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INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

OVERALL NETWORK ASPECTS AND FUNCTIONS

ISDN 64 kbit/s CONNECTION TYPE AVAILABILITY PERFORMANCE

ITU-T Recommendation I.355

(Previously “CCITT Recommendation”)

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The 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 their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation I.355 was revised by ITU-T Study Group 13 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 19th of March 1995.

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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SUMMARY

The purpose of this Recommendation is to define parameters and objectives describing availability performance of the following 64 kbit/s ISDN connection types:

- Packet-Switched Connection Type (PSCT);
- Circuit-Switched Connection Type (CSCT);
- Dedicated-Circuit Connection Type (DCCT).

Connection types are categorized according to their characteristics into different portion types, with Measurement Points (MPs) delimiting each portion. Parameters defined are Connection Portion Availability (A) and Mean Time Between Connection Portion Outages (M_O). Availability performance is described by specifying worst-case objectives for these parameters for each portion type. These objectives are intended to assist in network design and planning by limiting the aggregate effect of network impairments, including blocking, equipment failures and transmission errors, on ISDN network availability.

In order to define the availability function for the different connection types, the approach taken is to specify a set of performance decision items and associated outage criteria. A two-state availability model is used whereby the availability state of a portion over a specific measurement interval is determined by comparing observed performance with the particular outage criteria. Guidance is propvided on practical measurement of the parameters, including statistical techniques for sampling. Examples are also included illustrating how representative end-to-end availability performance can be calculated using the observed performance of the individual portions.

ISDN 64 kbit/s CONNECTION TYPE AVAILABILITY PERFORMANCE

(Helsinki, 1993; revised 1994)

1 Introduction

1.1 Purpose

The purpose of this Recommendation is to define network performance parameters describing the availability of 64 kbit/s ISDN connection types and to establish values and allocations for these values. This Recommendation also provides guidance on the measurement of these parameters.

The worst-case objectives specified in this Recommendation are intended to assist providers in network design and planning by limiting the aggregate effect of network impairments, including blocking, equipment failures, and transmission errors, on ISDN network availability.

The objectives given in this Recommendation for connection type availability do not directly correspond to the level of Quality of Service to be expected by customers.

1.2 Scope

This Recommendation defines availability parameters and specifies worst-case availability objectives for national and international portions of three 64 kbit/s ISDN connection types (see Table 1): packet-switched connection type (PSCT), circuit-switched connection type (CSCT), and dedicated-circuit connection type (DCCT)[1]. This Recommendation also provides methods for estimating the defined availability parameters.

TABLE 1/I.355

I.355 Connection types

I.355 Connection type	Information transfer mode	Information transfer rate (layer 1)	Establishment of connection
PSCT (Note 1)	Packet	64 kbit/s	Switched
CSCT (Note 2)	Circuit	64 kbit/s	Switched
DCCT (Note 3)	Circuit	64 kbit/s	Semi-permanent, permanent

NOTES

1 Packet-switched connection type (PSCT) includes ISDN connection types B1 in Table 2/I.340 for access via B-channel (Case B) (Figure 2-2/X.31).

2 Circuit-switched connection type (CSCT) includes ISDN connection type A1 in Table 2/I.340

3 Dedicated-circuit connection type (DCCT) includes ISDN connection types A2 and A3 in Table 2/I.340.

[1] Availability performance of other ISDN connection types is for further study.

1.3 Abbreviations

For the purposes of this Recommendation, the following abbreviations apply:

A( )	Connection portion availability
CEP	Call set-up Error Probability
CFP	Call set-up Failure Probability
CSCT	Circuit-Switched Connection Type
DCCT	Dedicated-Circuit Connection Type
ISC	International Switching Centre
ISDN	Integrated Services Digital Network
M_O( )	Mean time between connection portion outages
MP	Measurement Point
MPI	Measurement Point "I"
MPT	Measurement Point "T"
PD	Premature Disconnect
PDP	Premature Disconnect Probability
PDSP	Premature Disconnect Stimulus Probability
PSCT	Packet-Switched Connection Type
RE	Reference Event
RER	Residual Error Ratio
RP	Reset Probability
RSP	Reset Stimulus Probability
SES	Severely Errored Second
SPRT	Sequential Probability Ratio Test
TC	Throughput Capacity

1.4 Related Recommendations

In characterizing availability performance, this Recommendation applies concepts and definitions provided in related ISDN performance Recommendations. These include Recommendations I.350 and X.140 (General framework), Recommendation I.353 (Relevant measurement points) and Recommendations I.354, I.352 and G.821 (Primary performance parameters).

ISDN performance is considered in the context of the 3×3 matrix defined in Recommendations I.350 and X.140. Three protocol-independent communication functions are identified in the matrix: access, user information transfer, and disengagement. These general functions correspond to connection set-up, data transfer, and clearing of 64 kbit/s connections conforming to recommended ISDN protocols. Each function is considered with respect to three general performance concerns (or "performance criteria"): speed, accuracy, and dependability. These express, the delay or rate, degree of correctness, and degree of certainty with which the function is performed, respectively.

Recommendation I.353 defines the following:

– physical measurement points (MPs) at which ITU-T recommended ISDN protocols may be observed;

– particular MPs (designated MPT and MPI) that delimit portions of an end-to-end ISDN connection for which performance objectives may be specified;

– a set of performance-significant reference events (REs), each of which corresponds to the transfer of a discrete unit of control or user information across an MP in accordance with an ITU-T recommended protocol;

– rules for identifying the time of occurrence of any RE at any MP.

Recommendation I.354 defines protocol-specific speed, accuracy, and dependability performance parameters for packet-switched ISDN connections. Recommendation I.352 defines protocol-specific speed, accuracy, and dependability performance parameters for circuit-switched ISDN connection set-up and clearing. Recommendation G.821 defines error (accuracy) performance parameters for user information transfer in circuit-switched and dedicated-circuit ISDN connections. The ISDN performance parameters defined in these three Recommendations are used in distinguishing available and unavailable periods. They are called “primary parameters” to emphasize their direct derivation from ISDN performance-significant reference events.

1.5 Methodology of availability specification

A two-state model establishes the basis for describing the overall availability of 64 kbit/s ISDN connection portions. Specified availability functions compare the values for subsets of the primary parameters with corresponding outage thresholds to classify the connection portion as “available” (no portion outage) or “unavailable” (portion outage) during planned available time. This Recommendation specifies the availability functions and defines the availability parameters and objectives that characterize the resulting binary random process.

The term “portion availability” refers to the ability of a user at one MP to establish and maintain a useful connection to (or through) another specific MP. This ability is evaluated by the specified availability functions. If a connection cannot be established despite repeated trials, or if the quality of the connection is unacceptable (as determined by the outage thresholds), the connection portion is said to be unavailable between those two MPs. (Note that the connection portion may be unavailable between MP_x and MP_y and at the same time the connection portion may be available between MP_x and MP_z). The connection portion delimited by a pair of MPs may also be unavailable if connections established between the specified MPs are repeatedly disconnected. A single premature disconnect of a switched connection is insufficient to declare the portion unavailable – in other words the user should reestablish the connection. However, if several successive connections between two MPs are disconnected during a short time interval, then the portion is declared unavailable between these MPs[2)].

Two generic availability parameters are defined in this Recommendation:

– *connection portion availability* (A); and

– *mean time between connection portion outages* (M_O).

Each parameter can be assessed between any pair of MPs associated with an end-to-end ISDN 64 kbit/s connection. This generality makes the parameters useful in performance allocation and concatenation.

NOTE – The performance parameter mean time between connection portion outages describes time-related aspects of availability performance. This parameter is analogous to the parameter MTBSO in Recommendation X.137.

This Recommendation specifies availability objectives up to four portion types (see Table 2). Performance values for ISDN terminal equipment are not specified, but the parameters defined in this Recommendation may be employed in such specification to assist users in establishing quantitative relationships between network performance and Quality of Service (see Recommendation I.350).

Worst-case objectives for the defined availability parameters are specified in clauses 2 to 4 below. Different objectives are specified for portion types A and B for PSCT connections, whereas in the case of CSCT and DCCT connections, one set of objectives is specified which applies to both portion types. The relevant values should be met by any connection portion used in providing ISDN communications. The performance of a 64 kbit/s connection portion may be better than the worst-case objectives specified in this Recommendation.

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2) Often, a connection can be established between two specific MPs over more than one physical path. The availability measures defined in this Recommendation apply to the set of network facilities that can be used to interconnect a specific pair of MPs, rather than the path used to interconnect the MPs in a particular instance.

TABLE 2/I.355

Portion types for which availability performance values of ISDN 64 kbit/s connection types are specified

Portion type (Note 1)	Typical characteristics (Note 2)
MPT-MPI (type A)	Connection via one access network
MPT-MPI (type B)	Connection via an access network and one or more transit networks
MPI-MPI- (type A)	Connection via a direct internetwork circuit
MPI-MPI (type B)	Connection via one or more transit networks

NOTES

1 For apportionment of packet-switched connection type (PSCT) availability values, the international switching centre (ISC) associated with an MPI is included in the MPT-MPI portion and excluded from the MPI-MPI portion. For apportionment of circuit-switched connection type (CSCT) and dedicated-circuit connection type (DCCT) availability values, the ISC associated with an MPI is excluded from the MPT-MPI portion and included in the MPI-MPI portion. Recommendation I.353 defines the MPT and MPI-boundaries.

2 The values specified for type B portions also apply to ISDN portions not explicitly identified as type A of type B.

1.6 Organization of this Recommendation

The remainder of this Recommendation consists of three clauses and four annexes. Clause 2 specifies packet-switched connection type (PSCT) availability performance. Clause 3 specifies circuit-switched connection type (CSCT) availability performance. Clause 4 specifies dedicated-circuit connection type (DCCT) availability performance. Within each clause, the availability function, availability parameters, and availability performance objectives for connection portions of the associated connection type are defined. Annex A provides procedures for estimating availability parameter values, including minimal tests for determining PSCT and CSCT availability states. Annex B provides numerical methods for combining individual portion performance values to estimate end-to-end (i.e. MPT-to-MPT) availability performance, and derives MPT-to-MPT values for two example hypothetical reference connections. Annex C defines related parameters that may be used in describing availability performance. Annex D identifies factors which should be specified in reporting ISDN availability performance.

2 ISDN 64 kbit/s packet-switched connection type (PSCT) availability performance

Clause 2 has three subclauses. Subclause 2.1 defines the availability function for 64 kbit/s connection types supporting ISDN packet-switched services. Subclause 2.2 defines the PSCT availability parameters. Subclause 2.3 specifies the worst-case PSCT availability objectives.

2.1 PSCT availability function

Eight performance parameters from Recommendations I.354, X.135 and X.136 are used in computing PSCT availability performance: throughput capacity, call set-up failure probability, call set-up error probability, residual error ratio, reset probability, reset stimulus probability, premature disconnect probability, and premature disconnect stimulus probability. Five particular combinations of these parameters, which are called *availability decision parameters*, are used to define the PSCT availability function. These decision parameters and their associated outage criteria are listed in Table 3.

TABLE 3/I.355

Outage criteria for ISDN 64 kbit/s packet-switched connection type (PSCT) availability decision parameters

Decision item	Availability decision parameters	Outage criteria
i)	Call set-up error probability (CEP) Call set-up failure probability (CFP)	CEP + CFP > 0.9
ii)	Throughput capacity (TC)	TC < 80 bit/s
iii)	Residual error ratio (RER)	RER > 0.001
iv)	Reset probability (RP) Reset stimulus probability (RSP_1, RSP_2)	$RSP_1 + RP + RSP_2 > 0.015$
v)	Premature disconnect stimulus probability for each direction, $PDSP_1$, $PDSP_2$ Premature disconnect probability (PDP)	$PDSP_1 + PDP + PDSP_2 > 0.001$
NOTE – Subscripts 1 and 2 refer to the endpoints of the portion.		

The premature disconnect stimulus probability (PDSP) is defined in Recommendation X.136.

Performance is considered independently with respect to each outage criterion. If the observed performance value is equal to or better than the defined outage threshold, performance relative to that outage criterion is defined to be acceptable. If the observed performance value is worse than the outage threshold, performance relative to that outage criterion is defined to be unacceptable.

A PSCT portion between specified MPs is defined to be *available* (or to be in the available state) if the performance measured at the MPs that delimit that portion is acceptable relative to all PSCT outage criteria. A PSCT portion between specified MPs is defined to be *unavailable* (or in the unavailable state) if:

1) the performance measured at the MPs that delimits that portion is unacceptable relative to one or more of the five PSCT outage criteria; or

2) the reference events that are used in defining the PSCT decision parameters cannot be generated due to link unavailability at one or both MPs[3)].

Instances of link unavailability due to causes outside the portion are excluded.

The intervals during which a PSCT portion is unavailable are identified by superimposing the unacceptable performance periods for all PSCT outage criteria (and any periods of unacceptable performance due to link unavailability) as illustrated in Figure 1.

In order to exclude transient impairments from being considered as periods of unavailability, a single test of the availability state must last at least five minutes. In order to reduce the probability of state transitions during a test of the current availability state, that test should last less than 20 minutes. A minimal availability test meeting these restrictions is defined in Annex A.

2.2 PSCT availability parameters

This subclause specifies worst-case objectives for two PSCT availability parameters: PSCT availability and mean time between PSCT outages.

3) Link unavailability at an MP delimiting a portion may be caused, for example, by failure of a physical circuit or data link layer controller inside the portion. Criteria for defining data link layer unavailability are specified in Recommendation X.137.

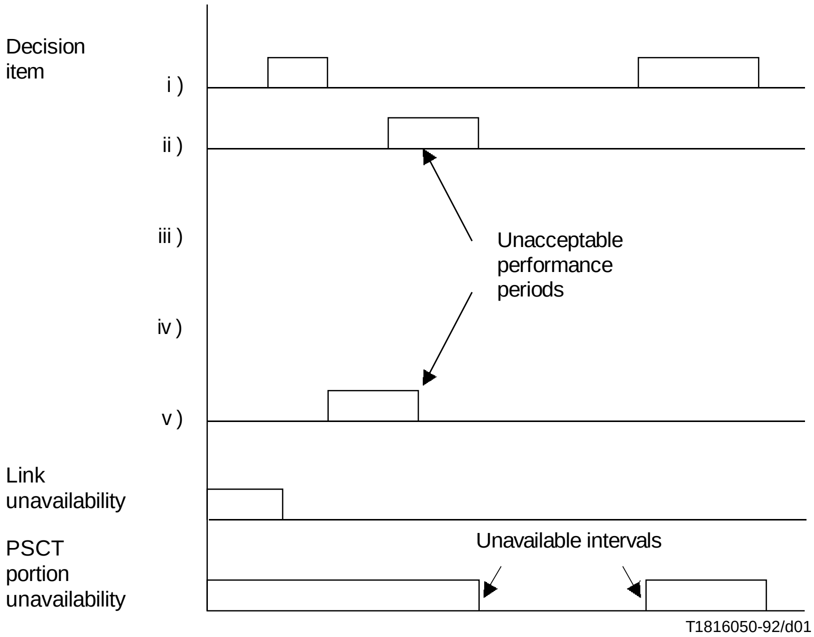

FIGURE 1/I.355

Determination of PSCT availability states

2.2.1 PSCT availability definition: PSCT availability applies to both virtual call and permanent virtual circuit services. The PSCT availability, A(PSCT), for a PSCT portion is the long-term percentage of planned available time in which that portion is actually available.

Planned available time for a connection portion is the time during which the network provider has agreed to make that portion available to support ISDN communications. Annex A describes a procedure for estimating PSCT availability.

2.2.2 mean time between PSCT outages definition: The mean time between PSCT outages applies to both virtual call and permanent virtual circuit services. The mean time between PSCT outages, M_O(PSCT), for a connection portion is the average duration of any continuous interval during which the portion is available. Consecutive intervals of planned available time are concatenated. Annex A describes a procedure for estimating M_O(PSCT).

2.3 PSCT availability objectives

Table 4 specifies worst-case PSCT availability objectives for the four portion types defined in Table 2.

3 ISDN 64 kbit/s circuit-switched connection type (CSCT) availability performance

Clause 3 has three subclauses. Subclause 3.1 defines the availability function for 64 kbit/s connection types supporting ISDN circuit-switched services. Subclause 3.2 defines the CSCT availability parameters. Subclause 3.3 specifies the worst-case CSCT availability objectives.

TABLE 4/I.355

Worst-case PSCT availability [A(PSCT)] and mean time between PSCT outages [M_O(PSCT)] objectives

Parameter	Portion type			
	MPT-MPI		MPI-MPI	
	A	B	A	B
A(PSCT) (percent)	99.5	99.0	99.5	99.0
M_O(PSCT) (hours)	1200	800	1600	800

3.1 CSCT availability function

Four primary performance parameters[4)] are used in computing CSCT availability performance:

- connection set-up error probability,
- connection set-up failure probability;
- premature disconnect stimulus probability; and
- premature disconnect probability.

Two particular combinations of these parameters, which are called *availability decision parameters*, are used to define the CSCT availability function. These decision parameters and their associated outage criteria are listed in Table 5.

TABLE 5/I.355

Outage criteria for ISDN 64 kbit/s circuit-switched connection type (CSCT) availability decision parameters

Decision item	Availability decision parameters	Outage criteria
i)	Connection set-up error probability (CEP) Connection set-up failure probability (CFP)	CEP + CFP > 0.9
ii)	Premature disconnect probability (PDP) Premature disconnect stimulus probability ($PDSP_1$, $PDSP_2$)	$PDSP_1 + PDP + PDSP_2 > 0.001$
NOTE – Subscripts 1 and 2 refer to the endpoints of the portion.		

Performance is considered independently with respect to each outage criterion. If the observed performance value is equal to or better than the defined outage threshold, performance relative to that outage criterion is defined to be acceptable. If the observed performance value is worse than the outage threshold, performance relative to that outage criterion is defined to be unacceptable.

4) The exact definition of these parameters is for further study and will appear in a separate Recommendation.

A CSCT portion between specified MPs is defined to be *available* (or to be in the available state) if the performance measured at the MPs that delimit that portion is acceptable relative to all CSCT outage criteria. A CSCT portion between specified MPs is defined to be *unavailable* (or in the unavailable state) if:

1) the performance measured at the MPs that delimit that portion is unacceptable relative to one or more of the two outage criteria; or

2) the reference events that are used in defining the CSCT decision parameters cannot be generated due to link unavailability at one or both MPs[5].

Instances of link unavailability due to causes outside the portion are excluded.

The intervals during which a CSCT portion is unavailable are identified by superimposing the unacceptable performance periods for all CSCT decision parameters (and any periods of unacceptable performance due to link unavailability) as illustrated in Figure 2.

In order to exclude transient impairments from being considered as periods of unavailability, a single test of the availability state must last at least five minutes. In order to reduce the probability of state transitions during a test of the current availability state, that test should last less than 20 minutes. A minimal availability test meeting these restrictions is defined in Annex A.

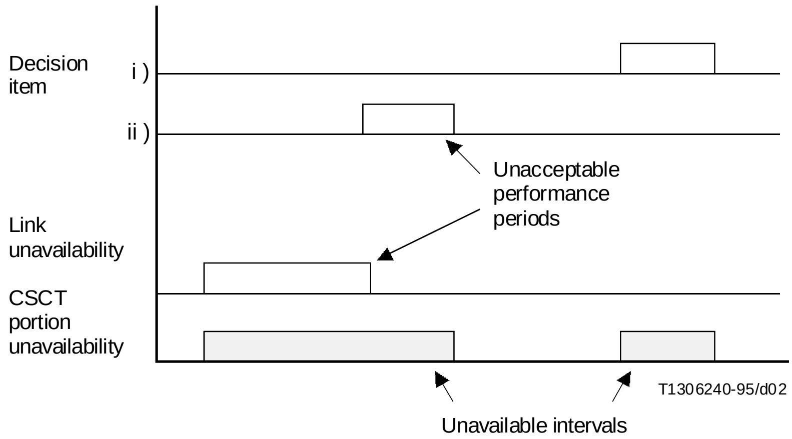

FIGURE 2/I.355

Determination of CSCT availability states

3.2 CSCT availability parameters

This subclause specifies worst-case objectives for two CSCT availability parameters: CSCT availability and mean time between CSCT outages.

3.2.1 CSCT availability definition: The CSCT availability, A(CSCT), for a CSCT portion is the long-term percentage of planned available time in which that portion is actually available.

Planned available time for a connection portion is the time during which the network provider has agreed to make that portion available to support ISDN communications. Annex A describes a procedure for estimating CSCT availability.

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[5] Link unavailability at an MP delimiting a portion may be caused, for example, by failure of a physical circuit or data link layer controller inside the portion. Criteria for defining data link layer unavailability are specified in Recommendation X.137.

3.2.2 mean time between CSCT outages definition: The mean time between CSCT outages, M_O(CSCT), for a connection portion is the average duration of any continuous interval during which the portion is available. Consecutive intervals of planned available time are concatenated. Annex A describes a procedure for estimating M_O(CSCT).

3.3 CSCT availability objectives

Table 6 specifies worst-case CSCT availability objectives for each of the two portion types defined in Table 2.

TABLE 6/I.355

Worst-case CSCT availability [A(CSCT)] and mean time between CSCT outages [M_O(CSCT)] objectives

Parameter	Portion type	
	MPT-MPI	MPI-MPI
A(CSCT) (percent)	99.5	99.5
M_O(CSCT) (hours)	1200	1600

4 ISDN 64 kbit/s dedicated-circuit connection type (DCCT) availability performance

Clause 4 has three subclauses. Subclause 4.1 defines the availability function for 64 kbit/s connection types supporting ISDN dedicated-circuit services. Subclause 4.2 defines the DCCT availability parameters. Subclause 4.3 specifies the worst-case DCCT availability objectives.

4.1 DCCT availability function

Transition between the available and unavailable states are defined on the basis of consecutive SES[6)] outcomes. A DCCT portion in the available state transitions to the unavailable state at the first occurrence of ten consecutive SES. A DCCT portion in the unavailable state transitions to the available state at the first occurrence of 10 consecutive seconds containing no SES (see Figure 3).

NOTE – Under these criteria, an availability state transition event must be observed before the availability state of a DCCT portion can be determined.

4.2 DCCT availability parameters

This subclause specifies worst-case objectives for two DCCT availability parameters: DCCT availability and mean time between DCCT outages.

4.2.1 DCCT availability definition: The DCCT availability, A(DCCT), for a DCCT portion is the long-term percentage of planned available time in which that portion is actually available.

Planned available time for a connection portion is the time during which the network provider has agreed to make that portion available for ISDN communications.

4.2.2 mean time between DCCT outages definition: The mean time between DCCT outages, M_O(DCCT), for a connection portion is the average duration of any continuous interval during which that portion is available. Consecutive intervals of planned available time are concatenated.

6) SES is defined in Recommendation G.821.

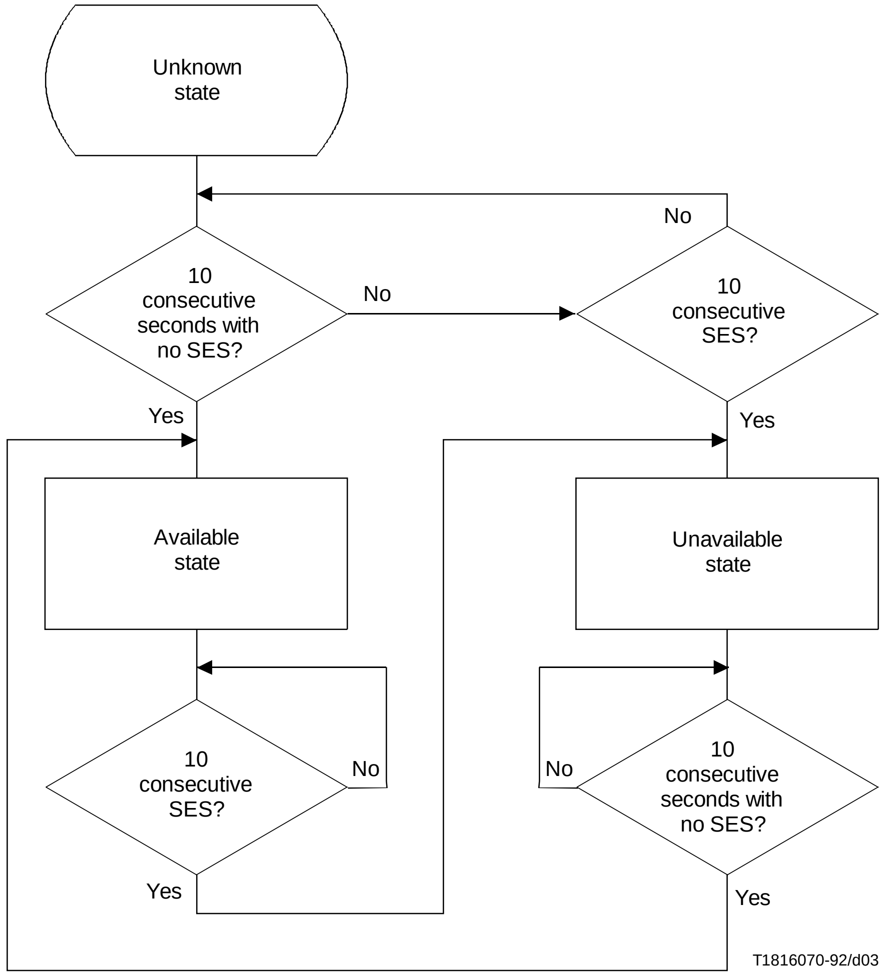


FIGURE 3/I.355

Determination of DCCT availability states

4.3 DCCT availability objectives

Table 7 specifies worst-case DCCT availability objectives for each of the two portion types defined in Table 2.

TABLE 7/I.355

Worst-case DCCT availability [A(DCCT)] and mean time between DCCT outages [M_O(DCCT)] objectives

Parameter	Portion type	
	MPT-MPI	MPI-MPI
A(DCCT) (percent)	For further study	For further study
M_O(DCCT) (hours)	For further study	For further study
NOTE – All values are for further study.		

Annex A

Sampling estimation of ISDN availability parameters

(This annex forms an integral part of this Recommendation)

NOTE – This Annex provides provisional methods and associated values for sampling estimation of ISDN availability parameters. The estimated values obtained by these methods do not directly correspond to the level of Quality of Service to be expected by customers.

A.1 Estimation of the availability state of switched ISDN 64 kbit/s connection type portions

This subclause defines minimal tests for determining the availability states of switched ISDN 64 kbit/s connection types. Subclause A.1.1 defines a minimal test for packet-switched connection type (PSCT) availability state determination and A.1.2 defines a minimal test for circuit-switched connection type (CSCT) availability state determination. A minimal test is not defined for dedicated-circuit connection type (DCCT) availability state determination because such connection types are provided on a permanent or semi-permanent basis and can be monitored continuously.

The risks of wrong decisions corresponding to this minimal test are as follows:

a) the probability of declaring the connection available when the true CEP + CFP is longer than 0.9 is equal to or less than 35%;

b) the probability of declaring the connection is unavailable when the true CEP + CFP is less than 0.7 is equal or less than 24%.

However, since during available periods CEP + CFP is usually significantly smaller than 0.7, the actual probability of falsely declaring unavailability is significantly less than 24%.

Also, since during unavailable periods CEP + CFP is usually more than 0.9, the actual probability of falsely declaring availability is less than 35%.

A.1.1 Definition of the minimal test for PSCT availability state determination

The definition of PSCT availability requires that observed performance for all five decision parameters be compared with outage thresholds. A single success of the following test is defined to be sufficient for declaring the connection portion available. A single failure of a portion to meet any of the individual decision criteria is defined to be sufficient for declaring the portion unavailable. This test and its decision criteria are defined to be the minimum criteria necessary to sample the PSCT availability of a connection portion.

The minimal PSCT availability state test can be initiated in either direction across the portion by equipment and components outside of the portion. The test is divided into two phases: access and user information transfer. The access phase is used in conjunction with switched virtual calls only.

Phase I: Attempt four consecutive call set-ups across the portion under test ("portion A").

Phase II: If the test did not fail in Phase I, attempt to maintain a virtual connection across portion A for five minutes. If portion A prematurely disconnects the connection, the connection should be re-established to complete the five minutes. Attempt to maintain an average throughput greater than 150 bits/s during that interval.

There are six criteria for deciding if the test has succeeded or failed:

1) The test fails in Phase I if all four call set-up attempts result in either call set-up error or call set-up failure (switched virtual calls only). A statistical analysis of this Phase I test is presented in A.4. As an alternative, the sequential probability ratio test (SPRT) presented in A.5 may be used in place of the above Phase I test. The SPRT methodology provides more flexibility in controlling Type I and Type II errors.

2) The test fails in Phase II if the total reset events plus reset stimuli is five or greater.

3) The test fails in Phase II if the throughput is less than 80 bits/s.

4) The test fails in Phase II if the residual error ratio is greater than 10^{-3}.

5) The test fails in Phase II if a premature disconnect (PD) or premature disconnect stimulus (PDS) is followed by a second PD or PDS within the five minute interval (switched virtual calls only).

6) The test fails in Phase I or Phase II if a data link at a portion boundary is unavailable during the five minute interval due to causes inside of portion A.

If the test passes all six decision criteria, the test is successful and the ISDN 64 kbit/s packet-switched connection across portion A is considered to be available during the test. If any of the decision criteria are failed, the connection across portion A is considered to have been unavailable for the duration of the test.

Because several performance parameters must be supported simultaneously in order for portion A to be considered available, during normal operation it is not possible (without a testing procedure like the one described above) to prove the portion is available (e.g. it may not be possible to observe both access and user information transfer simultaneously). Therefore, during normal operation, if the portion is correctly performing the currently requested function, the portion is assumed to be available.

PSCT availability and mean time between PSCT outage values can be estimated on the basis of this minimal test (see A.2 and A.3). Such estimation is more practical than measurement based on continuous observation.

A.1.2 Definition of the minimal test for CSCT availability state determination

The definition of CSCT availability requires that observed performance for both decision parameters be compared with outage thresholds. A single success of the following test is defined to be sufficient for declaring the connection portion available. A single failure of a portion to meet any of the individual decision criteria is defined to be sufficient for declaring the portion unavailable. This test and its decision criteria are defined to be the minimum criteria necessary to sample the CSCT availability of a connection portion.

The minimal CSCT availability state test can be initiated in either direction across the portion by equipment and components outside of the portion. The test is divided into two phases: access and user information transfer.

Phase I: Attempt four consecutive call set-ups across the portion under test (“portion A”).

Phase II: If the test did not fail in Phase I, attempt to maintain a connection across portion A for five minutes. If portion A prematurely disconnects the call, the call should be re-established to complete the five minutes. If an SES premature disconnect stimulus occurs, disconnect the call and return to Phase I. If another SES premature disconnect stimulus occurs, end Phase II.

There are four criteria for deciding if the test has succeeded or failed:

1) The test fails in Phase I if all four call set-up attempts result in either call set-up error or call set-up failure. A statistical analysis of this Phase I test is presented in A.4. As an alternative, the sequential probability ratio test (SPRT) presented in A.5 may be used in place of the above Phase I test. The SPRT methodology provides more flexibility in controlling Type I and Type II errors.

2) The test fails in Phase II if two or more SES premature disconnect stimuli are received and acted upon.

3) The test fails in Phase II if a premature disconnect (PD) caused within portion A is followed by a second PD within the five minute interval.

4) The test fails in Phase I or Phase II if a data link at a portion boundary is unavailable during the five minute interval due to causes inside of portion A.

If the test passes all four decision criteria, the test is successful and the ISDN 64 kbit/s circuit-switched connection across portion A is considered to be available during the test. If any of the decision criteria are failed, the connection across portion A is considered to have been unavailable for the duration of the test.

Because several performance parameters must be supported simultaneously in order for portion A to be considered available, during normal operation (without a testing procedure like the one described above) it is not possible to prove the portion is available (e.g. it may not be possible to observe both access and user information transfer simultaneously). Therefore, during normal operation, if the portion is correctly performing the currently requested function, the portion is assumed to be available.

CSCT availability and mean time between CSCT outage values can be estimated on the basis of this minimal test (see A.2 and A.3). Such estimation is more practical than measurement based on continuous observation.

A.2 Procedure for estimating availability of switched ISDN 64 kbit/s connection type portions

A sufficient estimate of the parameters PSCT availability and CSCT availability can be computed as follows. Based on an *a priori* estimate of the availability, choose a sample size "s", not less than 300. Choose "s" testing times during planned available time and distribute them across a long measurement period (e.g. six months). Because of expected outage durations, choose no two testing times closer together than seven hours (this serves to keep the observations uncorrelated). The testing times should be uniformly distributed across the planned available time. At each predetermined testing time perform the appropriate availability test described above. If the test fails, the portion is declared unavailable for that sample. Otherwise, the portion is declared available. The estimate of the PSCT or CSCT availability percentage is the number of times the portion was declared available multiplied by 100 and divided by the total number of samples.

A.3 Procedure for estimating mean time between connection portion outages of switched ISDN 64 kbit/s connection types

A sufficient estimate of the parameters mean time between PSCT outages, M_O(PSCT), and mean time between CSCT outages, M_O(CSCT), can be computed by conducting consecutive availability performance samples and by counting the observed changes from the available state to the unavailable state.

Prior to performing any tests, choose *k* disjoint intervals of time each not less than 30 minutes nor more than three hours. The total amount of time in the *k* intervals should exceed three times the *a priori* estimate of mean time between connection portion outages. For the duration of each pre-defined interval conduct consecutive availability performance samples. The amount of time observed in the available state will be added to a cumulative counter called "counter A". The number of observed transitions from the available state to the unavailable state will be accumulated in a counter called "counter F"[7].

For each pre-defined interval:

- If all of the consecutive availability samples succeed, then add the total length of the interval to counter A. Do not change the cumulative value of counter F.
- If the first availability sample succeeds and any subsequent sample in the interval fails, increase counter F by one. Add to counter A the total length of all availability samples prior to the first failure. Following the first failed availability sample the remaining time in the interval may be discarded without testing its availability.
- If the first availability sample fails, assume that the state transition occurred before the interval began. Add nothing to the counter of observed availability time, counter A. Add nothing to the cumulative count of observed state changes, counter F. The remaining time in the interval may be discarded without testing its availability.

After the results of every pre-defined interval have been accumulated, the ratio of the counters A and F, A/F, is an estimate of the mean time between connection portion outages. A statistically more precise estimate can be obtained by increasing the number of observed intervals, *k*.

---

[7] Each counter is initially set to zero.

The estimate of mean time between connection portion outages assumes that, if an outage begins during an availability performance sample, either this sample or the following sample will decide that the section is unavailable. This is a reasonable assumption since connection portion outages, in contrast to transient failures, will last more than five minutes.

Discarding the remainder of the interval following a failed availability sample is both practical and statistically justifiable. The connection portion must return to the available state before any more available time can be accumulated and before any more transitions to the unavailable state can be observed. First, the expected time to restore communications may be large with respect to the remaining time in the interval. It can be inappropriate and counterproductive to continue testing a failed or congested network section. Second, if transitions to the unavailable state are statistically independent, then discarding the remainder of the interval, which may include time in the available state and a proportional number of transitions back into the unavailable state, will not bias the result[8)]. The only consequence of discontinuing the test is the loss of testing time. To minimize that loss, the test intervals should be short with respect to the sum of the expected time to connection portion restoral and the expected time between connection portion outages. Thus, each test should be no longer than three hours.

There are two sources of bias in the estimation procedure described above. First, if an outage begins during the last availability sample of the interval, that transition may or may not cause the sample to fail. If it does not fail, the state transition is missed and the mean time between connection portion outages is overestimated. Second, a state transition to the unavailable state during the first availability sample of the interval may or may not cause that sample to fail. According to the estimation procedure, if the sample does fail, the interval will be discarded, the state transition is missed, and the mean time between connection portion outages is overestimated. These edge effects can be minimized by increasing the length of each interval, consequently increasing the number of availability samples, and thus decreasing the effect of the first and last sample outcomes as a proportion of the total sampled outcomes. A minimum recommended interval length is 30 minutes and six five minute availability samples.

Alternatively, both biases can be corrected by replacing the first instruction above with:

- If all of the consecutive availability samples succeed, then add the total length of the interval to counter A. Take one additional availability sample immediately following the interval. If that sample fails, increase counter F by one. If that sample succeeds, do not change counter F. The length of the additional sample has no effect on counter A.

This modification identifies any state transitions that occurred during the last sample of the interval and eliminates the first source of bias. It also counts certain transitions that occurred outside of the interval. These transitions are counted with the same probability as the probability that the second source of bias inappropriately discards transitions. Thus, this modified procedure corrects both sources of bias. Using this modification, the mean time between connection portion outages can be more accurately estimated.

A.4 Statistical basis of Phase I minimal test with $N = 4$

This subclause provides supporting material intended to help clarify the statistical basis of the Phase I minimal test for availability.

By definition a PSCT connection portion is unavailable if the probability of call set-up error plus the probability of call set-up failure is greater than 0.9 (the analysis also holds for CSCT availability):

$$\text{CFP} + \text{CEP} > 0.9$$

[8)] If outages tend to be clustered, discontinuing a test following a transition to the unavailable state will tend to overestimate the mean time between connection portion outages. If outages tend to be negatively clustered, discontinuing a test following a transition to the unavailable state will tend to underestimate the mean time between connection portion outages.

Therefore, take the following as the null hypothesis, H_o, and the alternative hypothesis, H_a:

$$H_o\text{: CEP} + \text{CFP} < z$$

$$H_a\text{: CEP} + \text{CFP} > 0.9$$

Using the minimal availability test (A.1.1 and A.1.2), the probability of Type I and Type II errors are given below:

$$\text{Pr (Type I Error)} < z^4 = 0.24 \text{ (for } z = 0.7)$$

$$\text{Pr (Type II Error)} < 1 - (0.9)^4 \approx 0.35$$

Table A.1 presents the probabilities of various events given the actual level of call set-up failure and error probability. Table A.1 shows the extent to which this test protects against calling an available state unavailable. Also with more than 65% probability, the test will correctly identify the unavailable state.

TABLE A.1/I.355

Error performance of the Phase I minimal test with *N* = 4

Actual CEP + CFP	Probability of correctly identifying the available state	Probability of correctly identifying the unavailable state	Probability of identifying available state as unavailable Pr (Type I error)	Probability of identifying available state as unavailable Pr (Type II error)
0.1	0.999	NA	0.0001	NA
0.2	0.998	NA	0.002	NA
0.3	0.992	NA	0.008	NA
0.4	0.974	NA	0.026	NA
0.5	0.937	NA	0.063	NA
0.6	0.87	NA	0.13	NA
0.7	0.76	NA	0.24	NA
0.8	0.59	NA	0.41	NA
> 0.9	NA	> 0.65	NA	< 0.35
0.95	NA	0.81	NA	0.19
0.99	NA	0.96	NA	0.04
0.999	NA	0.996	NA	0.004
NA Not applicable				

A.5 Application of the sequential probability ratio test (SPRT) to the Phase I minimal test for availability

This subclause applies the sequential probability ratio test (SPRT) to the Phase I test for availability. The SPRT method provides an alternative, non-minimal test for those situations where greater flexibility in managing the Type I and Type II errors is required.

A.5.1 SPRT test procedure

Phase I: Perform an SPRT[9] of the following pair of hypotheses, utilizing an appropriate value of z ($z < 0.9$). This test will use successive call set-up attempts across the portion under test, A. If the SPRT decides that H_o is true, then proceed to Phase II of the minimal test. If the SPRT decides that H_a is true, then terminate the test and conclude that the PSCT connection portion is unavailable due to the sum of call failure probability and call error probability exceeding the outage threshold of 0.9.

H_o: $\text{CEP} + \text{CFP} < z$ (outage criterion is not met)

H_a: $\text{CEP} + \text{CFP} > 0.9$ (outage criterion is met)

A.5.2 SPRT methodology

The hypotheses used are based on the criterion in this Recommendation that the sum of the call failure probability and call error probability exceeding 0.9 (i.e. $\text{CFP} + \text{CEP} > 0.9$) determines a connection portion outage. Implicit in this criterion is the assertion that one can in fact distinguish between $\text{CFP} + \text{CEP} > 0.9$ and $\text{CFP} + \text{CEP} < 0.9$. However, the best that one can really do is to distinguish between $\text{CFP} + \text{CEP} > 0.9$ and $\text{CFP} + \text{CEP} < z$ ($0 < z < 0.9$).

The sequential probability ratio test (SPRT) methodology controls both the Type I and Type II errors simultaneously, and, for deciding between two alternatives, is the most powerful statistical tool available[10]. For simplicity, this annex uses the same probability of a wrong decision for both Type I and Type II errors. The assumption of a binomial distribution for the success or failure of an individual call set-up attempt is made in this subclause.

The material below discusses the hypotheses to be tested, the decision rule, the upper and lower decision points, the least number of successful or failed attempts to end the SPRT, and the expected number of call set-up attempts.

1) *Hypotheses*

   The SPRT uses the following pair of hypotheses, where H_o corresponds to the outage threshold not being exceeded, and H_a corresponds to the outage threshold being exceeded.

   H_o: $\text{CEP} + \text{CFP} < z$ (outage criterion is not met)

   H_a: $\text{CEP} + \text{CFP} > 0.9$ (outage criterion is met)

2) *Decision rule and upper and lower decision points*

   The SPRT reaches a decision based on observed performance being greater or less than particular values. These values depend on the number of observations taken, n, and are denoted by UD(n), and LD(n) respectively. Formulas for LD(n) and UD(n) are given below after the decision rule[11].

3) *Decision rule*

4) If, upon making n attempts, the number of failed attempts is greater than UD(n), then the outage criterion is met.

$$\sum_{j=1}^{n} x_j > \text{UD}(n)$$

   If, upon making n attempts, the number of failed attempts is less than LD(n) then the outage criterion is not met.

$$\sum_{j=1}^{n} x_j < \text{LD}(n)$$

---

9) The SPRT methodology is given in A.5.2.

10) See, for example, George G. Roussas, *A First Course in Mathematical Statistics* (Addison-Wesley, 1973).

11) In the formulas below, error = P (Type I error) = P (Type II error). Values of error from 0.01 to 0.10 are commonly used.

Keep attempting calls until a decision is reached.

4) *Formulas for UD(n) and LD(n)*

$$\mathrm{UD}(n) = \frac{\log\left(\frac{(1 - \mathrm{error})}{(\mathrm{error})}\right) - n \log\left(\frac{(1 - 0.9)}{(1 - z)}\right)}{\log\left(\frac{0.9\,(1 - z)}{z\,(1 - 0.9)}\right)}$$

$$\mathrm{LD}(n) = \frac{\log\left(\frac{(\mathrm{error})}{(1 - \mathrm{error})}\right) - n \log\left(\frac{(1 - 0.9)}{(1 - z)}\right)}{\log\left(\frac{0.9\,(1 - z)}{z\,(1 - 0.9)}\right)}$$

5) *Least number of failure or successes to end an SPRT*

The quantities L and U represent the least number of call set-up attempts required by the SPRT to decide if H_o or H_a, respectively, are true. If all L call set-up attempts are successful, then the outage criterion is not met, while if all U of the call set-up attempts fail, then the outage criterion is met. Tabulated values of U and L are provided in Table A.2.

6) *Expected number of call set-up attempts*

The expected number of call set-up attempts until the SPRT reaches a decision is useful in determining the length and cost of the test. Under H_o and H_a, the expected number of call set-up attempts are $E_o(n)$ and $E_a(n)$ respectively. Asymptotic approximations for them are as follows, and are based on the use of a binomial probability for the sum of call set-up error and call set-up failure. Calculations resulting in entries in Table A.3 greater than 100 were made using these approximations. The rest of Table A.3 was constructed using interactive matrix techniques yielding more precise values.

$$E_o(n) = \frac{[1 - 2\,(\mathrm{error})] \log\left(\frac{(\mathrm{error})}{(1 - \mathrm{error})}\right)}{z \log\left(\frac{0.9\,(1 - z)}{z\,(1 - 0.9)}\right) + \log\left(\frac{(1 - 0.9)}{(1 - z)}\right)}$$

$$E_a(n) = \frac{[1 - 2\,(\mathrm{error})] \log\left(\frac{(1 - \mathrm{error})}{(\mathrm{error})}\right)}{0.9 \log\left(\frac{0.9\,(1 - z)}{z\,(1 - 0.9)}\right) + \log\left(\frac{(1 - 0.9)}{(1 - z)}\right)}$$

Tabulated values of $E_o(n)$ and $E_a(n)$ are provided in Table A.3.

TABLE A.2/I.355

Minimum number of call set-up attempts

U/L (Note 1)			
z	Percent error (Note 3)		
(Note 2)	10%	5%	1%
0.85	39/6	52/8	81/12
0.80	19/4	25/5	40/7
0.75	13/3	17/4	26/6
0.70	9/2	12/3	19/5
0.65	7/2	10/3	15/4
0.60	6/2	8/3	12/4
0.55	5/2	6/2	10/4
0.50	4/2	6/2	8/3
0.45	4/2	5/2	7/3
0.40	3/2	4/2	6/3
0.35	3/2	4/2	5/3
0.30	2/2	3/2	5/3
0.25	2/2	3/2	4/3
0.20	2/2	2/2	4/3
0.15	2/2	2/2	3/3
0.10	2/2	2/2	3/3

NOTES

1 U and L are the least number of successive call set-up errors or failures needed to terminate the SPRT deciding in favour of H_a and H_o respectively.

2 *z* is the threshold value specified in the null hypothesis (H_o).

3 The column headings represent the specified error rates. Due to approximations used in the SPRT, the error rates are bounded above by error/(1 – error). The differences are small over the range of error rates being considered.

TABLE A.3/I.355

Expected number of call set-up attempts

$E_a(n)/E_o(n)$ (Note 1)			
z	Percent error (Note 3)		
(Note 2)	10%	5%	1%
0.85	161.3/143.7	243.2/216.6	413.3/368.1
0.80	51.5/45.3	74.5/65.1	122.7/101.4
0.75	27.4/22.3	39.3/32.5	63.9/52.2
0.70	17.1/14.4	24.5/20.1	40.1/32.3
0.65	12.1/10.2	17.3/13.9	27.9/22.2
0.60	9.2/7.4	13.3/10.8	21.0/16.3
0.55	7.4/6.1	10.0/7.7	16.5/13.0
0.50	5.8/4.9	8.6/6.5	13.0/10.1
0.45	5.4/4.3	7.0/5.4	10.9/8.4
0.40	4.0/3.7	5.6/4.8	8.8/7.2
0.35	3.9/3.4	5.5/4.3	7.0/5.7
0.30	2.6/2.8	4.1/3.7	6.5/5.2
0.25	2.6/2.6	3.7/3.3	5.4/4.6
0.20	2.4/2.5	2.7/2.8	5.0/4.1
0.15	2.4/2.3	2.5/2.7	3.7/3.7
0.10	1.0/1.0	2.4/4.4	3.7/3.7

NOTES

1 $E_a(n)$ and $E_o(n)$ are the expected number of trials needed to terminate the SPRT when the portion is unavailable and available respectively.

2 *z* is the threshold value specified in the null hypothesis (H_o).

3 The column headings represent the specified error rates. Due to approximations used in the SPRT, the error rates are bounded above by error/(1 – error). The differences are small over the range of error rates being considered.

Annex B

Representative end-to-end availability performance of ISDN 64 kbit/s connection types

(This annex forms an integral part of this Recommendation)

B.1 Representative end-to-end design availability performance of ISDN 64 kbit/s packet-switched connection type (PSCT)

Subclause B.1 provides two examples to illustrate how end-to-end (MPT to MPT) design availability performance associated with ISDN packet-switched service using 64 kbit/s connection types can be estimated from the individual connection portion performance values specified in this Recommendation. Two example concatenations of connection portions are defined below. End-to-end connection portion availability and mean time between connection portion outage design values are calculated for both examples. Although alternative network models and statistical assumptions are possible, the methods presented in this annex provide one practical way of estimating the end-to-end performance from the performance of the individual network portions.

B.1.1 Definition of the example end-to-end PSCT connections

For ease of reference, the two example PSCT end-to-end (i.e. MPT to MPT) connections presented in this annex will be referred to as “Case 1” and “Case 2” configurations. These hypothetical, but representative, configurations apply the portion types (i.e. A and B) defined in Table 2.

The Case 1 and Case 2 example PSCT configurations are defined in Figure B.1.

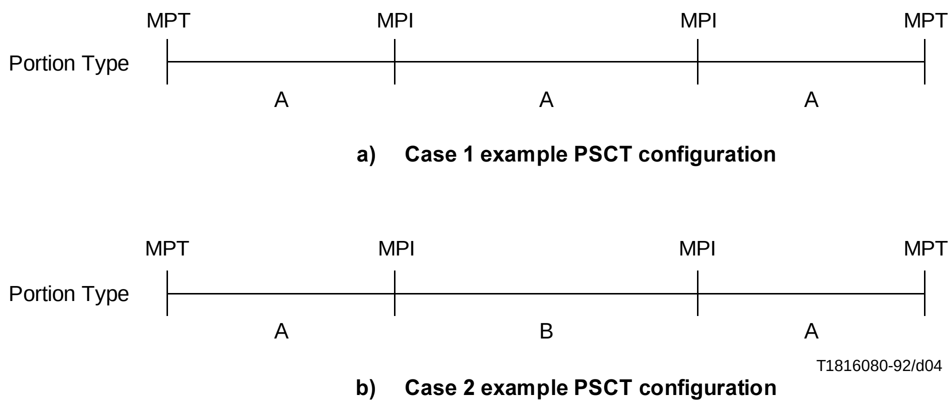


FIGURE B.1/I.355

Definition of Case 1 and Case 2 example PSCT configurations

B.1.2 End-to-end PSCT availability performance for the Case 1 and Case 2 configuration examples

End-to-end PSCT availability performance values have been calculated for the example Case 1 and Case 2 connection configurations and are presented in Tables B.1 and B.2. These calculations have been made by applying the methods described below to the individual network portions that, for convenience in defining these examples, are characterized by the worst-case accuracy and dependability performance values specified in this Recommendation.

TABLE B.1/I.355

End-to-end availability and mean time between PSCT outages for the Case 1 configuration example

Case 1 example PSCT configuration	
Parameter	End-to-end value
PSCT availability (percent)	98.5
Mean time between PSCT outages (hours)	436

TABLE B.2/I.355

End-to-end availability and mean time between PSCT outages for the Case 2 PSCT configuration example

Case 2 example PSCT configuration	
Parameter	End-to-end value
PSCT availability (percent)	97.5
Mean time between PSCT outages (hours)	300

Assuming that the PSCT availability performance values associated with the individual connection portions are statistically independent, then the end-to-end performance values can be calculated by multiplying the percent of time each of the connection portions is available.

Example: To compute the end-to-end PSCT availability for the Case 1 configuration, refer to Table 4 to obtain the individual portion availabilities (MPT-MPI type A: percent = 99.5; MPI-MPI type A: percent = 99.5). The end-to-end availability in percent is then: (99.5) (99.5) (99.5) = 98.5.

The end-to-end performance for mean time between PSCT outages can be estimated by assuming that the mean time between PSCT outages in each individual connection portion is independent and exponentially distributed. It follows from these assumptions that the end-to-end mean time between PSCT outages performance objective, *T*, can be calculated using the following formula:

$$T = [T_1^{-1} + T_2^{-1} + \dots + T_i^{-1} + \dots + T_H^{-1}]^{-1}$$

where *T* will be in hours if the mean time between PSCT outages for each of the H connection portions, T_i (i = 1, 2, ..., H), is expressed in hours.

Example: For the Case 1 PSCT configuration, the MPT-MPI type A portion mean time between PSCT outages is 1200 hours and the MPI-MPI type A portion is 1600 hours (refer to Table 4). The end-to-end performance objective is then: $[1200^{-1} + 1600^{-1} + 1200^{-1}]^{-1} = 436$ hours.

B.1.3 Representative design availability performance of other ISDN 64 kbit/s connection types

The example methods used to calculate the end-to-end design availability values for the ISDN 64 kbit/s packet-switched connection type (see B.1) can also be used to calculate end-to-end availability performance for other connection types.

B.2 Derivation of the end-to-end "95th percentile" availability from "worst-case" availabilities of connection portions

This subclause describes a method for deriving the 95th percentile value of the unavailability of an end-to-end connection from the performances of connection portions.

It shows that such a derivation is possible only if the connection portions types are specified in terms of mean values and of percentile values (95th percentile for example).

1) *Notation*

$U_{95}i$ 95th percentile value of the unavailability of a connection portion

Umi Mean value of the unavailability of a connection portion

σi Standard derivation of the unavailability of a connection portion

Vi Variance of the unavailability of a connection portion

U_{95} 95th percentile value of the end-to-end connection unavailability

Um Mean value of the end-to-end connection unavailability

S Standard deviation of the end-to-end connection unavailability

V Variance of the end-to-end connection unavailability

2) *Assumption*

The values of Umi are supposed to be low enough so that Um can be approximated by Σ Umi. This assumption is valid for values currently specified in this Recommendation.

3) *Calculation*

a) For the sum of independent random variables, the following apply:

$$\text{Um} = \sum \text{Umi} \qquad \text{(B-1)}$$

$$V = \sum \text{Vi} = \sum (\sigma \text{i})^2 \qquad \text{(B-2)}$$

b) Many distributions can be modelled by the Gamma distributions, due to the flexibility of this type of distribution.

It can be shown that for this type of distribution the following applies:

$$\text{U}_{95}\text{i} = \text{Umi} + 2\,\sigma\text{i} \qquad \text{(B-3)}$$

Thus, if this Recommendation specifies the mean value Umi and the 95th percentile $U_{95}i$ of the availability of each network portion to be concatenated, then for each network portion one gets from formula (B-3):

$$\sigma\text{i} = (\text{U}_{95}\text{i} - \text{Umi})/2 \qquad \text{(B-4)}$$

and for the end-to-end unavailability, making use of formula (B-2) one obtains:

$$V = (0{,}5)^2 \sum (\text{U}_{95}\text{i} - \text{Umi})^2$$

or (B-5)

$$\text{S} = 0{,}5\,[\sum (\text{U}_{95}\text{i} - \text{Umi})^2]^{1/2}$$

c) The sum of independent random variables tends to be normally distributed when the number of added variables is large enough. In this case the 95th percentile of the sum is given by:

$$\text{U}_{95} = \text{Um} + 1{,}65\text{S} \qquad \text{(B-6)}$$

that is, using formulas (B-1) and (B-5):

$$\text{U}_{95} = \sum \text{Umi} + \frac{1{,}65}{2}\,[\sum (\text{U}_{95}\text{i} - \text{Umi})^2]^{1/2} \qquad \text{(B-7)}$$

For better accuracy U_{95} can be calculated by :

$$\text{U}_{95} = 1 - \prod_{\text{i}} \text{i Ami} + \frac{1{,}65}{2}\,[\sum (\text{U}_{95}\text{i} - \text{Umi})^2]^{1/2} \qquad \text{(B-8)}$$

when Ami is the mean availability of a connection portion.

d) As only three unavailability values have to be added (two National portions and one International portion), the assumption of a normal distribution for the sum of these three random variables might not be true. It is therefore more appropriate to estimate the value of U_{95} by:

$$U_{95} = 1 - \prod_{i} i \ Ami + [\sum (U_{95}i - Umi)^2]^{1/2} \qquad \text{(B-9)}$$

Annex C

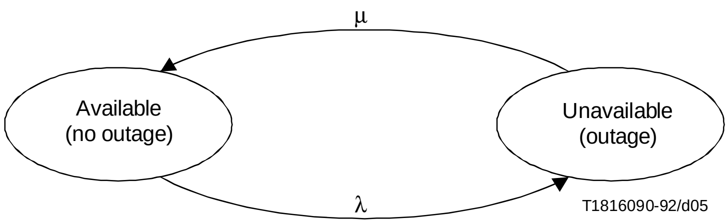
Related availability parameters

(This annex forms an integral part of this Recommendation)

Four other parameters are commonly used in describing availability performance. These are generally defined as follows:

- mean time to connection portion restoral (M_R) is the average duration of unavailable time intervals;
- failure rate (λ) is the average number of transitions from the available state to the unavailable state per unit available time;
- restoral rate (μ) is the average number of transitions from the unavailable state to the available state per unit unavailable time;
- connection portion unavailability (*U*) is the long-term ratio of actual unavailable time to planned available time, expressed as a percentage.

The mathematical values for any of these parameters may be estimated from the values for connection portion availability (*A*) and mean time between connection portion outages (M_O) as summarized in Figure C.1.



a) State diagram

$$M_O = \frac{1}{\lambda}$$

$$M_R = \frac{1}{\mu}$$

$$A = 100 \left(\frac{M_O}{M_O + M_R}\right) = 100 \left(\frac{\mu}{\lambda + \mu}\right)$$

$$U = 100 - A = 100 \left(\frac{M_R}{M_O + M_R}\right) = 100 \left(\frac{\mu}{\lambda + \mu}\right)$$

b) Parameter relationships

FIGURE C.1/I.355

Basic availability model and parameters

Annex D

Factors to be specified in reporting ISDN availability performance of 64 kbit/s connection types

(This annex forms an integral part of this Recommendation)

Many factors affect the availability performance that can be obtained on a particular 64 kbit/s connection portion. The following factors should be specified in reporting ISDN availability performance.

D.1 Planned hours of connection portion availability

These arrangements should be specified *a priori*.

For further study.