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SERIES X: DATA NETWORKS AND OPEN SYSTEM COMMUNICATIONS

Public data networks – Network aspects

Frame Relay network availability

ITU-T Recommendation X.147

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ITU-T Recommendation X.147

Frame Relay network availability

Summary

This Recommendation defines network performance parameters, objectives and measurement methods for describing the availability of Frame Relay networks. The specified parameters and objectives apply to international Frame Relay connection portions – National Portions, International Transit Network Portions and International Interoperator Portions. The objectives, which are worst-case values, are intended to assist service providers with network planning by limiting the aggregate effect of network impairments, including congestion, equipment failures and transmission errors.

A set of network objectives is specified which define the overall network performance based on a statistical sample of Frame Relay connections. The objectives do not apply to or define the performance of an individual Frame Relay connection.

A two-state availability model is defined along with criteria for determining if the service during specific periods of time should be declared to be either available or unavailable. A number of procedures are defined in order to assess the availability performance of virtual connections. An expression for determining a value for overall network availability is presented. Information for estimating availability from a minimal set of observations is also presented.

Source

ITU-T Recommendation X.147 was approved by ITU-T Study Group 17 (2001-2004) under the ITU-T Recommendation A.8 procedure on 29 October 2003.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), 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 WTSA 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.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

ITU-T Recommendation X.147

Frame Relay network availability

1 Scope

The purpose of this Recommendation is to define network performance parameters, worst-case objectives and measurement methods, for FR virtual connection availability together with allocations to national and international portions applicable to international frame relay services. The specified parameters and objectives apply to Frame Relay connection portions as defined in Figure 2.

This Recommendation applies to those networks supporting the service class options of ITU-T Recs X.36 and X.76. (Signalling and service class interworking issues are covered in ITU-T Recs X.36 and X.76.)

The 3×3 performance matrix defined in ITU-T Rec. X.134 (see Figure 1) is used as a guide to identify the applicability of this Recommendation. This Recommendation applies to both permanent and switched virtual connections.

An international Frame Relay virtual connection consists of two national portions and one international portion. The international portion may also be subdivided into a number of connection portions – transit network sections and interoperator circuit sections.

A two-state availability model is defined along with criteria for determining if the service during specific periods of time should be declared to be either available or unavailable. A number of procedures are defined in order to assess the availability performance of virtual connections. An expression for determining a value for overall network availability is presented.

Using this Recommendation, worst-case performance objectives can be derived for the national portions and the international portion of an international Frame Relay connection. Methods for estimating end-to-end availability performance are also provided.

The objectives specified in this Recommendation, which are worst-case values, are intended to assist service providers with network planning by limiting the aggregate effect of network impairments, including congestion, equipment failures and transmission errors, on Frame Relay virtual connection availability. They do not directly correspond to the level of Quality of Service to be expected by individual customers.

This Recommendation defines the availability of a Frame Relay connection in a way that is independent of user behaviour (i.e.,, a connection can be declared unavailable even if the user is not transmitting frame at a given time). Availability objectives need not be met on any connection that a network provider has determined to be non-compliant with the traffic contract defined by the CIR and EIR.

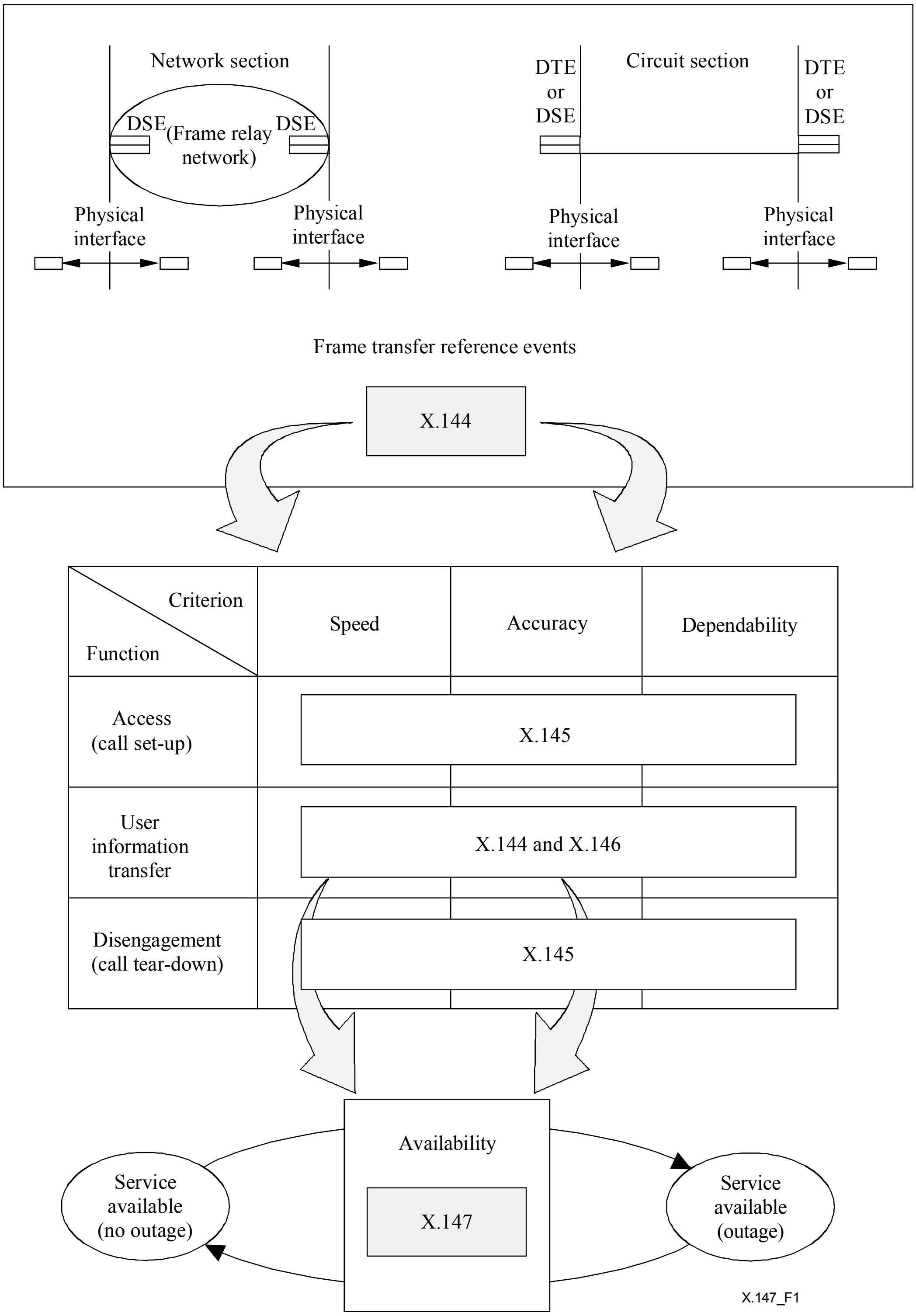


Figure 1/X.147 – Scope of this Recommendation

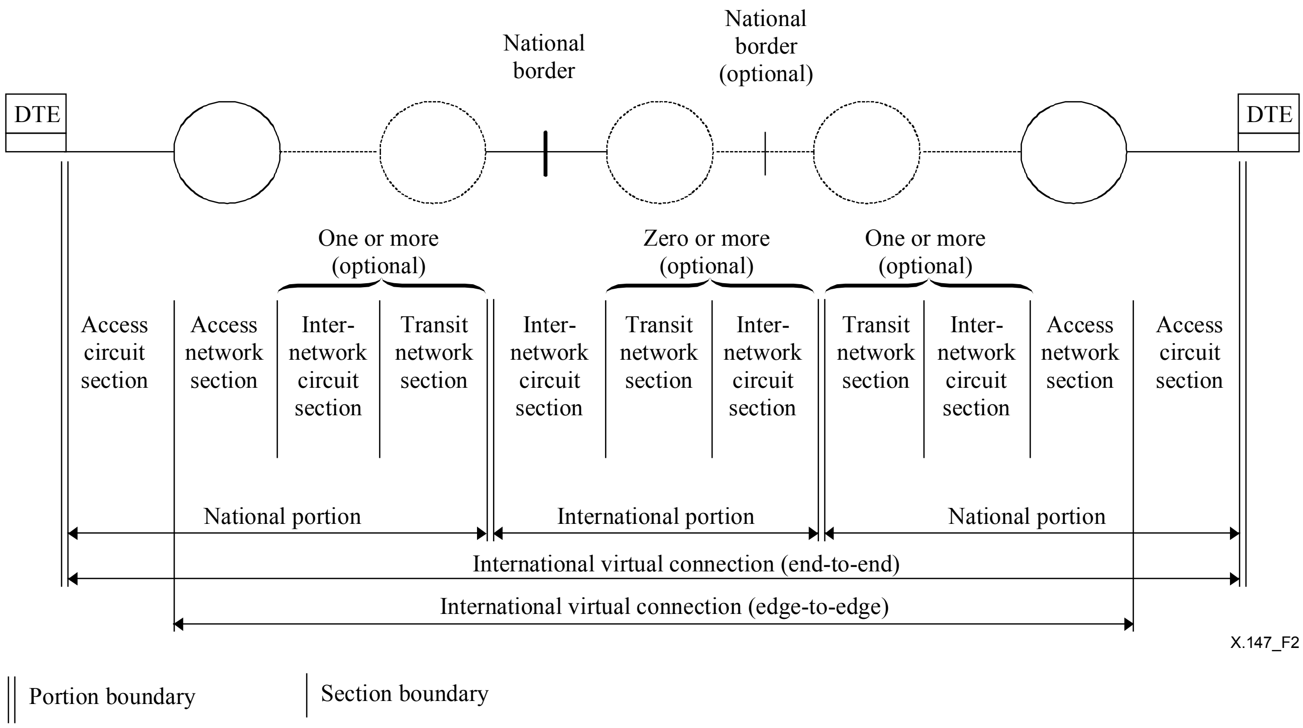


Figure 2/X.147 – General Reference model for the apportionment of national and international portions of a multiple-network international Frame Relay virtual connection

2 References

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

– ITU-T Recommendation X.36 (2003), *Interface between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for public data networks providing frame relay data transmission service by dedicated circuit*.

– ITU-T Recommendation X.76 (2003), *Network-to-network interface between public networks providing PVC and/or SVC frame relay data transmission service*.

– ITU-T Recommendation X.140 (1992), *General quality of service parameters for communication via public data networks*.

– ITU-T Recommendation X.144 (2003), *User information transfer performance parameters for public frame relay data networks.*

– ITU-T Recommendation X.145 (2003), *Connection establishment and disengagement performance parameters for public Frame Relay data networks providing SVC services*.

– ITU-T Recommendation X.146 (2000), *Performance objectives and quality of service classes applicable to frame relay*.

– ITU-T Recommendation X.148 (2003), *Procedures for the measurement of the performance of public data networks providing the international frame relay service.*

– ITU-T Recommendation X.151 (2003), *Frame Relay operations and maintenance – Principles and functions.*

– Frame Relay Forum Technical Committee: FRF.19 (2001), *Frame Relay Operations, Administration and Maintenance Implementation Agreement.*

3 Definitions

The terms and definitions used in this Recommendation are consistent with those used in ITU-T Recs X.140, X.144, X.145 and X.146 and in FRF.19. Specific definitions for Service Availability/Availability Ratio and Mean Time Between Service Outages are given in 7.5.

4 Abbreviations

This Recommendation uses the following abbreviations:

ACS	Access Circuit Section
ANS	Access Network Section
CEP	Connection set-up Error Probability
CFP	Connection set-up Failure Probability
CIR	Committed Information Rate
DE	Discard Eligible
DSE	Data Switching Exchange
DTE	Data Terminal Equipment
EFR	Extra Frame Rate
EIR	Excess Information Rate
FE	Frame Layer Reference Event
FLR	Frame Loss Ratio
FROMP	Frame Relay OAM Maintenance Point
FTD	Frame Transfer Delay
ICS	Internetwork Circuit Section
ISC	International Switching Centre
MP	Measurement Point
MTBSO	Mean Time Between Service Outages
MTTSR	Mean Time To Service Restoral
NNI	Network-to-Network Interface
PDP	Premature Disconnect Probability
PDSP	Premature Disconnect Stimulus Probability
PVC	Permanent Virtual Circuit
RFER	Residual Frame Error Ratio
SA	Service Availability
SVC	Switched Virtual Circuit
TE	Terminal Equipment

TNS Transit Network Section

5 Conventions

No specific conventions apply

6 General Frame Relay performance reference model

The performance model for this Recommendation is consistent with that used in ITU-T Recs X.144 and X.145. For completeness, this performance model is illustrated in Figure 2.

An end-to-end international Frame Relay virtual connection consists of two national portions and one international portion. In certain cases, the international portion could consist solely of an internetwork circuit section. In this Recommendation, the term "edge-to-edge" denotes the performance of the end-to-end connection excluding the two access circuit sections. This model is applicable to either a Switched Virtual Connection (SVC) or a Permanent Virtual Connection (PVC).

The Data Terminal Equipment (DTE) is not part of the end-to-end international virtual connection; hence, its contribution to the user experience is not considered in this Recommendation. Private frame relay networks are considered as DTE, and as such their performance contribution is not considered in this Recommendation.

6.1 Frame Relay virtual connection portions and measurement points

An international Frame Relay connection consists of a number of connection portions. For the purpose of assessing availability performance, each portion may be delimited by Measurement Points (MPs). The MPs are located at interfaces where the Frame Relay layer is accessible.

The establishment of a MP on the national side of the International Switching Centre (ISC), and its performance allocation in the national portion, are national matters, depending on the network topology of each country.

For the purpose of availability performance management, Frame Relay connections may be divided into three types of connection portions:

- *National Portions*
- *International Transit Network Portion*
  - An International Transit Network Portion may involve one or more transit networks.
- *International Interoperator Portions*
  - An International Interoperator Portion provides a connection between:
    - i) a National Portion to an International Transit Network Portion; or
    - ii) two adjacent International Transit Portions; or
    - iii) two adjacent National Portions.

The set of International Transit Portions and International Interoperator Portions constitutes the International Portion of the connection. Figures 3 and 4 illustrate these concepts for connections with one International Transit Network Portion and no International Transit Portions respectively.

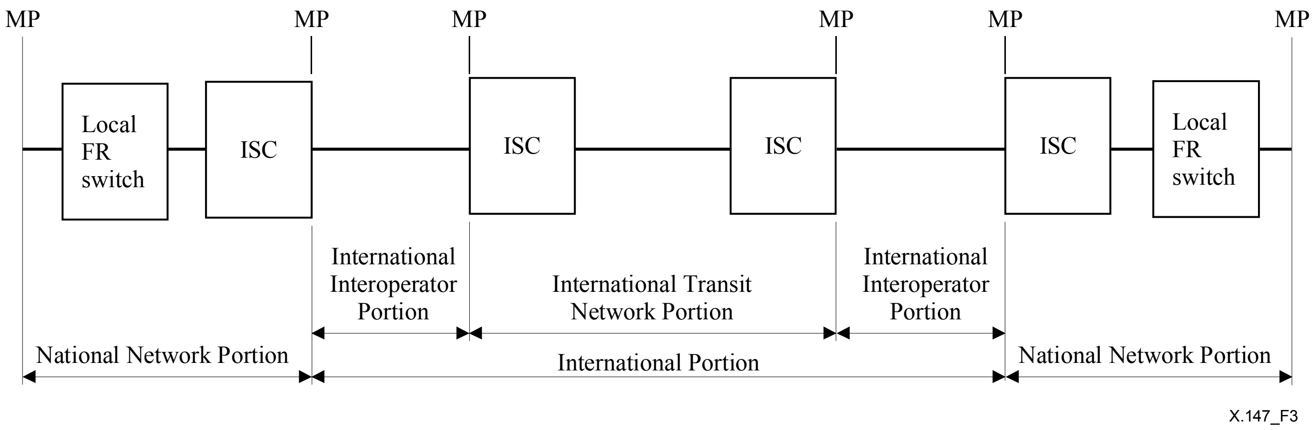


Figure 3/X.147 – Connection with one international transit operator

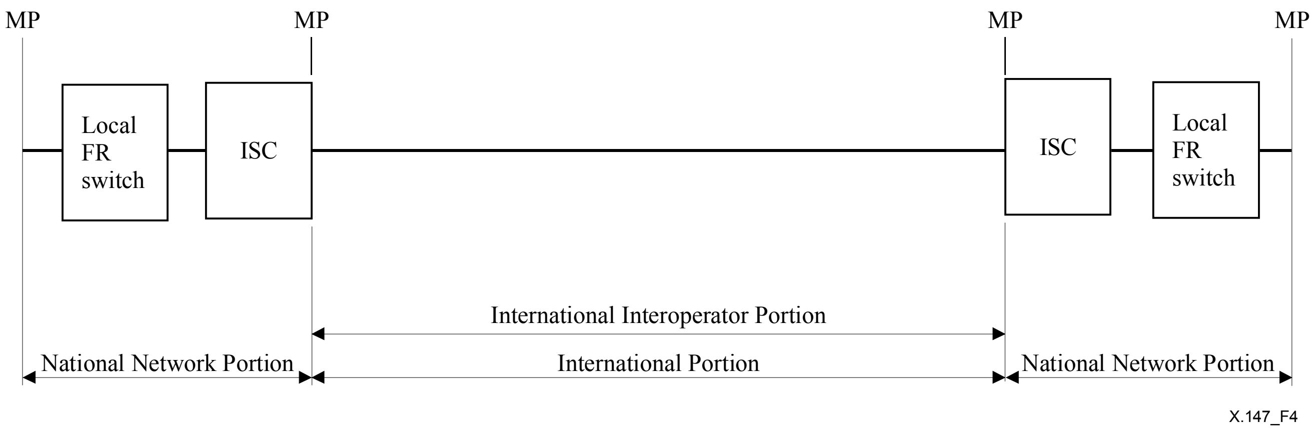


Figure 4/X.147 – Connection with no international transit operators

7 Method for specifying availability

7.1 General definition of availability

From a dependability point of view, a portion of an international Frame Relay connection should have the following properties:

- The fraction of time during which a connection is in a down state (i.e.,, unable to support a specific transaction) should be as low as possible.
- Once a transaction has been established, it should have low probability of being either terminated (because of insufficient data transfer performance) or prematurely released (due to the failure of a network component) before the intended end of transaction.

Availability of a Frame Relay virtual connection portion is defined as the fraction of time during which the portion is able to support a transaction (i.e.,, successfully transfer frames). Conversely, unavailability of a portion is the fraction of time during which the portion is unable to support a transaction (i.e.,, it is in the down state). A portion of a bidirectional Frame Relay connection is available, if and only if, both directions are available.

7.2 Availability model

This Recommendation uses a common availability model which applies to any Frame Relay virtual connection. The model uses two states corresponding to the ability or inability of the network to sustain a connection in the available state. Transitions between the states of the model are generally governed by the occurrence of specific frame layer reference events. This Recommendation views availability from the network perspective, where availability performance is characterized independently of user behaviour.

7.3 Definition of available/unavailable state

In order to define the availability of a Frame Relay virtual connection portion, a number of criteria are defined for declaring periods of time as either available or unavailable. These criteria are applicable to any Frame Relay virtual connection portion, whether the user continuously transmits frames or not. This Recommendation proposes a number of approaches for assessing if a period (block) of time should be declared as available or unavailable.

- Physical layer connectivity is a prerequisite for Frame Relay service availability. The virtual connection section (or set of contiguous sections) may be considered unavailable if the underlying physical layer at either section boundary is unavailable (no signal, alarm condition, etc.) due to causes within the connection section(s). That is, if the Frame Relay virtual connection is unable to transfer frames due to an unavailable physical layer, the connection is considered unavailable. Such a physical layer failure would prevent frames from being transmitted on the connection portion during the considered period of time, should the user attempt to transmit frames. An interruption corresponds to a failure occurring within the connection portion, either of the physical layer or of the Frame Relay layer. See Annexes B and C regarding use of STATUS messaging, alarm indication and OAM frames for assessing, over a defined period of time, if the virtual connection is either available or unavailable.
- From a transmission quality point of view, the connection section (or set of sections) may be considered unavailable if either the Frame Loss Ratio, the Residual Frame Error Ratio or the Extra Frame Rate performance parameters exceed a set threshold. Threshold levels are defined in Annex A. See Annex D regarding use of OAM frames to monitor Frame Loss Ratio in order to assess availability.
- From an accuracy and dependability point of view, the connection section (or set of sections) may be considered unavailable if either the Connection set-up Error Probability (CEP) and Connection set-up Failure Probability (CFP) or Premature Disconnect Probability (PDP) and Premature Disconnect Stimulus Probability (PDSP) exceed a set threshold. Threshold levels are defined in Annex A.

7.3.1 Declaring periods of time as available or unavailable

Availability Ratio is calculated by simply declaring periods of time as either available or unavailable. A period of time is declared to be unavailable if during the assessment period either the virtual circuit does not provide connectivity or the defined performance parameter thresholds are exceeded.

NOTE – This approach does not require the definition of criteria to assess transitions between the available and unavailable states.

It is recommended that the maximum period of time over which an assessment is made is 5 minutes. The recommended minimum period of time over which an assessment is made is 10 seconds. Network operators may choose time periods in accordance with the monitoring capabilities implemented within their network management systems. Appendix I describes sampling techniques for estimating availability performance. These techniques can be used in the case where network operators do not wish to undertake continuous monitoring of all virtual connections.

NOTE – If the time period, over which the availability assessment is made, is greater than 5 minutes, network operators should be aware that the accuracy of the estimate of the Frame Loss Ratio will decrease and accordingly the period of unavailable time might be underestimated.

7.4 Methods for assessing availability

The ability of frame relay networks to provide in-service monitoring of Frame Relay connections in order to assess availability performance, will greatly depend on the features and capabilities implemented by the network management system. It is recognized that in-service measurement of availability using all the performance parameter thresholds (as defined in 7.3) may not be practicable in many cases. Accordingly, this Recommendation describes a number of optional methods that can be employed for in-service estimation of availability performance. Network operators should clearly indicate which methods they utilize in order to obtain an availability figure when declaring network availability performance.

The contribution of Residual Frame Error Ratio, Extra Frame Rate, Connection set-up Error Probability (CEP), Connection set-up Failure Probability (CFP), Premature Disconnect Probability (PDP) and Premature Disconnect Stimulus Probability (PDSP) to declaring a period of time as unavailable is expected to be minimal. Accordingly, estimating availability only on the basis of the Frame Loss Ratio performance is not expected to significantly overestimate the total period of available time.

Annex A describes a method based on the use of performance parameter thresholds. Annex B describes a method based on the use of Status or Alarm Indication messages. Annexes C and D describes methods based on the use of Frame Relay OAM information.

7.5 Availability parameters

Performance objectives are defined in this Recommendation for two availability performance parameters: Availability Ratio (AR) and Mean Time Between Service Outages (MTBSO). These parameters apply to Frame Relay virtual connection portions in both the PVC and SVC cases.

7.5.1 Service availability/Availability Ratio

The service availability is the long-term percentage of scheduled service time in which a virtual connection section or concatenated set of virtual connection sections is available.

The Availability Ratio (AR) is defined as the proportion of scheduled service time that the virtual connection section is in the available state. The AR is calculated by dividing the total service available time by the duration of the scheduled service time.

Scheduled service time for a Frame Relay virtual connection is the time during which the network provider has agreed to make that connection available for service. Typically, the scheduled service is 24 hours per day, seven days a week. However, other scheduled service times may be specified in some networks. During the scheduled service time the user may or may not transmit frames.

7.5.2 Mean Time Between Service Outages

The Mean Time Between Service Outages (MTBSO) is the average duration of any continuous interval during which the virtual connection section or concatenated set of sections is available. Consecutive intervals of scheduled service time are concatenated.

The MTBSO is defined as the average duration of continuous periods of available time. Where scheduled service time is not contiguous, they are concatenated in calculating MTBO.

7.5.3 Related availability performance parameters

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

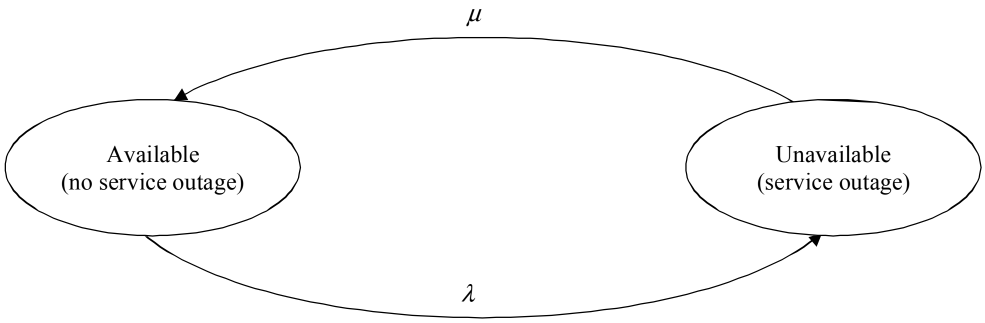
– **mean time to service restoral (MTTSR)** is the average duration of unavailable service time intervals;

– **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;

– **unavailability (U)** is the long-term ratio of unavailable service time to scheduled service time, expressed as a percentage.

Under an exponential distribution assumption of failure and restoration, the mathematical values for any of these parameters may be estimated from the values for Service Availability (SA) and Mean Time Between Service Outages (MTBSO) as summarized in Figure 5.



a) State diagram

$$MTBSO = \frac{1}{\lambda} \qquad MTTSR = \frac{1}{\mu}$$

$$SA = 100 \left[\frac{MTBSO}{MTBSO + MTTSR}\right] = 100 \left[\frac{\mu}{\lambda + \mu}\right]$$

$$U = 100 - SA = 100 \left[\frac{MTTSR}{MTBSO + MTTSR}\right] = 100 \left[\frac{\mu}{\lambda + \mu}\right]$$

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b) Parameter relationships

Figure 5/X.147 – Basic availability model and related parameters

8 Availability performance objectives

This clause specifies performance objectives for the Availability Ratio and MTBSO parameters for the following connection portion types:

- National Network Portion;
- International Transit Network Portion;
- International Interoperator Portion.

A single set of objectives is specified which are worst-case and are applicable to each individual connection portion. The objectives define the performance of a statistical sample of Frame Relay connections. They do not apply to or define the performance of an individual Frame Relay connection. All values are provisional and they need not be met by networks until they are revised (up or down) based on real operational experience.

The end-to-end availability performance of an international Frame Relay virtual connection can be estimated by simply multiplying the availability values for each portion.

8.1 Availability Ratio

The AR objective for each connection portion type is specified in Table 1.

Table 1/X.147 – Objectives for Availability Ratio

Connection portion	Availability Ratio objective
National Network Portion (Note)	For further study
International Transit Network Portion	For further study
International Interoperator Portion	For further study
NOTE – Does not include the contribution of the Access Circuit Sections.	

8.2 Mean Time Between Outages

The MTBO objective for each connection portion type is specified in Table 2.

Table 2/X.147 – Objectives for Mean Time Between Outages

Connection portion	MTBO objective
National Network Portion	For further study
International Transit Network Portion	For further study
International Interoperator Portion	For further study

Annex A

Determining availability states by use of performance parameter thresholds

A.1 Frame Relay virtual connection availability

This annex specifies a set of criteria for assessing the availability of Frame Relay virtual connections. A two-state model provides a basis for describing overall service availability. A specified availability function compares the operational values for a set of "supported" primary performance parameters with corresponding outage thresholds to classify the service as "available" (no service outage) or "unavailable" (service outage) during successive observation periods. This annex specifies the availability functions and defines the availability threshold values that characterize the resulting binary random process for both PVC and SVC services.

A.1.1 Frame Relay virtual connection availability functions

To assess Frame Relay PVC availability, four outage criteria (based on the performance parameters defined in ITU-T Rec. X.144), are used in computing the PVC availability:

– User Information Frame Loss Ratio (for offered traffic conforming with the CIR);

– User Information Frame Loss Ratio (for offered traffic conforming with EIR);

– Residual Frame Error Ratio; and

– Extra Frame Rate.

To assess Frame Relay SVC availability, two additional outage criteria (based on the performance parameters defined in ITU-T Rec. X.145) are specified in conjunction with the outage criteria for PVC availability:

– Connection set-up Error Probability (CEP) and Connection set-up Failure Probability (CFP);
– Premature Disconnect Probability (PDP) and Premature Disconnect Stimulus Probability (PDSP).

These parameters are called the availability decision parameters. Each decision parameter is associated with an outage threshold. These decision parameters and provisional values for their outage thresholds are listed in Table A.1.

Table A.1/X.147 – Outage criteria for the availability decision parameters

Availability decision parameters	Criteria (Note 3)
FLR_c (Note 1): User information frame loss ratio for a population of frames with DE = 0 when all DE = 0 frames conform with the CIR	$FLR_c > C_1$
FLR_e (Note 2): User information frame loss ratio for a population of frames input with DE = 1 when all input DE = 1 frames conform with the EIR and all DE = 0 frames conform with the CIR	$FLR_e > C_2$
RFER – Residual Frame-Error Ratio	$RFER > C_3$
EFR – Extra Frame Rate	$EFR > C_4$
Connection set-up Error Probability (CEP) and Connection set-up Failure Probability (CFP)	$CEP + CFP > C_5$
Premature Disconnect Probability (PDP) and Premature Disconnect Stimulus Probability (PDSP)	$PDP + PDSP > C_6$
NOTE 1 – Applicable as an availability decision parameter only when CIR > 0. If high FLR is observed, the offered DE = 0 traffic should be reduced to CIR before judging the availability state.	
NOTE 2 – Applicable as an availability decision parameter only when CIR = 0 and there are no DE = 0 frames. If high FLR is observed, the offered DE = 1 traffic should be reduced to EIR before judging the availability state.	
NOTE 3 – The following threshold criteria values are specified: $C_1 = 10\%$, $C_2 = 25\%$, $C_3 = 1\%$, $C_4 = 1/300$, $C_5 = 0.9$, and $C_6 = 0.01$. All values are provisional and they need not be met by networks until they are revised (up or down) based on real operational experience.	
NOTE 4 – The connection section (or set of sections) may also be considered unavailable if the underlying physical layer at either section boundary is unavailable (no signal, alarm condition, etc.) due to causes within the connection section(s). See Annex B.	

A.1.2 Assessment of availability

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

A set of connection sections bounded by boundaries B_i and B_j is defined to be *available* (or to be in the available state) if the performance is acceptable relative to all decision parameters; i.e.,, the performance parameter thresholds are not exceeded during the period of time over which the performance is assessed.

A set of connection sections bounded by boundaries B_i and B_j is defined to be *unavailable* (or to be in the unavailable state) if the performance of one or more of the decision criteria is unacceptable; i.e.,, one or more of the performance parameter thresholds are exceeded during the period of time over which the performance is assessed.

The intervals during which a connection section or concatenated set of connection sections is unavailable are identified by superimposing the unacceptable performance periods for all decision parameters as illustrated in Figure A.1.

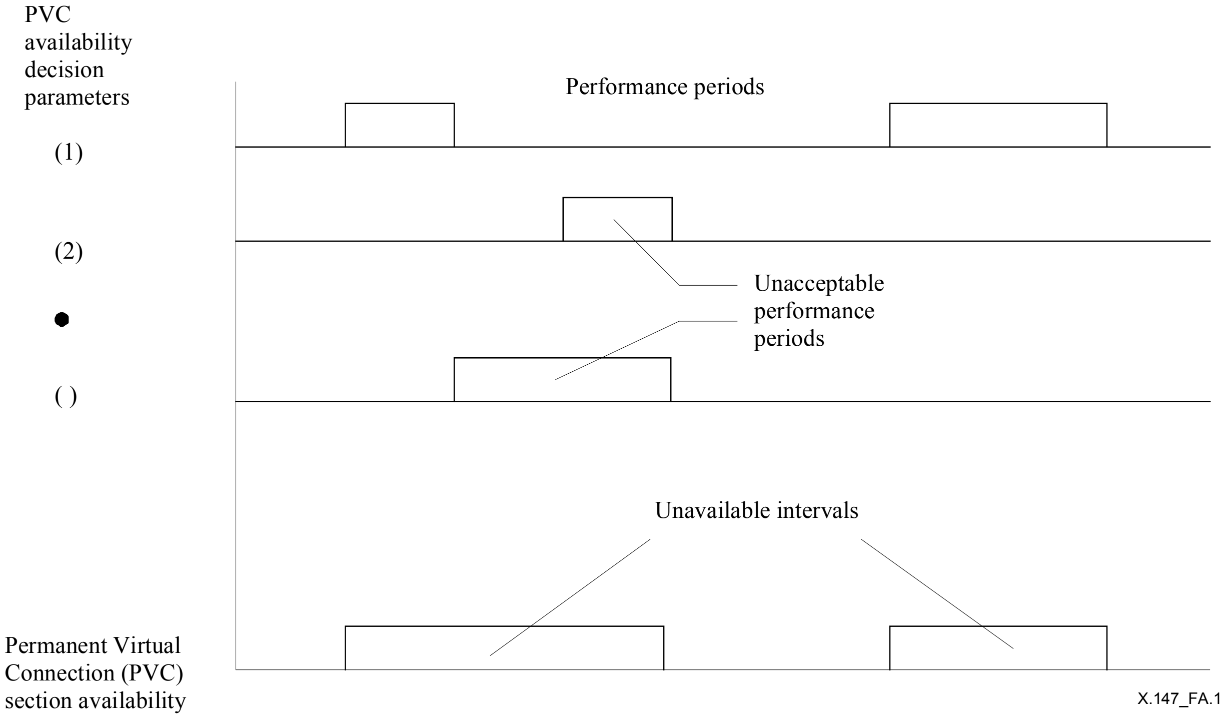

Figure A.1/X.147 – Determination of Frame Relay PVC availability states

A.1.3 Use of Frame Loss Ratio as the only criteria for assessing availability

Noting that the ability of Frame Relay networks to provide in-service monitoring of the quality of a Frame Relay connection in order to assess availability, will greatly depend on the features and capabilities implemented within the network management system, network operators have the option of choosing which parameters they will use for assessing connection availability.

For example, a value of the Frame Loss Ratio may be able to be readily estimated from accounting records. However, obtaining a value for the Residual Frame Error Ratio or the Extra Frame Rate may require more specialized monitoring equipment.

NOTE 1 – It is expected that the Residual Frame Error Ratio or the Extra Frame Rate would generally be quite low. Hence, use of only the Frame Loss Ratio parameter as the decision criteria is not expected to greatly impact on the value achieved for Availability Ratio.

NOTE 2 – ITU-T Rec. X.148 specifies methods for measuring Frame Loss Ratio using FR OAM techniques. See also Annex D.

Annex B

Use of Frame Relay STATUS Messages or Alarm Indication as availability criteria

For Frame Relay virtual connections that implement the STATUS messaging procedures defined in ITU-T Recs X.36 and X.76 (or in Annex A/Q.933), and utilize bidirectional procedures only on the network-to-network interfaces (NNIs), transmission of specific pairs of STATUS message indications or Alarm Indications shall also serve as availability criteria.

For a set of connection sections under test bounded by boundaries B_i and B_j, the transmission of an inactive indication exiting the section under test shall serve as a transition from the available state to the unavailable state. A set of connection sections bounded by boundaries B_i and B_j is defined to be *unavailable* (or to be in the unavailable state) if the transmission of an inactive indication in a STATUS message exiting the sections bounded by B_i and B_j occurs.

Re-entry to the available state shall be accomplished by the transmission of an active indication in a STATUS message or the clearing of an alarm indication exiting the section under test.

Periods of scheduled unavailability are excluded.

NOTE – In this case, availability is being assessed only on the ability of a virtual connection to transmit frames. The achieved quality of service (judged, for example, by Frame Loss Ratio) is not considered.

Annex C

Use of FR OAM non-latching loopback messages for estimation of Frame Relay connection availability when using connectivity as the outage criteria

C.1 Introduction

This annex describes a method for estimating bidirectional virtual connection availability. This estimation is based on the use of FR OAM non-latching loopback messages as defined in FRF.19 and ITU-T Rec. X.151. The criterion is based on the outage of a connection. When a connection experiences an outage, it is defined as unavailable. When the connection exits outage, the connection is defined as available.

NOTE – FR OAM loopback capability can be used for fault isolation and connection management. Frame Relay OAM diagnostics may be performed on a segment of a VC between two OAM devices belonging to the same domain. There are two forms of diagnostics supported by FRF.19, a latching VC loopback and a non-latching loopback:

- Latching loopback is a service maintenance action that will remove the VC from service – (i.e., user data frames will not be able to be sent over the VC where the loopback is applied).
- non-latching loopback is used to echo an individual OA&M frame without taking the VC out of service. The non-latching loopback message causes only the non-latching loop message itself to be looped back to the initiator and can thus be used for in-service estimation.

This estimation method may not detect some shorter interruptions which are strictly unavailable time. However, as it is expected that most fault events causing outages will result in greater than 10 seconds of interruption to the service, it is considered that this technique should yield a satisfactory estimation.

Consider a connection or portion of a connection delimited by Frame Relay OAM Maintenance Points (FROMP) X and Y, as shown in Figure C.1. If and only if both virtual connections X → Y and Y → X are available, the connection (X, Y) is said to be available; otherwise the connection (X, Y) is said to be unavailable

NOTE 1 – OAM loopback frames can be initiated at either Frame Relay OAM Maintenance Point (FROMP) X or Measurement Point Y.

NOTE 2 – Generally, an observer at a measurement point judges whether the incoming connection is available based on the incoming data stream, and this judgement is known as near-end estimation. In the case where Measurement Point X initiates the OAM loopback frames, X is called the *Near end*, with frames heading from X to Y being considered to be travelling in the forward direction. When the frames reach Y (*Far end*) they are echoed back to X and are considered to be travelling in the backward direction.

NOTE 3 – As evident from Figure C.1, it is clear that the measurement is symmetrical with respect to the estimation method defined below. Consequently, it is immaterial whether the measurement point is taken as either X or Y in what follows.

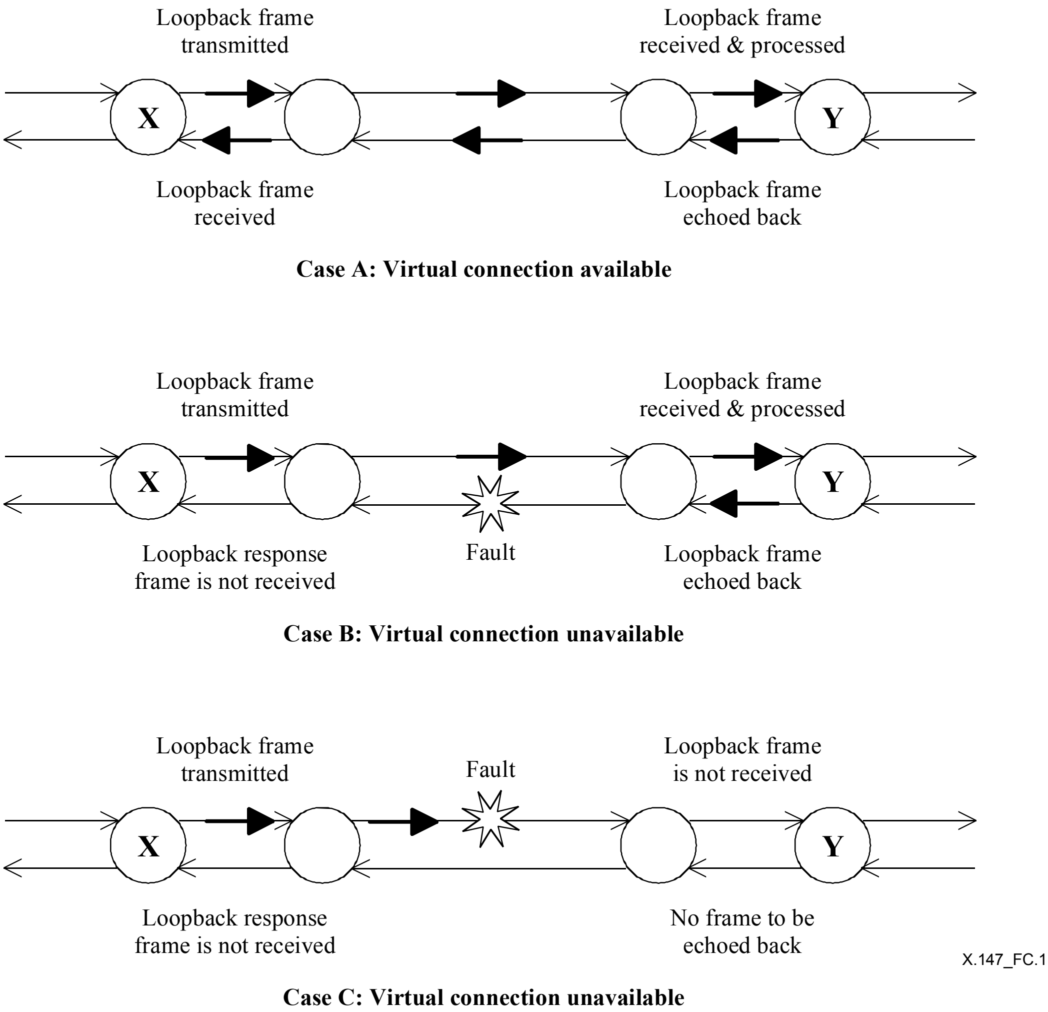

Figure C.1/X.147 – Use of FR OAM loopback for fault detection

One advantage of the estimation method described in this clause is that it can provide the bidirectional availability estimation at one measurement point. In other words, this method can give both near-end and far-end availability estimations of the connection from one measurement point.

For the following estimation method, the non-latching loopback OAM message functionality (of FRF.19) must be activated on the connection which is undergoing the availability estimation.

NOTE – Prior to the regular transmission of loopback messages, a FROMP must initiate a request for a peer device to perform a non-latching loopback by using the non-latching loopback message with the latched loopback code of the non-latching loopback information field set to request.

C.2 The declaration from connection available to connection unavailable

When the connection is in the available state:

a) The near end (X) will regularly transmit a non-latching loopback message using a specific destination location which designates the far end (Y). non-latching loopback messages will be sent at regular intervals. It is recommended that a Non-latching loopback message is sent every one second. Network Operators may choose other interval periods.

b) On receiving the Non-latching loopback message, the far end (Y) must determine if the message's Domain Identification indicates membership within one of the domains supported at the receiving location and if the message's Destination Location Indicator indicates this OAM device. If the message is addressed for this location and the device supports this capability, then the message is processed. The far end responds with a Non-latching loopback message of identical length and content, with the information field set to indicate a response. On receipt of the non-latched loopback response, at (X) the message is terminated.

c) If there is a physical layer failure, on either the forward or backward direction, between the MPs (as shown in Case B and Case C of Figure C.1) the non-latched loopback response message will not be received back at Measurement Point (X). Assume that Non-latching loopback messages are being transmitted at one-second intervals. In the course of normal operations it is expected that a response message would be received within approximately 400 ms. The period of time during which response messages are not received count as unavailable time.

NOTE – Due to the nature of Frame Relay networks, frames may be discarded due to network congestion. Accordingly, the loss of a single loopback response frame may not necessarily mean that there is a physical fault on the connection, but may imply significant congestion. In the case where a Non-latching loopback message is being sent every one second and although there is no physical fault condition, loopback response frames are still not received, the period of time would be declared as unavailable due to the Frame Loss Ratio threshold being exceeded.

C.3 The declaration from connection unavailable to connection available

When the connection is in the unavailable state:

a) The near end node will continue to transmit non-latched loopback messages at the defined insertion interval. As soon as the near-end node (X) receives a non-latched loopback response message from the far end (Y), the virtual connection will exit the unavailable state. At that time, the bidirectional connection will become available.

b) If the virtual connection was in the unavailable state and either the near end or far end starts receiving user information frames, the virtual connection will exit the unavailable state.

C.4 In-service estimation of availability

Once periods of time have been declared as available or unavailable based on the receipt or non-receipt of loopback response frames, the value of the Availability Ratio and MTBO parameters (for a defined observation period) can then be calculated as follows:

- The Availability Ratio is estimated as the ratio of the accumulated durations of the availability periods to the duration of the observation period.
- The MTBO is estimated as the mean time between successive unavailability periods.

Annex D

Use of FR OAM to monitor Frame Loss Ratio in order to assess availability

This annex describes a method for estimating availability when Frame Loss Ratio is used as the outage criteria. ITU-T Rec. X.148 specifies procedures for the estimation of Frame Loss Ratio using X.151 | FRF.19 OAM procedures. The procedure specified in ITU-T Rec. X.148 actually measures the Frame Delivered Ratio which is the complement of Loss Ratio. In general the procedure is well suited to estimating the long-term Frame Loss Ratio, but may be used to assess the FLR over shorter periods.

Annex A specifies:

– User Information Frame Loss Ratio (for offered traffic conforming with the CIR); and

– User Information Frame Loss Ratio (for offered traffic conforming with EIR);

as outage criteria that may be used for computing availability.

NOTE – X.151 | FRF.19 OAM enables counts to be made of offered and received frames for both the CIR and EIR traffic streams.

In assessing Frame Loss Ratio, the assessment is made over a defined measurement period. In order to capture periods where the Frame Loss Ratio exceeds the threshold, the measurement period must be sufficiently short.

It is recommended that the Frame Loss Ratio performance be assessed across periods of time between ten seconds and five minutes in duration. The Frame Delivered Ratio/Frame Loss Ratio can be computed for each period of time. If the Frame Loss Ratio for the CIR traffic stream (in the case CIR > 0) is greater than 10% or the Frame Loss Ratio for the EIR traffic stream (in the case CIR = 0) is greater than 25%, then the time over which the assessment was made should count as unavailable time.

Network operators may optionally choose not to monitor the FLR for the EIR traffic stream and judge availability on the quality of the CIR traffic stream alone.

Annex E

Calculation of Mean Network Availability Ratio based on the measurement of individual Virtual Connection Unavailability

This annex provides an expression for calculating a value for overall network availability from measurements of virtual connection unavailability. The expression is independent of how unavailability is defined for a virtual connection or how it might be measured.

Define the following parameters:

- N is the total number of frame relay virtual connections in the network.
- T (seconds) is the interval over which availability will be evaluated.
- U_i (seconds) is the amount of time for which a virtual connection i ($1 \le i \le N$) is unavailable during the evaluation interval T.
- R_i is the unavailability ratio for virtual connection i ($1 \le i \le N$), i.e., $R_i = U_i/T$
- A is the average network availability ratio assessed over time T.

The average unavailability ratio within the network is then:

$$R_u = \frac{\sum_{i=1}^{N} U_i}{NT} \text{ or, equivalently, } R_u = \frac{\sum_{i=1}^{N} R_i}{N}.$$

Mean Availability Ratio within the network is:

$$A = (1 - R_u) \times 100\%$$

Appendix I

Sampling estimation of PVC availability parameters

I.1 A minimal test for PVC service availability

The definition of Permanent Virtual Circuit (PVC) service availability (as defined in A.1.1) requires that observed performance for all four decision parameters be compared with outage thresholds. A single success of the following test is defined to be sufficient for declaring the PVC section available. A single failure of a section to meet any of the four individual criteria is defined to be sufficient for declaring the PVC section unavailable. This test and its decision criteria are defined to be the minimum criteria necessary to sample the availability of the section.

The minimal availability test can be performed in either direction across the section by equipment and components outside of the section. To ensure that the availability test does not fail as a result of insufficient or excessive input, for five minutes attempt to maintain DE = 0 traffic conforming with CIR, if CIR > 0, and DE = 1 traffic conforming to EIR, if CIR = 0. There are three criteria for deciding if the test has failed or succeeded:

1a) (CIR > 0) – The test fails if the FLR_c is greater than C_1;

1b) (CIR = 0) – The test fails if the FLR_e is greater than C_2;

2) The test fails if the RFER is greater than C_3;

3) The test fails if the Extra Frame Rate is greater than C_4.

If a test passes the decision criteria, the test is successful and the PVC supported by the section is considered to be available during the test. If the section fails the test for one or more decision criteria, the PVC supported by the section is considered to have been unavailable for the duration of the test.

NOTE – The threshold values (C_1, C_2, C_3, C_4) are defined in Table A.1.

I.2 Procedures for estimating PVC service availability

A sufficient estimate of PVC service availability percentage can be computed as follows. Based on an *a priori* estimate of the service availability, choose sample sizes not less than 300. Choose *s* testing times during scheduled service time and distribute them across a long measurement period (for instance, six months). Because of the expected duration of service outages, 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 scheduled service time. At each predetermined testing time, perform the availability test described in I.1. If the test fails, the section is declared unavailable for that sample. Otherwise, the section is declared available. The estimate of the PVC service availability percentage is the number of times the section was declared available, multiplied by 100, and divided by the total number of samples.

I.3 Procedures for estimating mean time between PVC service outages

A sufficient estimate of the mean time between PVC service outage parameter 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 or 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 PVC service outages. For the duration of each predefined interval conduct consecutive availability performance samples. The amount of time observed in the available state will be added to a cumulative counter called *A*. The number of observed transitions from the available state to the unavailable state will be accumulated in a counter called *F*[1].

For each predefined interval:

a) If all of the consecutive availability samples succeed, then add the total length of the interval to *A*. Do not change the cumulative value of *F*;

b) If the first availability sample succeeds and any subsequent sample in the interval fails, increase *F* by one. Add to *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;

c) If the first availability sample fails, assume that the state transition occurred before the interval began. Add nothing to the count of observed availability time, *A*. Add nothing to the cumulative count of observed state changes, *F*. The remaining time in the interval may be discarded without testing its availability.

After the results of every predefined interval have been accumulated, the ratio, *A/F*, is an estimate of the mean time between PVC service outages. A statistically more precise estimate can be obtained by increasing the number of observed intervals, *k*.

The estimate of mean time between PVC service 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 service 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 PVC section 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 PVC service may be long 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, will not bias the result[2]. 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 restore PVC service and the expected time between PVC service outages. Thus, each test should be no longer than three hours.

There are two sources of bias in the estimation procedure described in I.3. 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 PVC service 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 PVC service 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, using five-minute availability samples.

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1 Each counter is initially set to zero.

2 If outages tend to be clustered, discontinuing a test following a transition to the unavailable state will tend to overestimate the mean time between service 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 service outages.

Alternatively, both biases can be corrected by replacing instruction a) in I.3 with:

a) If all of the consecutive availability samples succeed, then add the total length of the interval to A. Take one additional availability sample immediately following the interval. If that sample fails, increase F by one. If that sample succeeds, do not change F. The length of the additional sample has no effect on 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 PVC service outages can be more accurately estimated.

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