unavailable, but the combined period at the path level is greater than 10 seconds, the path remains in the available state.

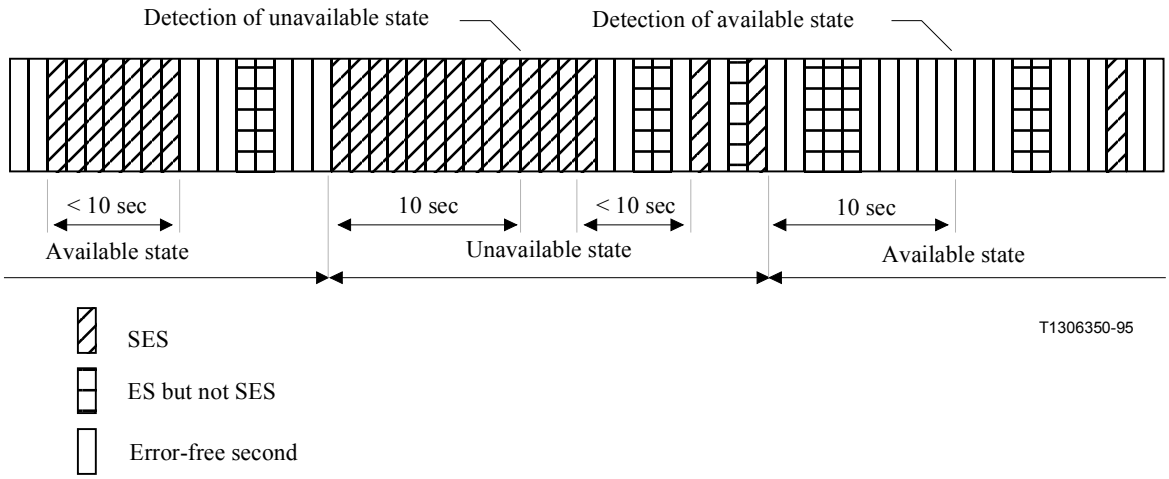


Figure 4/G.827 – Transition between the availability states

Performance objectives are given in this Recommendation for two availability performance parameters, availability ratio and mean time between digital path outages. They are applicable to all PE categories.

5.2 Availability ratio

Availability ratio, AR, is defined as the proportion of time that a PE is in the available state during an observation period. AR is calculated by dividing the total available time during the observation period by the duration of the observation period.

The converse of AR, the unavailability ratio, UR, is defined as the proportion of time that a PE is in the unavailable state during an observation period. UR is calculated by dividing the total unavailable time during the observation period by the duration of the observation period.

Either ratio can be used for design, measurement and maintenance applications. The ratios are related by the following equation:

$$AR + UR = 1 \qquad (5\text{-}1)$$

5.3 Mean time between digital path outages

The mean time between digital path outages, Mo, for a digital path portion is the average duration of any continuous interval during which the portion is available. Consecutive intervals of planned available time are concatenated.

The Mo parameter, or the reciprocal of Mo, defined as the Outage Intensity (OI), can be used for design, measurement and maintenance applications. They are related by the following equation:

$$\text{Mo} = 1/\text{OI} \qquad (5\text{-}2)$$

NOTE – Unavailability events can be broadly categorized as self-healing and non-self-healing. In general, outages due to self-healing events are limited to under a few minutes in length and typically account for the majority of all outages, whereas outages due to non-self-healing events are longer. In analysing outages for maintenance purposes in accordance with the principles in ITU-T M.20, it will be useful to separate events into these categories.

6 Availability performance objectives

This clause states the objectives for availability performance of the various PE categories. Performance objectives for PEs are derived using a fixed block allocation plus a distance-based allocation. The end-to-end performance of an international path can be calculated from these objectives using the guidance given in Annex A. For the benefit of end-to-end performance derivation, the equations in Annex A use UR and OI.

Two types of objectives are specified:

- mean values, i.e. the ensemble average of all PEs of a given category in a country;
- worst-case values, i.e. the minimum acceptable value for individual PEs.

The objectives apply to observation periods of one year (365 consecutive days), using a sliding window with 24-hour granularity. Annex B gives guidance on how performance of PEs can be measured.

The objectives are intended for the following purposes:

- *Network design/planning*

  Both mean and worst-case objectives are appropriate for network design/planning purposes.

- *Operational objectives*

  Worst-case objectives are appropriate for operational purposes, and are applicable to each individual PE. Achieving and testing the compliance with these objectives is under the responsibility of each network operator. Note that the responsibility for testing compliance of PEs which span different operators' networks is for further study.

  The applicability of mean objectives for operational purposes is for further study.

To meet these requirements, it may be necessary for design purposes to use more stringent values.

Digital paths operating at bit rates covered by this Recommendation are carried by transmission systems (digital sections) operating at equal or higher bit rates. Such systems must meet their allocated objectives for the highest bit-rate paths which are foreseen to be carried. Meeting the allocated objectives for the highest bit-rate path should be sufficient to ensure that all paths through the system achieve their objectives. For example, in the SDH, an STM-1 section may 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 – Objectives are allocated in this Recommendation to PEs of an international path. In the above example, if the STM-1 section does not form a complete PE, the corresponding allocation for the PE must be subdivided to determine the appropriate allocation for the digital section. This is outside the scope of this Recommendation.

6.1 Path elements operating at the primary rate

6.1.1 Availability ratio

The AR objective is determined by the following equations:

$$AR_j = \begin{cases} 1-\left(b_{jn}+i\cdot x_{jn}\right) & \text{for L} < 2\,500 \text{ km} \\ 1-\left(b_{jn}+(i-5)\cdot x_{jn}\right) & \text{for } 2\,500 \text{ km} \le \text{L} < 7\,500 \text{ km} \\ 1-\left(b_{jn}+(i-15)\cdot x_{jn}\right) & \text{for } 7\,500 \text{ km} \le \text{L} < 10\,000 \text{ km} \\ 1-\left(b_{jn}+21\cdot x_{jn}\right) & \text{for L} \ge 10\,000 \text{ km} \end{cases} \quad (6\text{-}1)$$

where:

j = {NPE, IPCE, ICPCE}

b_{jn} = block allowance for PE type j, length range n

i = length category (see Formula 4-1)

x_{jn} = distance-based allowance for PE type j, length range n

Values for b_{jn} and x_{jn} are shown in Tables 1 and 2.

Table 1/G.827 – Values for availability ratio calculations ($\times 10^{-4}$), mean values

	L < 2 500 km		2 500 km ≤ L < 7 500 km		L ≥ 7 500 km	
PE type	**b_{j1}**	**x_{j1}**	**b_{j2}**	**x_{j2}**	**b_{j3}**	**x_{j3}**
NPE	0	20	100	For further study	For further study	For further study
IPCE	0	15	75	For further study	For further study	For further study
ICPCE	0	20	100	For further study	For further study	For further study
NOTE 1 – Satellite links may be used to implement each of the PEs or a combination of them. The mean AR objective for satellite links is for further study. NOTE 2 – The objective for Pes greater than 10 000 km is limited by Formula (6-1).						

Table 2/G.827 – Values for availability ratio calculations ($\times 10^{-4}$), worst-case values

	L < 2 500 km		2 500 km ≤ L < 7 500 km		L ≥ 7 500 km	
PE type	**b_{j1}**	**x_{j1}**	**b_{j2}**	**x_{j2}**	**b_{j3}**	**x_{j3}**
NPE	52	47	287	For further study	For further study	For further study
IPCE	40	35	215	For further study	For further study	For further study
ICPCE	52	47	287	For further study	For further study	For further study
NOTE 1 – Satellite links may be used to implement each of the PEs or a combination of them. The worst-case AR objective for satellite links is for further study. NOTE 2 – The objective for PEs greater than 10 000 km is limited by Formula (6-1).						

6.1.2 Mean time between digital path outages

The Mo objective is determined by the following equations:

$$Mo_j = \begin{cases} 1/(b_{jn} + i \cdot x_{jn}) & \text{for L} < 2\,500 \text{ km} \\ 1/(b_{jn} + (i-5) \cdot x_{jn}) & \text{for } 2\,500 \text{ km} \le \text{L} < 7\,500 \text{ km} \\ 1/(b_{jn} + (i-15) \cdot x_{jn}) & \text{for } 7\,500 \text{ km} \le \text{L} < 10\,000 \text{ km} \\ 1/(b_{jn} + 21 \cdot x_{jn}) & \text{for L} \ge 10\,000 \text{ km} \end{cases} \quad (6\text{-}2)$$

where:

j = {NPE, IPCE, ICPCE}

b_{jn} = block allowance for PE type j, length range n

i = length category (see Formula 4-1)

x_{jn} = distance-based allowance for PE type j, length range n

Values for b_{jn} and x_{jn} are shown in Tables 3 and 4.

Table 3/G.827 – Values for mean time between digital path outage calculations, mean values

	L < 2 500 km		**2 500 km ≤ L < 7 500 km**		**L ≥ 7 500 km**	
PE type	**b_{j1}**	**x_{j1}**	**b_{j2}**	**x_{j2}**	**b_{j3}**	**x_{j3}**
NPE	57	42	267	For further study	For further study	For further study
IPCE	30	20	130	For further study	For further study	For further study
ICPCE	18	13	83	For further study	For further study	For further study
NOTE 1 – Satellite links may be used to implement each of the PEs or a combination of them. The mean Mo objective for satellite links is for further study. NOTE 2 – The objective for PEs greater than 10 000 km is limited by Formula (6-2).						

Table 4/G.827 – Values for mean time between digital path outage calculations, worst-case values

	L < 2 500 km		**2 500 km ≤ L < 7 500 km**		**L ≥ 7 500 km**	
PE type	**b_{j1}**	**x_{j1}**	**b_{j2}**	**x_{j2}**	**b_{j3}**	**x_{j3}**
NPE	443	58	733	For further study	For further study	For further study
IPCE	222	27	357	For further study	For further study	For further study
ICPCE	130	20	230	For further study	For further study	For further study
NOTE 1 – Satellite links may be used to implement each of the PEs or a combination of them. The worst-case Mo objective for satellite links is for further study. NOTE 2 – The objective for PEs greater than 10 000 km is limited by Formula (6-2).						

6.2 Path elements operating at bit rates above the primary rate

For further study.

ANNEX A

Examples of path topologies and end-to-end availability performance derivations

A.1 Purpose

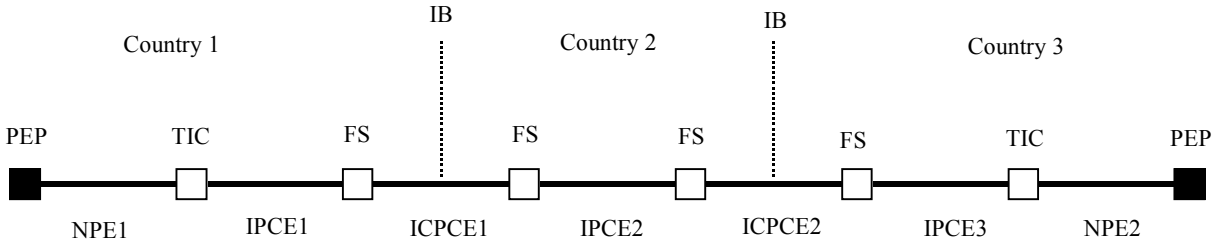
The purpose of this Annex is to provide guidance for the calculation of the end-to-end performance of a path from the performances of path elements (PEs), using examples of basic topologies (linear and redundant).

In some cases, more complex topologies will result from negotiations between operators, but the principles of calculation given here will still apply.

Currently, there are no objectives specified for end-to-end performance. This is under study and will be included in a later revision.

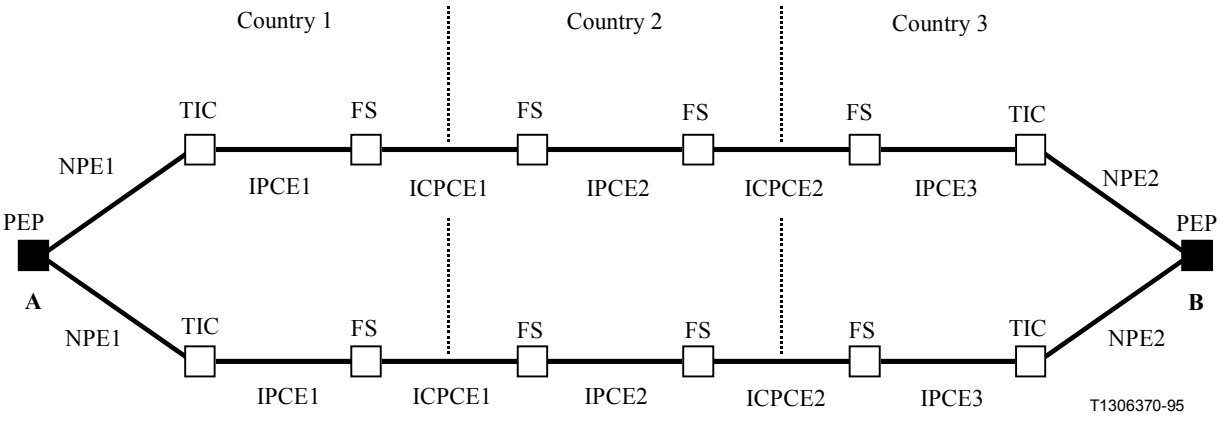
A.2 Path topologies

Figures A.1 and A.2 give the basic path topologies that can be built using the PEs defined in this Recommendation.



FS Frontier Station
IB International Border
ICPCE Inter-Country Path Core Element
IPCE International Path Core Element
NPE National Path Element
PEP Path End Point
TIC Terminal International Centre

Figure A.1/G.827 – Example of a path with linear topology



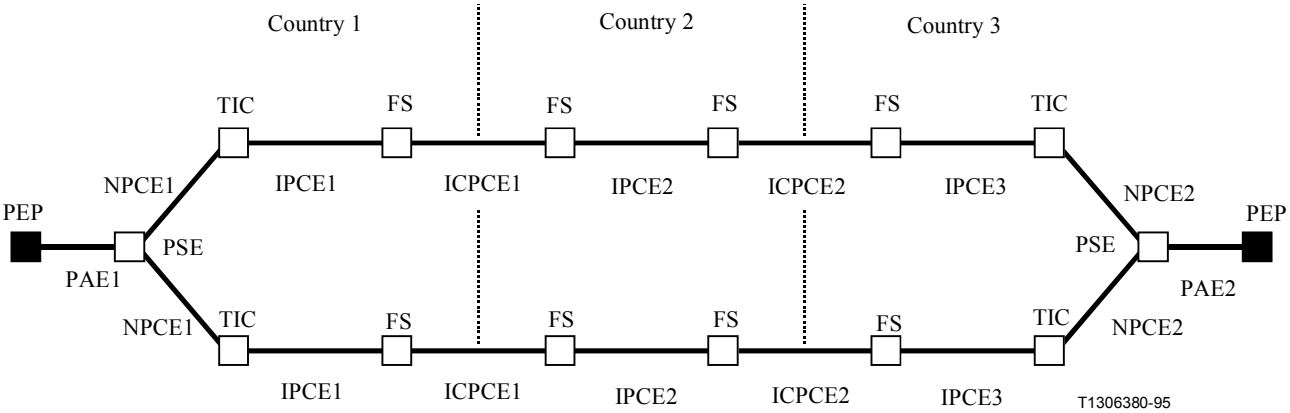
FS Frontier Station
IB International Border
ICPCE Inter-Country Path Core Element
IPCE International Path Core Element
NPE National Path Element
PEP Path End Point
TIC Terminal International Centre

Figure A.2/G.827 – Example of a path with redundant topology

A path may be built using a linear topology as seen from the outside of each transit and terminating country. This is shown in Figure A.1. Figure A.2 shows the situation in which two independent links are used end-to-end through all transit countries and terminating countries.

The protection is assumed to be on a 1-to-1 basis with one switching device at the receiver side.

More complex configurations will result from a combination of the basic ones. An example is given in Figure A.3.



FS	Frontier Station
IB	International Border
ICPCE	Inter-Country Path Core Element
IPCE	International Path Core Element

NPCE	National Path Core Element
PAE	Path Access Element
PEP	Path End Point
PSE	Path Switching Element
TIC	Terminal International Centre

Figure A.3/G.827 – Example of a path with both linear and redundant topologies

A.3 End-to-end unavailability

For the purposes of end-to-end calculations, it is more convenient to use the unavailability ratio.

The following notations are used in this paragraph:

ur_{im}: mean unavailability ratio of a PE.

ur_{iw}: worst-case unavailability ratio of a PE.

UR_M: mean unavailability of a path.

UR_W: worst-case unavailability of a path.

A.3.1 Linear topology

If a path is made of N path elements used in series, as indicated in Figure A.1, then the following approximations can be used for small values of unavailability ratios:

$$UR_M = \sum_i (ur_{im}) \tag{A-1}$$

$$UR_W = UR_M + \left\{\sum_i (ur_{iw} - ur_{im})^2\right\}^{1/2} \tag{A-2}$$

Formula (A-2) assumes that the unavailability ratios of the different PEs follow normal distributions.

A.3.2 Redundant topology

In a redundant configuration using two parallel paths and a protection switch at one end (for each direction of transmission), the availability of the protected path between points A and B in Figure A.2 is:

$$UR_{AB} \approx UR_1 \times UR_2 + UR_S \quad \text{(A-3)}$$

where UR_1, UR_2 are the unavailability ratios of the parallel paths and UR_S is the unavailability of the protection switch (for one direction).

A.3.2.1 Mean values

Replacing UR_1 and UR_2 in Formula (A-3) by their mean values, calculated according to Formula (A-1), leads to the mean value of UR_{AB} as follows:

$$UR_{M(AB)} = UR_{1M} \times UR_{2M} + UR_S \quad \text{(A-4)}$$

A.3.2.2 Worst-case values

Replacing UR_1 and UR_2 in Formula (A-3) by their worst-case values, calculated according to Formula (A-2), leads to an upper bound of the worst-case value of UR_{AB} as follows:

$$UR_{W(AB)} \leq UR_{1W} \times UR_{2W} + UR_S \quad \text{(A-5)}$$

A.4 End-to-end outage intensity

For the purposes of end-to-end calculations, it is more convenient to use the outage intensity parameter.

The following notations are used in this paragraph for outage intensity:

i_{jm}: mean outage intensity of a PE.

i_{jw}: worst-case outage intensity of a PE.

I_M: mean outage intensity of a path.

I_W: worst-case outage intensity of a path.

A.4.1 Linear topology

If a path is made of N PEs used in series, as indicated in Figure A.1, then the following formulae can be used to derive the mean and worst-case outage intensities of the end-to-end path:

$$I_M = \sum_j \left(i_{jm}\right) \quad \text{(A-6)}$$

$$I_W = I_M + \left\{\sum_j \left(i_{jw} - i_{jm}\right)^2\right\}^{1/2} \quad \text{(A-7)}$$

Formula (A-7) assumes that the outage intensities of the various PEs involved follow normal distributions.

A.4.2 Redundant topology

In a redundant configuration using two parallel paths and a protection switch at one end (for each direction of transmission), the outage intensity of the protected path between points A and B in Figure A.2 is:

$$I_{AB} \approx I_i \times UR_2 + I_2 \times UR_1 + I_S \quad \text{(A-8)}$$

where I_1 and I_2 are the outage intensities of the parallel paths and I_S is the outage intensity of the switch.

If the mean value for I_{AB} is to be derived, then I_1 and I_2 should be calculated as mean values according to Formula (A-6).

If the worst-case value for I_{AB} is to be derived, then I_1 and I_2 should be calculated as worst-case values according to Formula (A-7). Replacing I_1 and I_2 in Formula (A-8) will lead to an upper bound of the worst-case value of I_{AB}.

A.5 Numerical examples

For further study.

ANNEX B

Methods for measuring availability performance of path elements

B.1 Purpose

This Annex gives guidance on how availability performance of a Path Element (PE) can be measured. The methods specified in this Annex take into account that:

- A PE is a logical element.
- The PE under test may be carried on paths or digital sections operating at higher bit rates.
- There may be several digital sections operating at different bit rates which support a single PE.

B.2 Measurement methods

In order to test the compliance of a PE with the requirements of this Recommendation, three methods are identified below for guidance. The actual measurement method used is under the responsibility of each network operator.

- Measurement at the end points of the PE under test, at the bit rate of the path under test.
- Measurement at the end points of the PE under test, at a higher-order level and assuming a 1-to-1 mapping of unavailability events (for the 2 Mbit/s path under test in Figure B.1, the higher order path is at 8 Mbit/s).
- The PE performance may also be measured by considering the actual routing of the PE and by deriving the performance from the measured performances of the constituent portions, assuming a 1-to-1 mapping of unavailability events.

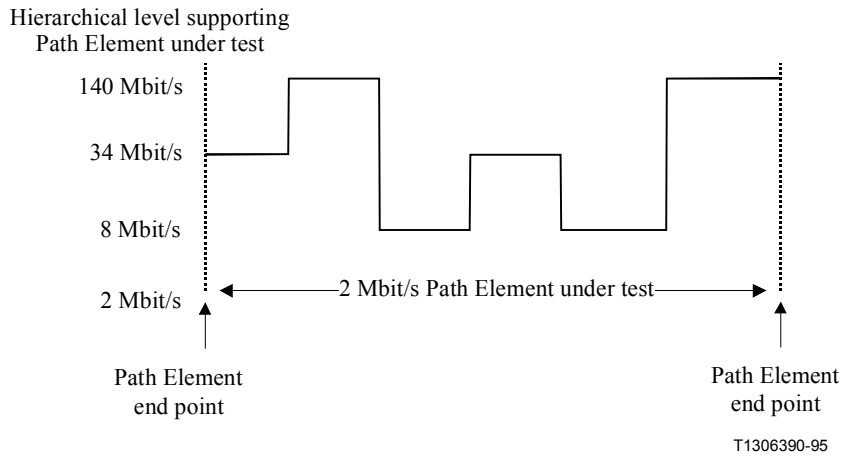


Figure B.1/G.827 – Example of a path element carried on higher-order digital sections

B.3 Sampling estimation procedure

A procedure for estimating PE availability performance using sampling techniques is for further study.

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