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Contents

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Technical Committee Network Aspects (NA), and is now submitted for the ETSI standards One-step Approval Procedure.

The present document specifies the availability performance of path elements for international digital paths.

The present document is the second version of the former I-ETS 300 416 which has been converted into an EN on request of the previous STC TM2 before its transfer to NA.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

Introduction

The present document contains availability requirements for a structured approach, based on path elements, to be used for planning, designing and operating international transmission networks. The present document should be used:

a) by transmission network planners to determine the required actions within the network (e.g. system reliability, maintenance organization, network protection techniques);

b) by the organization responsible for the provision of a path to determine whether and which additional end-to-end actions (such as end-to-end protection switching) are necessary to satisfy quality of service objectives;

c) by network operators providing path core elements which make up an international digital path, to ensure that availability requirements are met.

1 Scope

The present document is applicable to international constant bit rate digital paths at or above 64 kbit/s supported by digital networks. International constant bit rate digital paths may be based on the Plesiochronous Digital Hierarchy (PDH), the Synchronous Digital Hierarchy (SDH) or some other transport network such as cell-based. The present document is generic in that it defines parameters and requirements 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 between Customer Premises (CP) which consist of national and international portions. These paths are referred to as "type a" and "type b" respectively (see figures 1 and 2).

Both the national and international portions are made up of Path Elements (PEs). For the national portion of paths of "type b", the present document 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, the present document specifies availability parameters and requirements for the PEs making up the international portion.

NOTE: 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 requirements. Annex A gives guidance on evaluating the end-to-end unavailability of a path, taking into account the unavailability of each PE.

In some countries the network may be subdivided into parts which are under the responsibility of different network operators. The partitioning of the requirements between these parts is outside the scope of the present document. Similarly, application of the present document to national paths which do not cross International Borders (IBs) is outside the scope of the present document.

2 Normative references

References may be made to:

a) specific versions of publications (identified by date of publication, edition number, version number, etc.), in which case, subsequent revisions to the referenced document do not apply; or

b) all versions up to and including the identified version (identified by "up to and including" before the version identity); or

c) all versions subsequent to and including the identified version (identified by "onwards" following the version identity); or

d) publications without mention of a specific version, in which case the latest version applies.

A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] ITU-T Recommendation G.826 (1993): "Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate".

[2] ITU-T Recommendation G.821 (1993): "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".

[3] I-ETS 300 416: "Transmission and Multiplexing (TM); Availability performance of path elements of international digital paths".

3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

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
LT	Line Terminal
MUX	Multiplexer
NPCE	National Path Core Element
NPE	National Path Element
PAE	Path Access Element
PDH	Plesiochronous Digital Hierarchy
PE	Path Element
PEP	Path End Point
SDH	Synchronous Digital Hierarchy
SES	Severely Errored Second
SIE	Short Interruption Event
TIC	Terminal International Centre

4 Definitions

For the purposes of the present document, the following definitions apply:

4.1 Definition of paths, path elements and path element categories

4.1.1 Path

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

Paths are terminated at each end at the 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 CP.

4.1.2 Path element

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

NOTE: In the present document, paths are partitioned on the basis of geographical rather than architectural considerations. Therefore, PEs are 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 may only physically exist at 140 Mbit/s. In such situations, the constituent 2 Mbit/s signal at the international boundary can only be observed by 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.

4.1.3 Path element categories

PEs are categorized according to their location in the network, their length and their performance level.

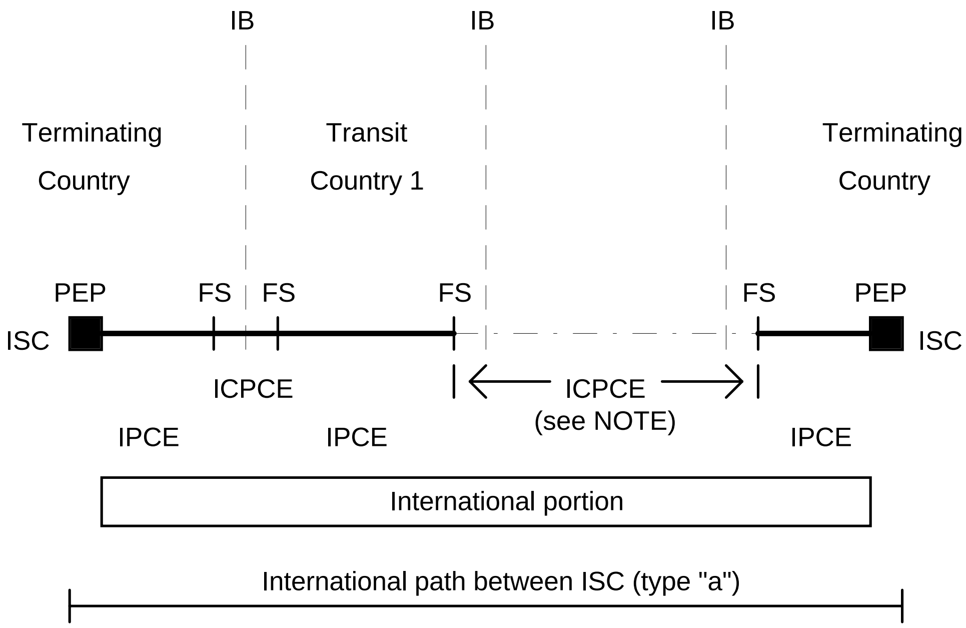
4.1.3.1 Network location categories

Paths may traverse different portions of networks having significantly different availability performance characteristics. For the purpose of the present document, three different portions are distinguished and accordingly three categories of PEs are defined:

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

The conceptual location of these path element types is shown in figures 1 and 2.

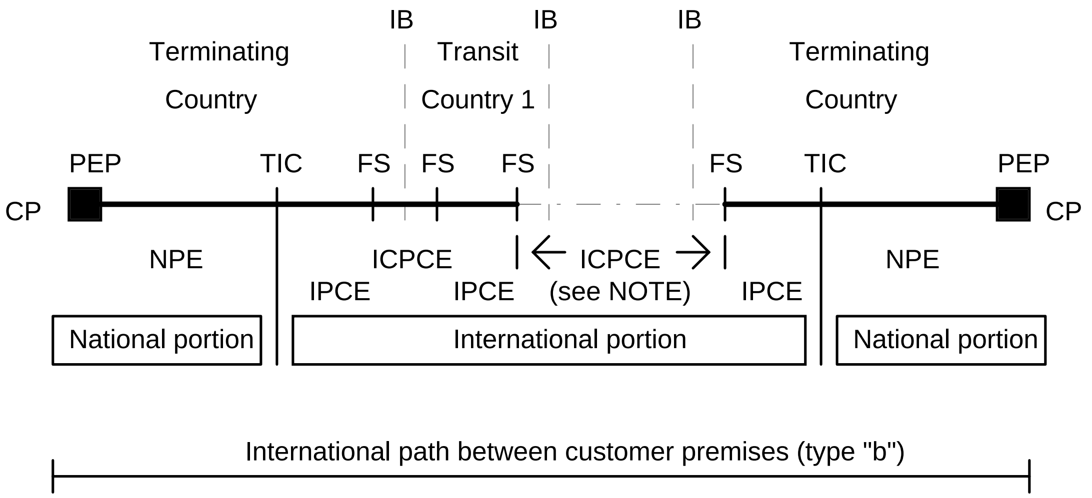
NOTE: The NPE is only applicable to paths of "type b".



NOTE: This ICPCE crosses two IBs and is typically supported by a satellite or undersea transmission system.

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

Figure 1: Conceptual location of the elements of an international path between ISCs



NOTE: This ICPCE crosses two IBs and is typically supported by a satellite or undersea transmission system.

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

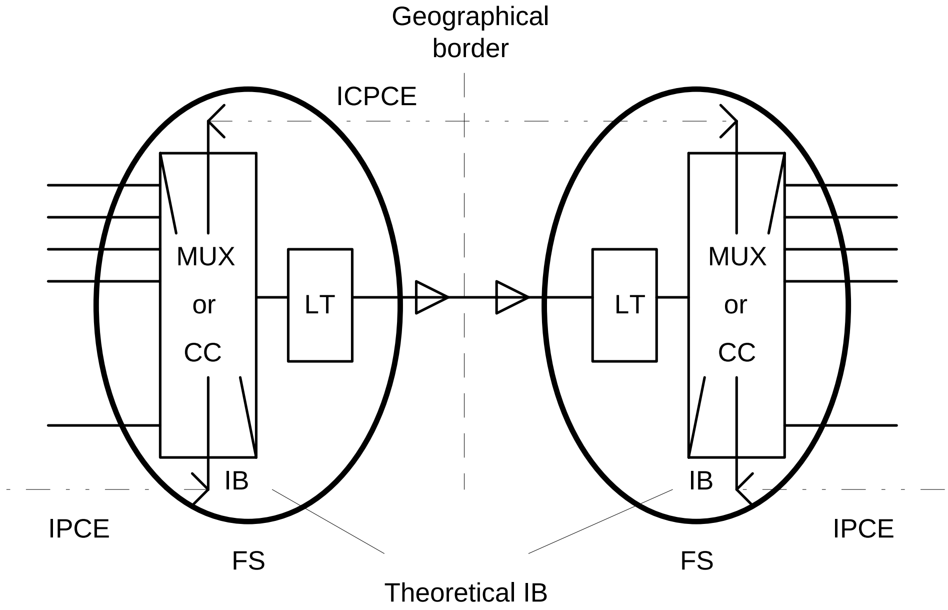
Figure 2: Conceptual location of the elements of an international path between customer premises

4.1.3.1.1 Inter-country path core element

The ICPCE is the PE carried on the highest order digital path across the geographical border between two countries.

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.

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.



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

Figure 3: Example of an ICPCE

4.1.3.1.2 International path core element

The IPCE is the PE used in the core network within one country. 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 Recommendation M.1010.

NOTE: The ISC and the TIC may be in the same location.

4.1.3.1.3 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 Path Access Elements (PAEs) and National Path Core Elements (NPCEs), the present document provides only a national requirement applicable to the NPE. Sub-allocation of this requirement to the PAE and NPCE is outside the scope of the present document.

4.1.3.2 Length categories

Length categories are defined by the following rules:

$500.(i-1) \leq L < 500.i$ where i = 1, 2, ...,5

This formula specifies 5 length categories, in 500 km intervals, in the range 0 to less than 2 500 km. Each category is represented by variable « i », which is used in the formula to determine the availability performance objectives for a PE of length L.

Except for PEs carried on undersea cables, the lengths refer to the actual route lengths or the air-route distance multiplied by a routing factor, whichever is less. The routing factor is as follows:

- If the air route distance is less than 1 000 km , then the routing factor is 1,5;
- If the air route distance is larger than 1 000 km and less than 1 200 km, then the calculated route length is taken to be 1 500 km;
- If the air route distance is larger or equal to 1 200 km, then the routing factor is 1,25.

For a PE carried on an undersea cable, the actual route length is used.

4.1.3.3 Performance level categories

Two performance level categories are considered:

a) standard performance level;

b) high performance level.

The "standard" performance category is the minimum requirement for a PE. The "high" performance category requires a level of performance above the "standard" level. This category mainly applies to "type b" paths and is optional in that network operators may or may not offer PEs satisfying these requirements.

4.2 Definition of parameters

4.2.1 General

A path is unavailable if one or both directions are unavailable.

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. These 10 consecutive non SES are not part of the unavailable time. For the definition of SES, refer for each bit rate to the appropriate ITU-T Recommendation (ITU-T Recommendation G.826 [1] for bit rates at or above the primary rate and ITU-T Recommendation G.821 [2] for bit rates below the primary rate down to 64 kbit/s).

Figure 4 illustrates the transitions between the availability states.

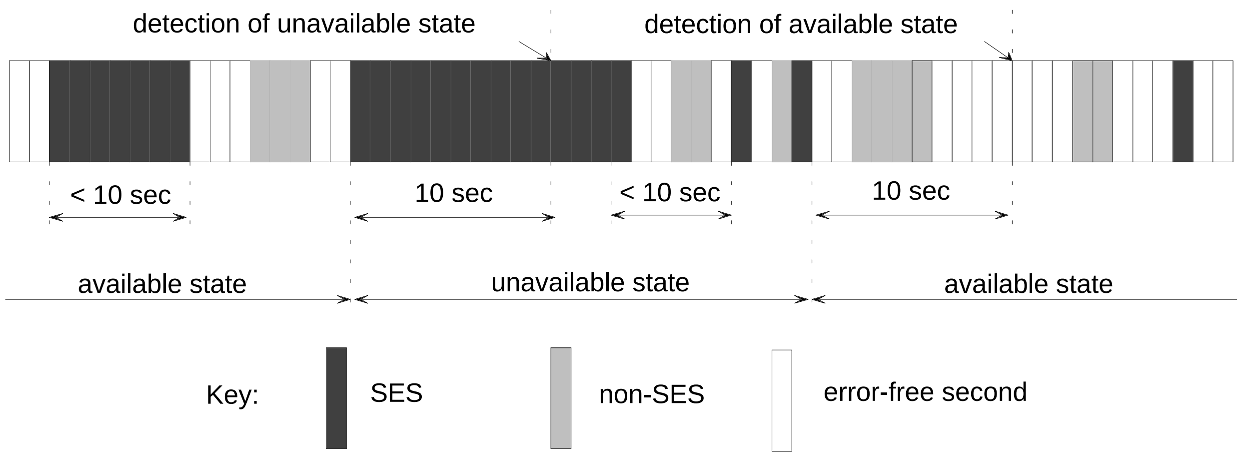


Figure 4: Transitions between the availability states

4.2.2 Parameters

Performance requirements are stated for two availability performance parameters. They are applicable to all PEs and are defined as follows:

- **unavailability ratio (UR):** unavailability ratio is defined as the proportion of time that a PE is in the unavailable state over an observation period. The unavailability ratio is calculated by taking the ratio of the total unavailable time during the observation period to the duration of the observation period;

- **outage Intensity (OI):** the outage intensity is defined as the number of unavailable periods in an observation period.

NOTE 1: 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 Recommendation M.20, it will be useful to separate events into these categories.

NOTE 2: The Short Interruption Event (SIE) , which is a period of unavailable time lasting 5 minutes or less, is useful for the purpose of long term trend analysis. SIE events are included in the Availability performance objectives in tables 1 to 4.

NOTE 3: The converse of UR, the 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. Either ratio can be used for design, measurement and maintenance applications. UR and AR are related by the following equation:
AR + R = 1.

NOTE 4: The reciprocal of OI, the Mean Time Between Outages (MO) is defined as the average duration of any continuous interval during which the PE is available. OI and MO are related by the following equation:
OI = 1/MO.

5 Requirements

This clause states the requirements for performance of PEs which shall be met. Clause 6 gives guidance on how performance of PEs can be measured.

Requirements are given for:

a) mean values: The mean value of a parameter is the average of all values of all PEs of the same category in a country's network. The mean values shall not exceed the specified limits given in tables 1 and 3;

b) worst case values: The worst case value of a parameter is the highest value of all the values of all PEs of the same category in a country's network. The worst case values shall not exceed the specified limits given in tables 2 and 4.

The requirements for the parameters apply to observation periods of one year (365 consecutive days).

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

The compliance with these requirements shall be tested according to I-ETS 300 416 [3].

5.1 2 048 kbit/s path elements

5.1.1 Unavailability ratio

The Unavailability ratio objectives are determined according to the following equations:

$UR_{jS} = A_{jS} + i \times X_{jS}$ for the Standard category,

$UR_{jH} = A_{jH} + i \times X_{jH}$ for the High Quality category,

where:

j = {IPCE, NPCE, ICPCE}

i is an integer depending on the length of the PE according to the following table:

PE length (Km)	L < 500	500 ≤ L < 1 000	1 000 ≤ L < 1 500	1 500 ≤ L < 2 000	2 000 ≤ L < 2 500
i	1	2	3	4	5

Values of A_{jS}, X_{jS}, A_{jH}, X_{jH} are shown in tables 1 and 2.

Table 1: Parameters for unavailability ratio, mean values (x10^{-4})

Path element	Performance level	A_j	X_j
IPCE	Standard	0	15
	High	0	3
NPE	Standard	0	20
	High	0	4
ICPCE	Standard	0	20
	High	0	4
NOTE: Satellite links may be used to implement each of the PEs or a combination of them. In any case the unavailability ratio limit for satellite links is for further study.			

Table 2: Parameters for unavailability ratio, worst case values (x10^{-4})

Path element	Performance level	A_j	X_j
IPCE	Standard	40	35
	High	8	7
NPE	Standard	52	47
	High	12	9
ICPCE	Standard	52	47
	High	12	9
NOTE: Satellite links may be used to implement each of the PEs or a combination of them. In any case the unavailability ratio limit for satellite links is for further study.			

5.1.2 Outage intensity

The outage intensity objectives are determined according to the following equations:

$OI_{jS} = B_{jS} + i \times Y_{jS}$ for the Standard category,

$OI_{jH} = B_{jH} + i \times Y_{jH}$ for the High Quality category,

where:

j = {IPCE, NPCE, ICPCE}

i is an integer depending on the length of the PE according to the following table:

PE length (Km)	L < 500	500 ≤ L < 1 000	1 000 ≤ L < 1 500	1 500 ≤ L < 2 000	2 000 ≤ L < 2 500
i	1	2	3	4	5

Values of B_{jS}, Y_{jS}, B_{jH}, Y_{jH} are shown in tables 3 and 4.

Table 3: Parameters for outage intensity, mean values (outages/ year)

Path element	Performance level	B_j	Y_j
IPCE	Standard	30	20
	High	6	4
NPE	Standard	57	42
	High	13	8
ICPCE	Standard	18	13
	High	2	3
NOTE: Satellite links may be used to implement each of the PEs or a combination of them. In any case the outage intensity limit for satellite links is for further study.			

Table 4: Parameters for outage intensity, worst case values (outages/ year)

Path element	Performance level	A_j	X_j
IPCE	Standard	222	27
	High	46	5
NPE	Standard	443	58
	High	87	12
ICPCE	Standard	130	20
	High	26	4
NOTE: Satellite links may be used to implement each of the PEs or a combination of them. In any case the outage intensity limit for satellite links is for further study.			

5.2 Path elements at bit rates less than 2 048 kbit/s

Paths at bit rates less than 2 048 kbit/s are carried on 2 048 kbit/s paths in most parts of the network, particularly in the core portions.

The performance requirements for PEs at bit rates less than 2 048 kbit/s are the same as those for 2 048 kbit/s PEs if they are carried on a 2 048 kbit/s server layer.

5.3 Path elements at bit rates greater than 2 048 kbit/s

For further study.

6 Measurement methods

In order to measure the performance of a single PE, three methods may be used:

a) measurement at the end points of the PE under test, at the bit rate of the path under test;

b) measurement at the end points of the PE under test, at a higher order path carrying the path under test, and assuming a 1 to 1 mapping of unavailability events (for a 2 Mbit/s path under test, the higher order path is at 8 Mbit/s in figure 5);

c) the path element performance may also be determined by considering the actual routing of the path element and by deriving the path element performance from the measured performances of the constituent portions, assuming a 1 to 1 mapping of unavailability events.

The actual measurement methods used are under the responsibility of each network operator. The selected method should be identified in measurement reports and publications.

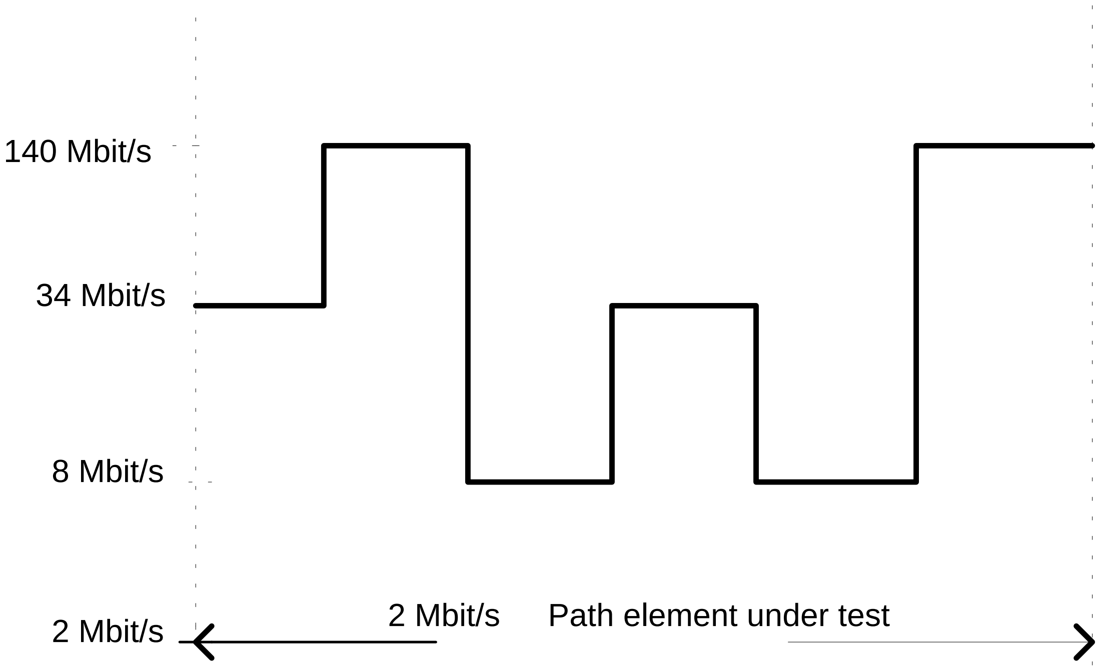


Figure 5: Example of a path element carried on a higher order path

Annex A (informative): Examples of path topologies and end-to-end availability performance derivations

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, using examples of basic topologies (linear and redundant).
In some cases, more complex topologies will result from negotiations between countries, but the principles of calculation given here will still apply.

A.1 Path topologies

Figures A.1 and A.2 give the basic path topologies that can be built using the path elements defined in the present document.

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 done on a 1-to-1 basis with one switching device at the receiver side.

As already stated, other configurations will result from a combination of the basic ones. An example is given in figure A.3.

A.2 End-to-end unavailability

The following notations are used in this clause:

- u_{im} mean unavailability of a path element;
- u_{iw} worst case unavailability of a path element;
- U_M mean unavailability of a path;
- U_w worst case unavailability of a path.

A.2.1 Linear topology

See figure A.1.

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:

$$U_M = \Sigma (u_{im}) \qquad \text{(1)}$$

$$U_w = U_M + \{\Sigma (u_{iw} - u_{im})^2 \}^{1/2} \qquad \text{(2)}$$

The latter formula assumes that the unavailability of the different path elements follow normal distributions.

A.2.2 Redundant topology

See figure A.2.

In a redundant configuration using two parallel paths and a protection switch at one end (for each direction of transmission) the unavailability of the protected path between A and B in figure A.2 can be obtained by:

$U_{AB} \approx U_1 \times U_2 + U_s$ .... (3)

where U_1, U_2 are the unavailability of the parallel paths, U_s is the unavailability of the protection switch, for one direction.

Mean values

Replacing U_1 and U_2 in formula 3 by their mean values, calculated according to formula 1 of subclause A.2.1 leads to the mean value of U_{AB}:

$U_{M(AB)} = U_{1M} \times U_{2M} + U_s$

Worst case values

Replacing U_1 and U_2 in formula 3 by their worst case values, calculated according to formula 2 of subclause A.2.1 leads to an upper bound of the worst case value of U_{AB}:

$U_{w(AB)} \leq U_{1w} \times U_{2w} + U_s$

A.3 End-to-end outage intensity

The following notations are used in this clause:

- i_{jm} mean outage intensity of a path element;
- i_{jw} worst case outage intensity of a path element;
- I_M mean outage intensity of a path;
- I_w worst case outage intensity of a path.

A.3.1 Linear topology

See figure A.1.

If a path is made of N path elements used in series, as indicated in figure A.1 then the following formulas can be used to derive the mean (I_M) and worst case (I_w) outage intensities of the end-to-end path.

$I_M = \Sigma (i_{jm})$ .... (4)

$I_w = I_M + \{\Sigma_j (i_{jw} - i_{jm})^2\}^{1/2}$ .... (5)

Formula 5 assumes that the outage intensities of the various path elements involved follow normal distributions.

A.3.2 Redundant topology

See figure A.2.

In a redundant configuration using two parallel paths with unavailabilities U1 and U2 ,respectively, and a switch at one end for choosing the good path, the outage intensity of the protected path as seen between A and B of figure A.2 can be obtained from the following formula:

$$I_{AB} \approx I_1 \times U_2 + I_2 \times U_1 + I_s \qquad (6)$$

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 subclause A.3.1, formula (4), and the mean values U_{1M}, U_{2M} should be substituted in formula (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 subclause A.3.1, formula (5), and the worst case values U_{1w}, U_{2w} should be substituted in formula (6). This will lead to an upper bound of the worst case value of I_{AB}.

A.4 Numerical examples

The following examples show how to use the formulae given in this annex. They are based on figure A.1 for the linear topology and on figure A.2 for the redundant topology for a 2 Mbit/s path.

A.4.1 Assumptions

The following assumptions are used for the purpose of this example:

1) the end-to-end path crosses one single transit country;

2) the different path elements have the performances (taken from tables 1, 2, 3 and 4 of the present document) summarized in table A.1;

Table A.1

Category	Length (km)	Unavailability ($\times 10^{-4}$)		Outage intensity (outages/year)	
		Mean	Worst	Mean	Worst
NPE1, NPE2, Standard	< 500	20	99	99	501
IPCE1 Standard	< 500	15	75	50	249
IPCE2 Standard	500 ≤ L < 1 000	30	110	70	376
IPCE3 Standard	< 500	15	75	50	249
ICPCE1 High	< 500	4	21	5	30
ICPCE2 Standard	< 500	20	99	31	150

3) for redundant configurations (see figure A.2) the parallel paths are assumed to have the same performances (identical paths).

A.4.2 Calculations

A.4.2.1 End-to-end unavailability for a linear topology

See figure A.1.

a) Mean value: see formula (1),

U_M = [20 + 15 + 4 + 30 + 20 + 15 + 20] x 10^{-4} = 124 x 10^{-4} = 1,24 %.

b) Worst case value - see formula (2),

U_W = 124 x 10^{-4} + [$79^2 + 60^2 + 17^2 + 80^2 + 79^2 + 60^2 + 79^2$]^{0,5} x 10^{-4}.

U_W = 124 x 10^{-4} + 181 x 10^{-4} = 305 x 10^{-4} = 3,25 %.

A.4.2.2 End-to-end unavailability for a redundant topology

See figure A.2.

$U1_M = U2_M$ = 124 x 10^{-4}.

a) Mean value: see formula (3),

U_M (AB) = (124 x $10^{-4})^2$ + U_s = 1,54 x 10^{-4} + U_s.

b) Worst case value: see formula (3),

U_w (AB) ≤ (305 x $10^{-4})^2$ + U_s.

U_w (AB) ≤ 9,3 x 10^{-4} + U_s.

A.4.2.3 End-to-end outage intensity for a linear topology

See figure A.1.

a) Mean value: see formula (4),

I_M = 404 outages/ year.

b) Worst case value: see formula (5),

I_w = 404 + 678 = 1 082 outages/ year.

A.4.2.4 End-to-end outage intensity for a redundant topology

See figure A.2.

a) Mean value for outage intensity: see formula (6),

I_M = 10,02 + I_S outages/ year.

b) Worst case value for outage intensity . see formula (6).

I_W = 66 + I_S outages/ year.

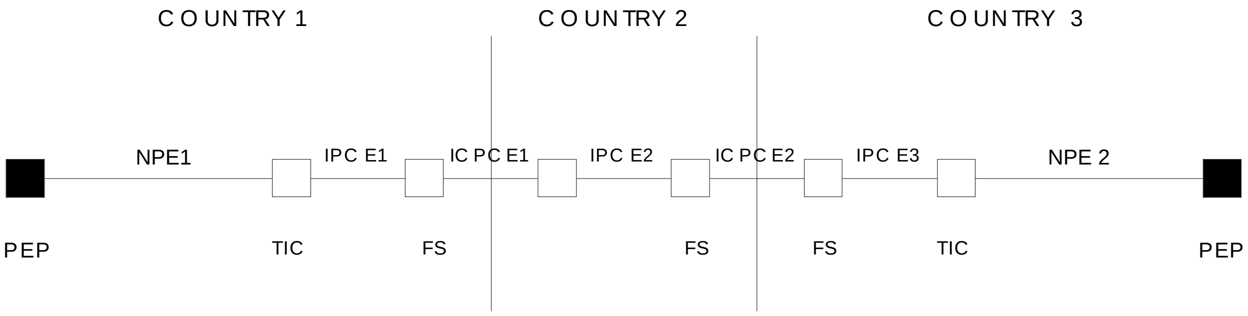


Figure A.1

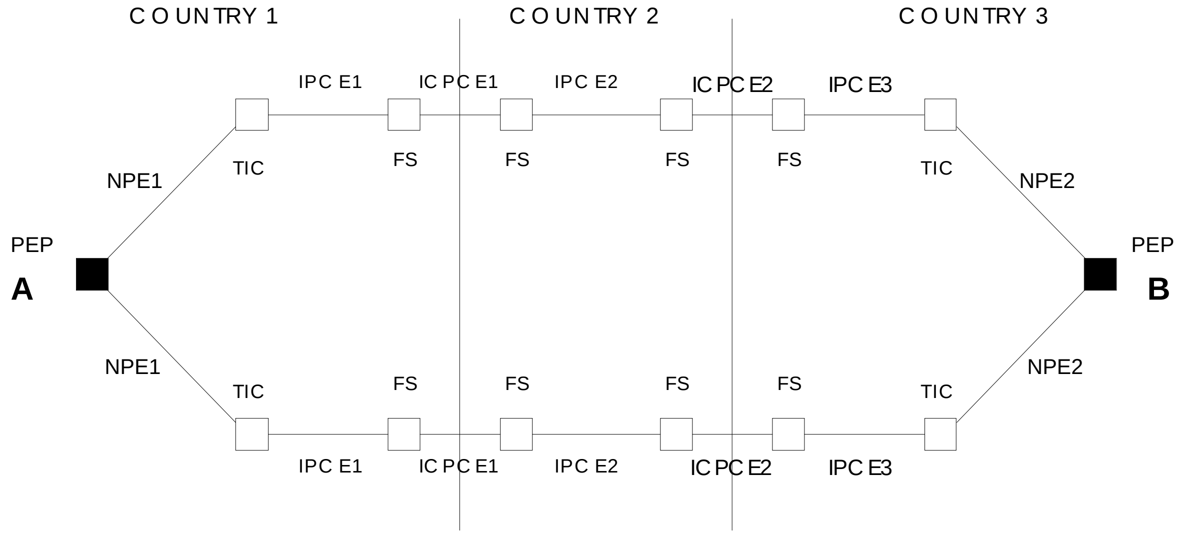


Figure A.2

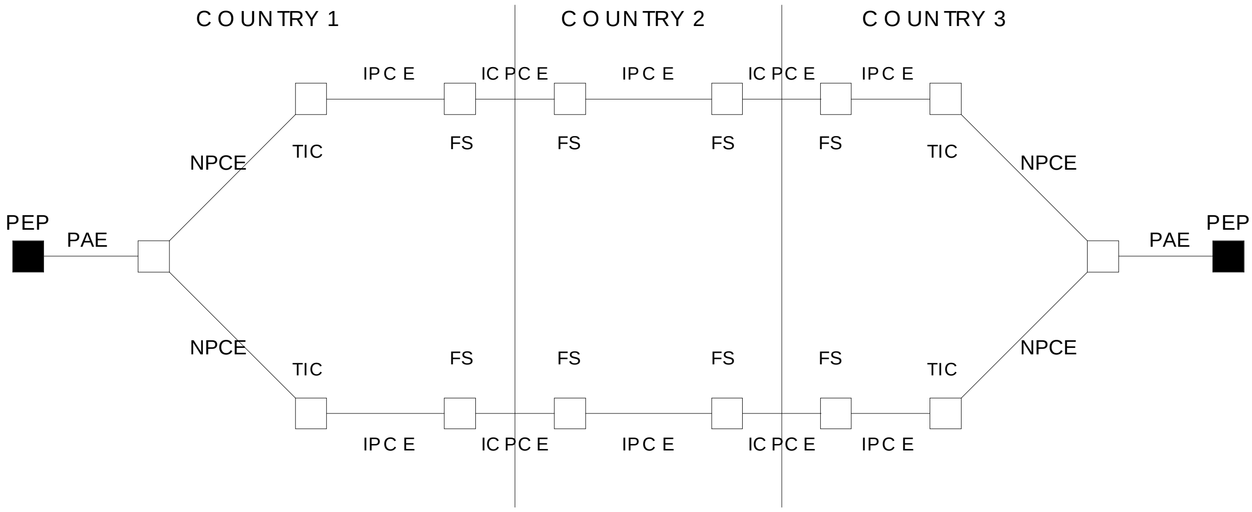


Figure A.3

Annex B (informative): Bibliography

For the purposes of the present document, the following references apply:

- ITU-T Recommendation M.1010: "Constitution and nomenclature of international leased circuits".
- ITU-T Recommendation M.20: "Maintenance philosophy for telecommunications networks".
- ITU-T Recommendation E.850: "Connection retainability objective for the international telephone service".
- ITU-T Recommendation Q.543: "Digital exchange performance design objectives".

History

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