INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

X.144

(04/95)

DATA NETWORKS AND OPEN SYSTEM COMMUNICATIONS – PUBLIC DATA NETWORKS – NETWORK ASPECTS

USER INFORMATION TRANSFER PERFORMANCE PARAMETERS FOR DATA NETWORKS PROVIDING INTERNATIONAL FRAME RELAY PVC SERVICE

ITU-T Recommendation X.144

(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 X.144 was prepared by ITU-T Study Group 7 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 10th of April 1995.

____

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

ITU-T X-SERIES RECOMMENDATIONS

DATA NETWORKS AND OPEN SYSTEM COMMUNICATIONS

(February 1994)

ORGANIZATION OF X-SERIES RECOMMENDATIONS

Subject area	Recommendation Series
PUBLIC DATA NETWORKS	
Services and Facilities	X.1-X.19
Interfaces	X.20-X.49
Transmission, Signalling and Switching	X.50-X.89
Network Aspects	X.90-X.149
Maintenance	X.150-X.179
Administrative Arrangements	X.180-X.199
OPEN SYSTEMS INTERCONNECTION	
Model and Notation	X.200-X.209
Service Definitions	X.210-X.219
Connection-mode Protocol Specifications	X.220-X.229
Connectionless-mode Protocol Specifications	X.230-X.239
PICS Proformas	X.240-X.259
Protocol Identification	X.260-X.269
Security Protocols	X.270-X.279
Layer Managed Objects	X.280-X.289
Conformance Testing	X.290-X.299
INTERWORKING BETWEEN NETWORKS	
General	X.300-X.349
Mobile Data Transmission Systems	X.350-X.369
Management	X.370-X.399
MESSAGE HANDLING SYSTEMS	X.400-X.499
DIRECTORY	X.500-X.599
OSI NETWORKING AND SYSTEM ASPECTS	
Networking	X.600-X.649
Naming, Addressing and Registration	X.650-X.679
Abstract Syntax Notation One (ASN.1)	X.680-X.699
OSI MANAGEMENT	X.700-X.799
SECURITY	X.800-X.849
OSI APPLICATIONS	
Commitment, Concurrency and Recovery	X.850-X.859
Transaction Processing	X.860-X.879
Remote Operations	X.880-X.899
OPEN DISTRIBUTED PROCESSING	X.900-X.999

CONTENTS

SUMMARY

This Recommendation defines speed, accuracy, dependability, and availability parameters that may be used in specifying and assessing user information transfer performance of public frame relay data communication services.

Recommendation X.144

USER INFORMATION TRANSFER PERFORMANCE PARAMETERS FOR DATA NETWORKS PROVIDING INTERNATIONAL FRAME RELAY PVC SERVICE

(Genève, 1995)

1 Scope

This Recommendation defines speed, accuracy, dependability, and availability parameters that may be used in specifying and assessing user information transfer performance of public frame relay data communication services. The defined parameters apply to end-to-end, point-to-point frame relay connections[1)] and to specified portions of such connections when provided in accordance with the Recommendations specified in clause 2.

The performance parameters defined in this Recommendation are intended to be used in the planning of international frame relay services. The intended users of this Recommendation include frame relay service providers, equipment manufacturers, and end users. This Recommendation may be used:

1) by service providers in the planning, development, and assessment of frame relay services that meet user performance needs;
2) by equipment manufacturers as performance metrics that will affect equipment design; and
3) by users in evaluating performance.

The scope of this Recommendation is summarized in Figure 1. The frame relay performance parameters are defined on the basis of frame transfer reference events that may be observed at physical interfaces associated with specified boundaries. For comparability and completeness, frame relay performance is considered in the context of the 3 × 3 performance matrix defined in Recommendation X.140. Three protocol-independent data communication functions are identified in the matrix: access, user information transfer and disengagement. Each function is considered with respect to three general performance concerns (or "performance criteria"):

– speed;
– accuracy; and
– dependability.

An associated two-state model provides a basis for describing Permanent Virtual Circuit (PVC) service availability.

The performance parameters defined in this Recommendation describe the speed, accuracy, dependability, and availability of user information transfer provided by frame relay networks. Other planned Recommendations will provide standard methods of measuring the frame transfer performance parameters and specific design objectives for the X.144 parameters. The performance of the frame relay access and disengagement functions, as well as the availability performance of Switched Virtual Circuit (SVC) frame relay services, will be addressed in separate Recommendations.

NOTES

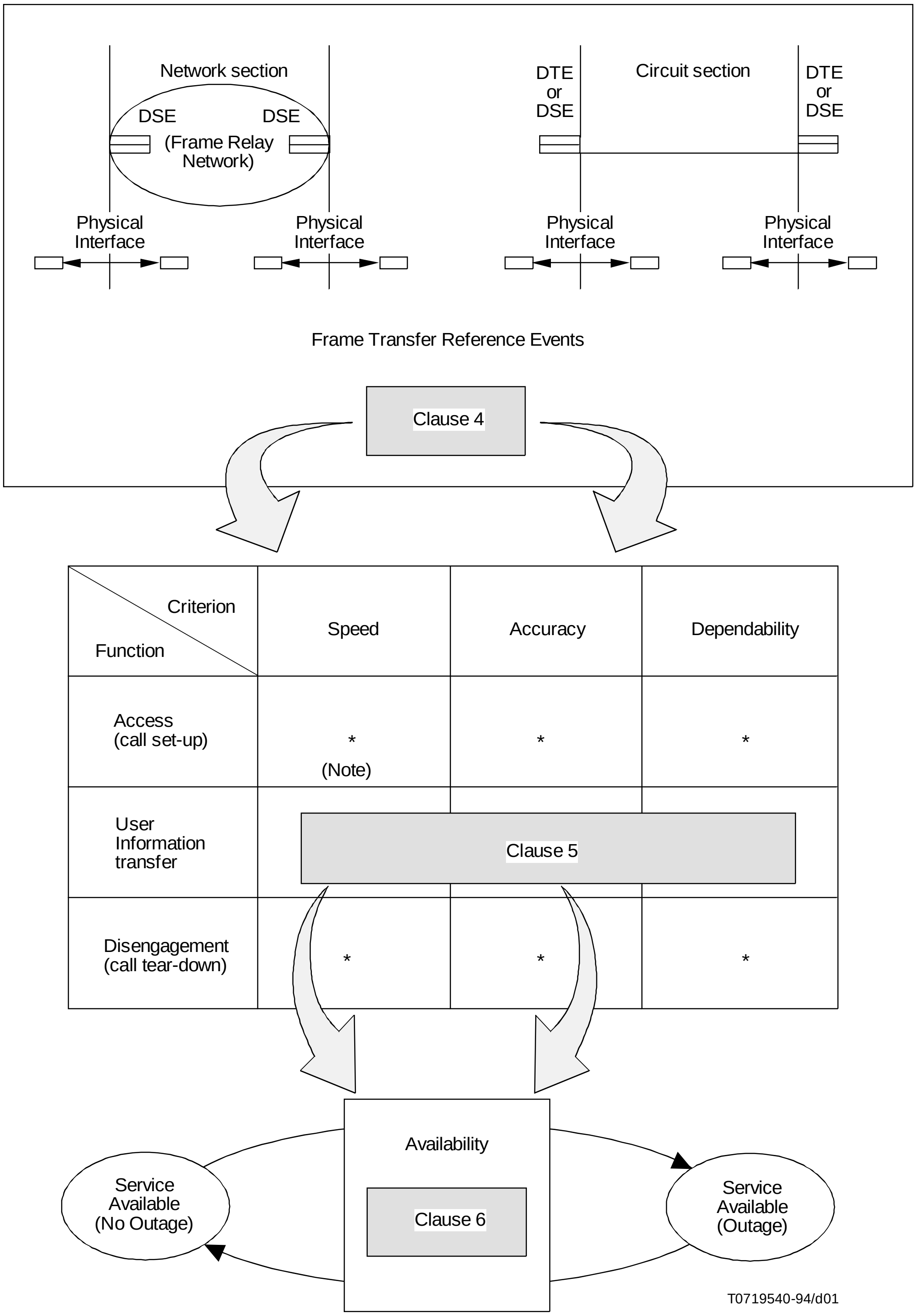
1 The parameters defined in this Recommendation may be augmented or modified based upon further study of the requirements of the frame relay supported on networks.

2 The defined parameters are intended to characterize frame relay connections in the available state.

3 The parameters of this Recommendation are designed to measure the performance of network elements between pairs of section boundaries. However, users of this Recommendation should be aware that the behavior of connection elements outside the pair of boundaries can adversely influence the measured performance of the elements between the boundaries. Examples are described in Appendix III.

---

1) In the context of this Recommendation, a frame relay connection (denoted hereafter, unless noted otherwise, by the term *connection*) refers to a virtual connection established between two specified end points.



NOTE – Subject of future switched virtual circuit frame relay performance standard.

FIGURE 1/X.144

Scope of Recommendation X.144

This Recommendation is organized as follows:

- Clause 2 presents references.
- Clause 3 presents abbreviations.
- Clause 4 defines a performance model and a set of frame transfer Reference Events (FEs) that provide a basis for performance parameter definition.
- Clause 5 defines frame-based speed of service, accuracy, and dependability parameters using the frame transfer reference events defined in clause 4.
- Clause 6 defines the PVC availability parameters using the primary parameters defined in clause 5.
- Annex A presents a test for judging traffic conformance for performance assessment purposes. Annex B defines bit-based accuracy and dependability parameters associated with the transfer of user information in frame relay services. Appendix I provides information on sampling estimation of the PVC availability parameters. Appendix II discusses the performance effects of network indications of congestion and makes general recommendations for controlling these effects. Appendix III discusses performance effects of excessive demand for connection resources.

2 References

The following Recommendations, and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision: all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of currently valid ITU-T Recommendations is regularly published.

- CCITT Recommendation I.122 (1988), *Framework for providing additional packet mode bearer services*.
- CCITT Recommendation I.233 (1991), *Frame mode bearer services*.
- CCITT Recommendation I.233.1 (1991), *ISDN frame relaying bearer service*.
- CCITT Recommendation I.370 (1991), *Congestion management for the ISDN frame relaying bearer service*.
- ITU-T Recommendation X.36 (1994), *Interface between Data Terminal Equipment (DTE) and Data circuit-terminating Equipment for public data networks providing frame relay data transmission service by dedicated circuit*.
- ITU-T Recommendation X.76 (1995), *Network-o-network interface between public data networks providing the frame relay data transmission service*.

3 Abbreviations

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

ACS	Access Circuit Section
ANS	Access Network Section
Bc	Committed Burst Size
BCTDR	Bit-based Conformant Traffic Distortion Ratio
Be	Excess Burst Size
BECN	Backward Explicit Congestion Notification
BLR	Bit Loss Ratio

CIR	Committed Information Rate
CLLM	Consolidated Link Layer Management
DE	Discard Eligible
DLCI	Data link Connection Identifier
DSE	Data Switching Exchange
DTE	Data Terminal Equipment
EFR	Extra Frame Rate
EIR	Excess Information Rate
FCTDR	Frame-based Conformant Traffic Distortion Ratio
FE	Frame Layer Reference Event
FECN	Forward Explicit Congestion Notification
FLR	Frame Loss Ratio
ICS	Internetwork Circuit Section
ISDN	Integrated Services Digital Network
MTBSO	Mean Time between Service Outages
MTTSR	Mean Time to Service Restoral
NT	Network Termination
PVC	Permanent Virtual Circuit
RBER	Residual Bit Error Ratio
RFER	Residual Frame Error Ratio
SA	Service Availability
SVC	Switched Virtual Circuit
TE	Terminal Equipment
TNS	Transit Network Section

4 Generic performance model

This clause defines a generic frame relay service performance model composed of four basic connection sections:

– the access circuit section;

– the internetwork circuit section;

– the access network section; and

– the transit network section.

These four basic connection sections are defined in 4.1. They provide a set of building blocks with which any end-to-end connection can be represented. Each of the performance parameters defined in this Recommendation can be applied to the unidirectional transfer of user information on a connection section or a concatenated set of connection sections.

Clause 4 also specifies a set of frame transfer reference events that provide a basis for performance parameter definition. These reference events are derived from and are consistent with relevant ITU-T frame relay service and protocol Recommendations. The reference events are specified in 4.2.

This Recommendation provides parameters for quantifying performance at the top of the data link (i.e. frame) layer Service Access Point (SAP). Quantitative relationships between frame layer network performance and the performance of the physical layer and the performance of layers above the frame layer (e.g. applications) are for further study.

4.1 Components of an end-to-end connection

In the context of this Recommendation, an end-to-end connection is composed of sections as defined below. The defined terms are shown in Figure 2.

4.1.1 circuit section: Either an access circuit section or an internetwork circuit section.

4.1.1.1 access circuit section (ACS): The physical circuit or set of circuits connecting a Data Terminal Equipment (DTE)[2)] to the (local) Data Switching Exchange (DSE). It does not include any parts of the DTE or DSE.

4.1.1.2 internetwork circuit section (ICS): The physical circuit or set of circuits connecting a DSE in one network with a DSE in a different network. It does not include any parts of either DSE.

4.1.2 network section: The network components that provide the connection between two circuit sections. A network section may be either an access network section or a transit network section.

4.1.2.1 access network section (ANS): A network section connected to (at least) one access circuit section.

4.1.2.2 transit network section (TNS): A network section between two internetwork circuit sections.

4.1.3 basic section of a connection: A general term for an access circuit section, an internetwork circuit section, an access network section, or a transit network section.

4.1.4 section boundary: The boundary that separates a network section from the adjacent circuit section, or separates an access circuit section from the adjacent DTE. (Also called *boundary*.)

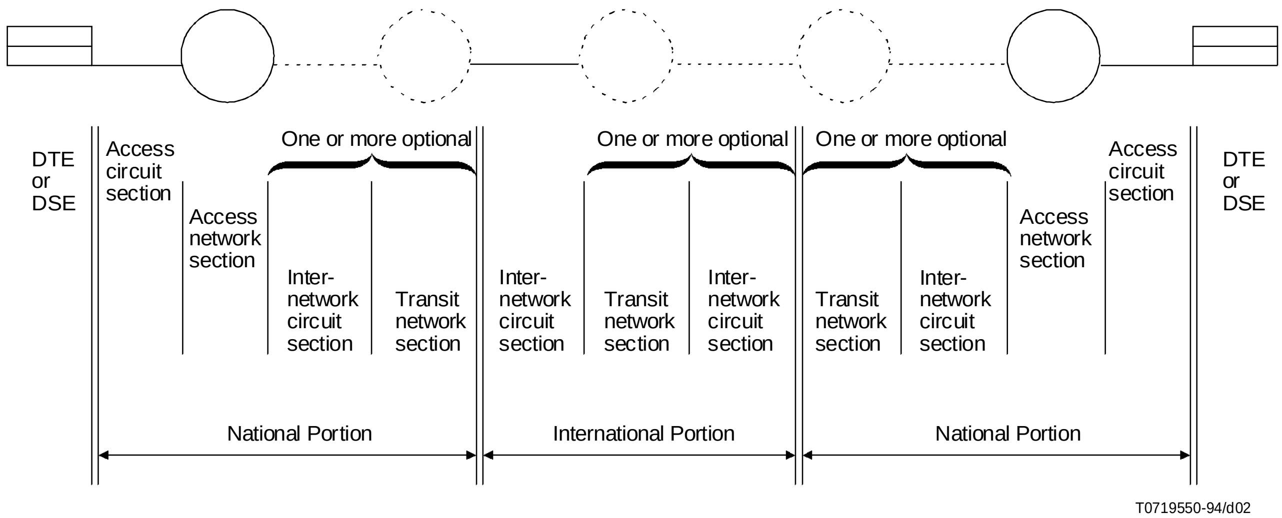


FIGURE 2/X.144

Sections of an international virtual connection

2) In the context of this Recommendation, routers are considered as DTEs.

4.2 Frame transfer reference events

In the context of this Recommendation, the following definitions apply on a specified connection. The defined terms are illustrated in Figure 3.

4.2.1 frame transfer reference event: The event that occurs when:

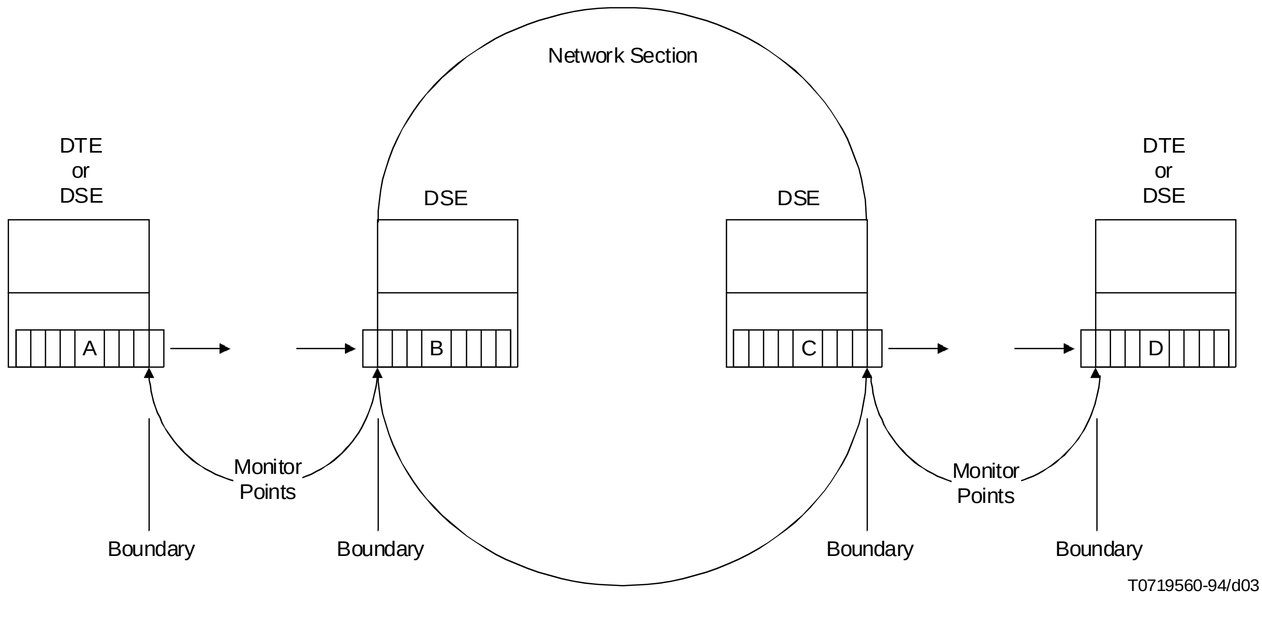
- a frame crosses a section boundary, and
- the frame is identified as a user information frame; and
- the DLCI field indicates that the frame belongs to this connection.

Frame transfer reference events can be observed at the physical boundaries terminating a circuit section.

Two classes of frame transfer reference events are defined:

4.2.1.1 frame entry event: A frame transfer reference event that corresponds to a frame entering a network section (from a circuit section) or a frame entering a DTE (from an access circuit section). The time of occurrence of a frame transfer entry event is defined to coincide with the time at which the last bit of the closing flag of the frame crosses the boundary into the network section or DTE.

4.2.1.2 frame exit event: A frame transfer reference event that corresponds to a frame exiting a network section (to a circuit section) or a frame exiting a DTE (to an access circuit section). The time of occurrence of a frame transfer exit event is defined to coincide with the time at which the first bit of the address field of the frame crosses the boundary out of the network section or DTE.



NOTES

1 Frame exit events for A and C.

2 Frame entry events for B and D.

FIGURE 3/X.144

Example frame transfer reference events

4.3 Frame transfer outcomes

In the following, it is assumed that the sequence of frames on a connection is preserved. Two events on a connection are said to be corresponding if they can be related to the same source frame.

By considering two frame transfer reference events, FE_1 and FE_2 at B_i and B_j,[3] respectively, four basic frame transfer outcomes may be defined. A transmitted frame is either *successfully transferred*, *residually errored*, or *lost*. A received frame for which no corresponding transmitted frame exists is said to be *extra*. Extra frames can occur as a result of errors in the address of a frame from a different connection[4]. Figure 4 illustrates the four basic frame transfer outcome definitions.

4.3.1 successful frame transfer outcome: A successful frame transfer outcome occurs when an FE_2 corresponding to FE_1 happens within a specified time T_{max} after FE_1 and:

1) the CRC of the received frame is valid; and
2) the binary content of the user information field of the received frame conforms exactly with that of the corresponding transmitted frame.

For performance purposes, T_{max} is a time limit beyond which a frame is assumed to be lost.

NOTE – The value of T_{max} is for further study.

4.3.2 residually errored frame outcome: A residually errored frame outcome occurs when an FE_2 corresponding to FE_1 happens within a specified time T_{max} of FE_1 and the CRC of the received frame is valid but the binary content of the received frame user information field differs from that of the corresponding transmitted frame (i.e. one or more bit errors exist in the received frame user information field).

4.3.3 lost frame outcome: A lost frame outcome occurs when an FE_2 fails to happen within time T_{max} of the corresponding FE_1 or the CRC of the received frame is invalid. The value of T_{max} is the same as that used in the definition of the successfully transferred frame outcome.

4.3.4 extra frame outcome: An extra frame outcome occurs when an FE_2 happens without a corresponding FE_1.

5 Frame transfer performance parameters

This clause defines five speed of service, accuracy, and dependability parameters associated with the transfer of user information frames:

– frame transfer delay;
– user information frame loss ratio;
– residual frame error ratio;
– extra frame rate; and
– frame-based conformant traffic distortion ratio.

All parameters may be estimated on the basis of observations at the section boundaries. Figure 5 shows the statistical populations used to calculate selected accuracy and dependability parameters[5].

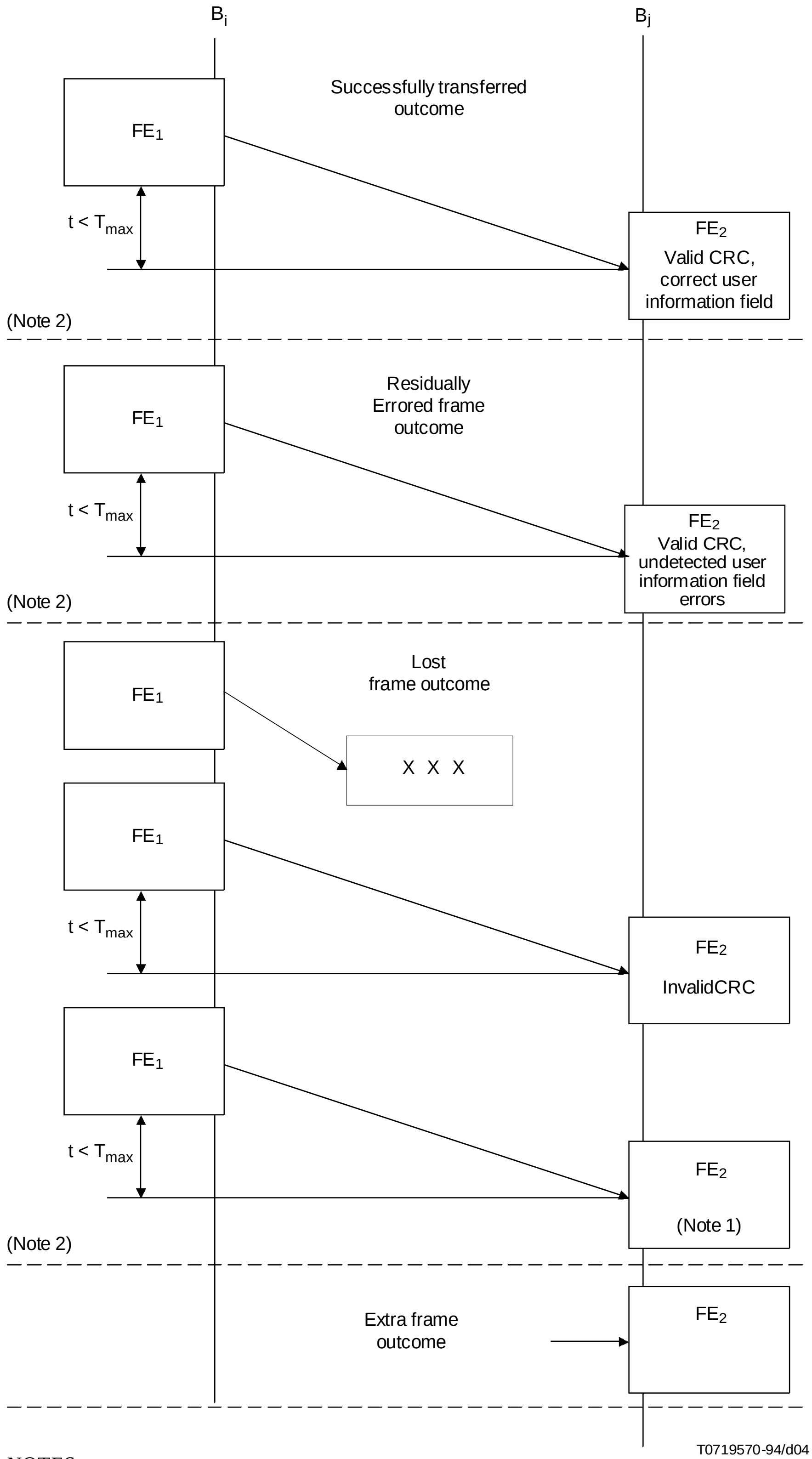
NOTE – Annex B defines three supplementary, bit-based accuracy and dependability parameters associated with the transfer of user information in frame relay services: user information bit loss ratio, residual bit error ratio, and bit-based conformant traffic distortion ratio. These parameters are relatable to the frame-based parameters defined in clause 5 (see Figure 5).

---

[3] Unless otherwise noted in this, boundaries B_i and B_j refer, respectively, to the frame input and frame output boundaries delimiting and arbitrary connection section or concatenated set of connection sections. Performance parameters are defined with respect to a unidirectional transfer of frames.

[4] Missequenced or duplicated frames are not anticipated. If an unanticipated network mechanism creates these events, measurement systems may categorize them as combinations of lost, residually errored, or extra frame outcomes.

[5] As shown in Figure 5, a successfully transferred or residually errored frame outcome is referred to as a "relayed frame".



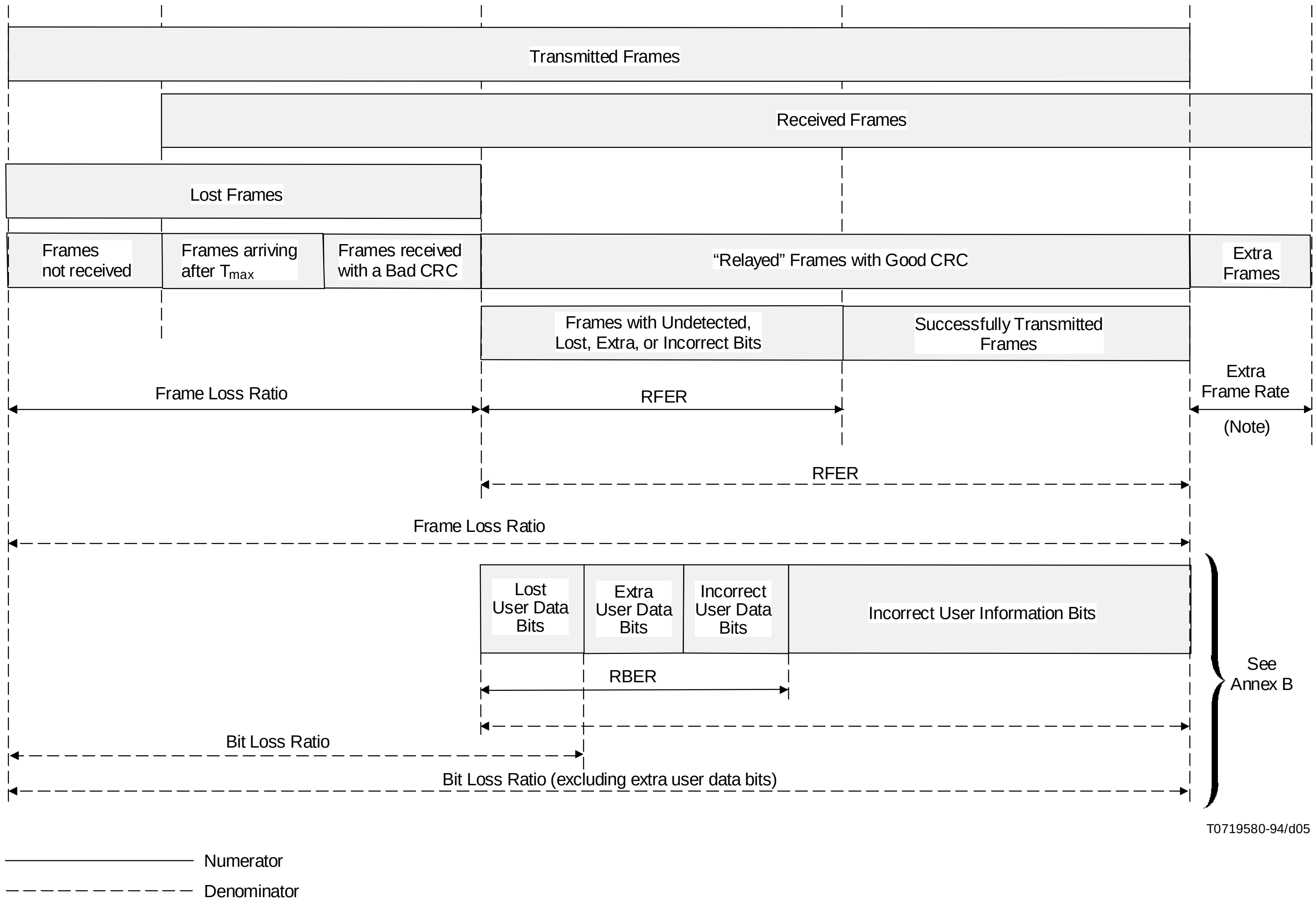
NOTES

1 Outcome occurs independently of CRC validity.

2 The variable t denotes elapsed time.

FIGURE 4/X.144

Frame transfer outcomes



NOTE – Measured as a rate, not a ratio.

FIGURE 5/X.144

Statistical populations used in defining selected accuracy and dependability parameters

5.1 User information frame transfer delay

The **user information frame transfer delay (FTD)** is defined as:

$$FTD = t_2 - t_1$$

where, in a specified population:

- t_1 is the time of occurrence for the first FE;
- t_2 is the time of occurrence for the second FE; and
- $t_2 - t_1 \leq T_{max}$.

The end-to-end user information frame transfer delay is the one-way delay between DTE boundaries (for example, B_1 and B_n in Figure 6).

5.2 User information frame loss ratio

The **user information frame loss ratio (FLR)** is defined as:

$$FLR = \frac{F_L}{F_L + F_S + F_E}$$

where, in a specified population:

- F_S is the total number of successfully transferred frame outcomes;
- F_L is the total number of lost frame outcomes; and
- F_E is the total number of residually errored frame outcomes.

Two special cases are of particular interest FLR_c et FLR_e.

5.2.1 FLR_c

The FLR for frames marked DE = 0 should remain relatively constant as long as the total DE = 0 traffic does not exceed the CIR = Bc/T_c. If the total DE = 0 traffic exceeds the CIR, some DE = 0 frames may be immediately discarded or converted to DE = 1 frames, possibly increasing the FLR for DE = 0 traffic[6)].

FLR_c is defined as the FLR for a population of frames with DE = 0 when all DE = 0 frames are conforming with the CIR. If the network accepts all conforming frames in accordance with the test described in Annex A, FLR_c is the probability that a DE = 0 frame accepted as conforming will subsequently be lost. Conformance with CIR is judged using the test described in Annex A.

NOTE – DE = 0 frames relayed with the DE bit changed to DE = 1 are included in the calculation of FLR_c.

5.2.2 FLR_e

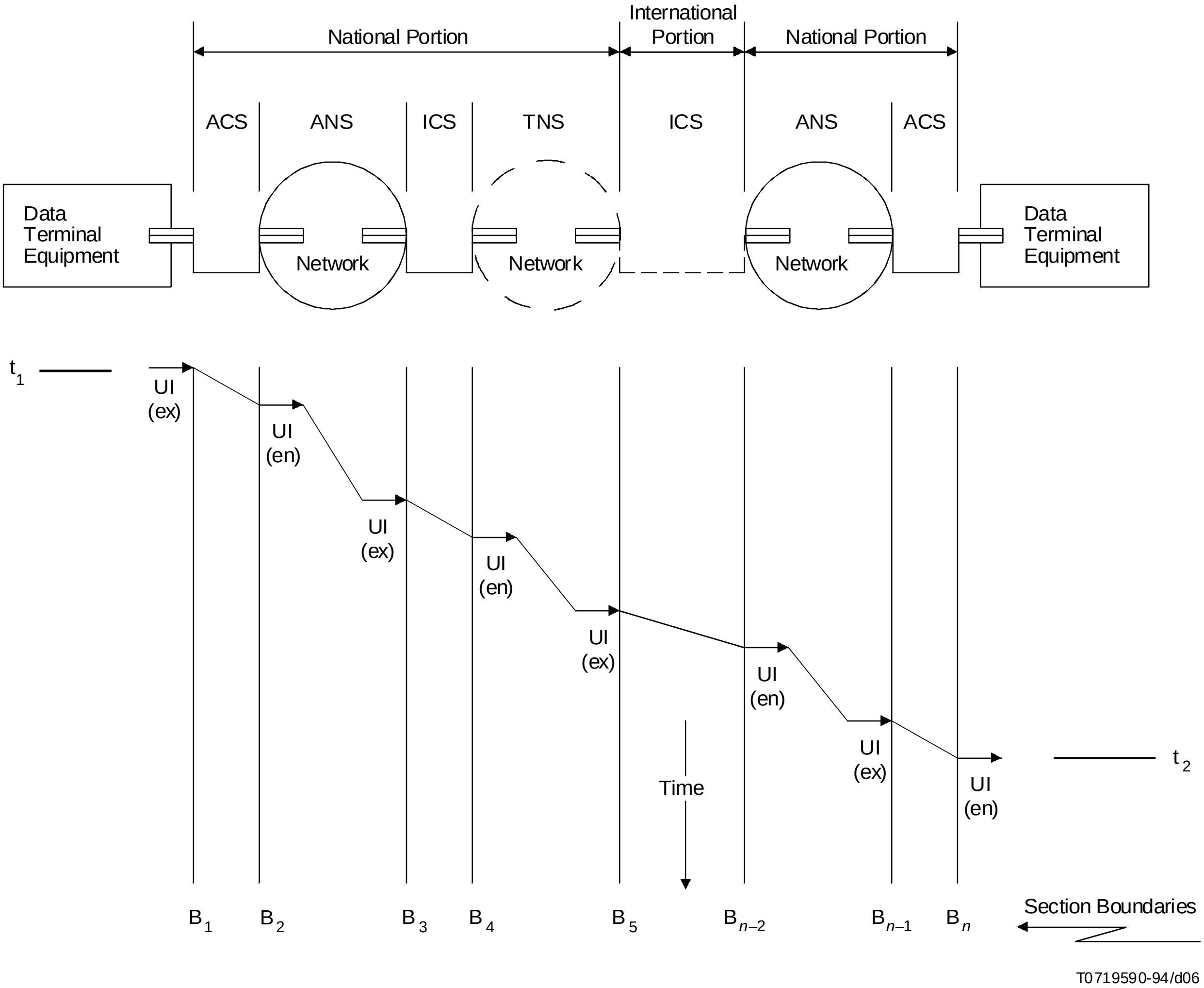
Frames can be marked DE = 1 either before or immediately after crossing the input section boundary. The loss performance for all such frames should remain relatively constant as long as the total DE = 1 traffic does not exceed the EIR = Be/T_c[7)]. If the total DE = 1 traffic exceeds the EIR, some DE = 1 frames may be immediately discarded, possibly increasing the FLR for DE = 1 traffic[8)].

---

6) The rate at which FLR increases when offered traffic exceeds CIR and EIR (= Be/T_c) may vary among network providers. Some network providers explicity offer to transport this extra traffic. Such offerings may have an increased probability of congestion notification, delays, or bursts of loss.

7) Bc, Be, T_c, and CIR are defined in, Recommendation I.370 – *Congestion Management for the ISDN Frame Relaying Bearer Service*, subclause 1.2. Their relationships to each other and to the DE bit are illustrated in 1.6/I.370.

8) See footnote [6)].



UI User Information Transfer FE (specific FEs for further study)

en Entry

ex Exit

NOTE – (t_1 - t_2) may be observed on the calling side and called side of any virtual connection portion.

FIGURE 6/X.144

User information frame transfer delay events

FLR_e is defined as the FLR 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. If the network accepts all conforming frames in accordance with the test described in Annex A, FLR_e is the probability that an input DE = 1 frame accepted as conforming will subsequently be lost. Conformance with EIR and CIR is judged using the test described in Annex A.

For evaluation purposes, as there is no precise way of quantifying the amount of DE = 0 traffic that the network converts to DE = 1, the FLR_e parameter is defined only in terms of frames input as DE = 1. As long as the total DE = 1 traffic does not exceed the EIR, it is expected that network marked DE = 1 traffic will experience loss ratios similar to FLR_e.

5.3 Residual frame error ratio

The **residual frame error ratio (RFER)**[9] is defined as:

$$RFER = \frac{F_E}{F_E + F_S}$$

where, in a specified population:

– F_S is the total number of successfully transferred frame outcomes, and

– F_E is the total number of residually errored frame outcomes.

5.4 Extra frame rate

The **extra frame rate (EFR)** is defined as:

$$EFR = \frac{E_F}{T_{EFR}}$$

where:

E_F is the total number of extra frame outcomes observed during a specified time interval T_{EFR}.

This rate may be expressed as the number of extra frame outcomes per connection second.[10]

5.5 Frame-based conformant traffic distortion ratio

Network caused frame clumping or excess marking of conforming traffic as DE = 1 can result in frame loss in downstream network elements. Therefore, the frame-based conformant traffic distortion ratio (FCTDR) is defined to help in diagnosing problems with FLR.

The relationship between FCTDR and downstream FLR depends strongly on how network providers collaborate to meet their (implied) end-to-end CIR and EIR commitments. In some cases, a downstream network may deliberately provision a larger Bc and Be, or smaller T_c, to compensate for upstream frame clumping. Also FCTDR may not be relevant for terminating devices that do not care about either the burstiness of arrivals or the DE status of frames received. For both these reasons, network objectives for FCTDR performance may not be established.

---

[9] This accuracy parameter refers to the residual (i.e. undetected) user information frame errors caused by transmission or switching impairments introduced on a specified connection.

[10] By definition, an extra frame is a received frame that has no corresponding transmitted frame on that connection. Extra frames on a particular connection can be caused by an undetected error in the address of a frame originated on a different connection or by an incorrectly programmed translation of addresses for frames originated on a different connection. Since neither of these mechanisms has a direct relation to the number of frames transmitted on the observed connection, this performance parameter cannot be expressed as a ratio of frame counts, but only as a rate.

Frames conforming to CIR at an input boundary may be lost, clumped, or tagged as DE = 1 so that the number of frames conforming to CIR at the output boundary is reduced. The frame-based conformant traffic distortion ratio for DE = 0 traffic ($FCTDR_c$) measures the reduction in conforming traffic due to only clumping or tagging.

The **$FCTDR_c$ parameter** is defined as follows:

$$FCTDR_c = \frac{1}{N} \sum_{n=1}^{N} F_n$$

where

$$F_n = \begin{cases} 1 \text{ if frame } A_n \text{ is non-conforming to } \hat{CIR} \text{ at } B_j \\ \quad \text{or is marked DE = 1 at } B_j, \\ 0 \text{ otherwise} \end{cases}$$

and

$\{A_1, A_2, ..., A_N\}$ denotes a sequence of N frames, all input with DE = 0, conforming to CIR at B_i, and are all relayed to B_j.

CÎR is the modification of CIR as described in Annex A.

Frames conforming to EIR at an input boundary, B_i, may be lost or clumped so that the number of frames conforming to EIR at the output boundary is reduced. The frame-based conformant traffic distortion ratio for DE = 1 traffic ($FCTDR_e$) measures the reduction in conforming traffic due only to clumping.

The **$FCTDR_e$ parameter** is defined as follows:

$$FCTDR_e = \frac{1}{N} \sum_{n=1}^{N} F_n$$

where

$$F_n = \begin{cases} 1 \text{ if frame } A_n \text{ is non-conforming to } \hat{EIR} \text{ at } B_j, \\ 0 \text{ otherwise} \end{cases}$$

and

$\{A_1, A_2, ..., A_N\}$ denotes a sequence of N frames, all input with DE = 1, conforming to EIR at B_i, and are all relayed to B_j.

EÎR is the modification of EIR as described in Annex A.

NOTE – The need for objectives for FCTDR is for further study.

5.6 Frame flow related parameters

The need for network performance parameters describing the actual flow of frames in a connection is for further study. Such parameters will be needed if flow control mechanisms are implemented in frame relay services. One useful parameter could be the (positive) difference between the negotiated committed information rate and the actual information transfer rate. Measures of specific flow control mechanisms may also be of value.

NOTE – Appendix II discusses performance effects associated with network indications of congestion (i.e. FECN, BECN, CLLM) and makes general recommendations for controlling these effects.

6 Permanent virtual circuit (PVC) availability

This clause specifies PVC availability parameters for the section types defined in clause 5. A two-state model provides a basis for describing overall PVC service availability. A specified availability function compares the values for a set of "supported" primary parameters with corresponding outage thresholds to classify the service as "available" (no service outage) or "unavailable" (service outage) during successive observation periods. This clause specifies the PVC availability function and defines the PVC availability parameters that characterize the resulting binary random process.

Two availability parameters are defined in clause 6: PVC service availability and mean time between PVC service outages. Each parameter can be applied to any basic section of an end-to-end connection.

6.1 PVC availability function

Four performance parameters, defined in clause 5, 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.

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

TABLE 1/X.144

Outage criteria for the availability decision parameters

Availability decision parameters	Criteria
FLR_c [a)] – 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_c [b)] – 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 trame Error Ratio	$RFER > C_3$
EFR – Extra trame Rate	$EFR > C_4$

a) 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.

b) 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 – 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).

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.

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 four decision criteria is unacceptable.

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 7.

In order to exclude transient impairments from being considered as periods of unavailability, a single test of the availability state must be 5 minutes or longer. In order to reduce the probability of state transitions during a test of the current availability state, each test should be less than 20 minutes.

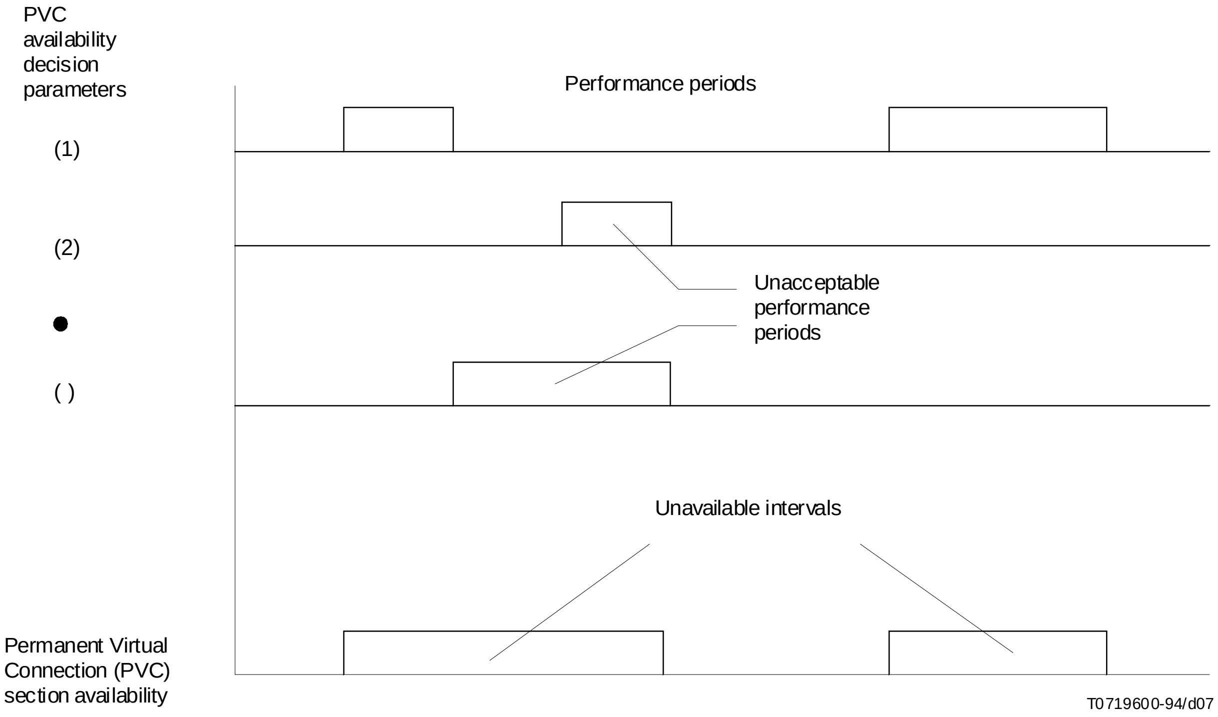


FIGURE 7/X.144

Determination of Frame Relay PVC availability states

6.2 PVC availability parameters

Two availability parameters are defined:

- – PVC Service Availability (SA); and
- – Mean Time Between PVC Service Outages (MTBSO).

6.2.1 Definition of PVC service availability

Service availability as defined in clause 6 applies to PVC services. The **PVC service availability** is the long-term percentage of scheduled service time in which a section or concatenated set of sections is available.

Scheduled service time for a PVC is the time during which the network provider has agreed to make that PVC available for service. Typically, the scheduled service is 24 hours per day, 7 days a week[11)].

6.2.2 Definition of mean time between PVC service outages

Mean time between service outages as defined in clause 6 applies to PVC services. The **mean time between PVC service outages** is the average duration of any continuous interval during which the PVC section or concatenated set of sections is available. Consecutive intervals of scheduled service time are concatenated.

---

11) Other scheduled service times may be specified in some networks.

6.2.3 Related parameters

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

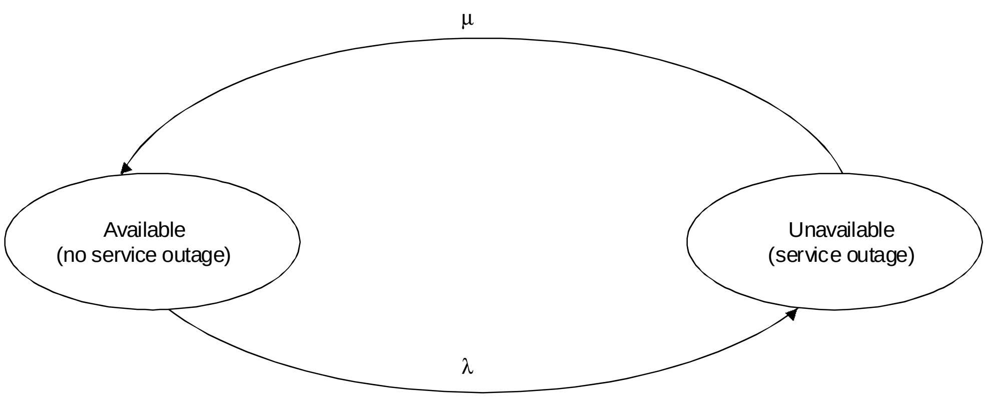
– **mean time to service restoral (MTTSR)** is the average duration of unavailable service time intervals;

– **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 the 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 8.



a) State diagram

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

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

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

T0719610-94/d08

b) Parameter relationships

FIGURE 8/X.144

Basic availability model and parameters

Annex A

Conformance test for performance evaluation

(This annex forms an integral part of this Recommendation)

A.1 Motivation

There are no standards for how networks should determine conformance with CIR and EIR. All reasonable network implementations that normally admit Bc and Be traffic in T_c time units are acceptable. However, FLR_c and FLR_e (in 5.2.1 and 5.2.2), FCTDR (in 5.5) and availability (see clause 6) all require the notion of conformance. For the purposes of evaluating FLR_c, FLR_e, FCTDR, and availability performance in a standard way, it is necessary to have a standard way of determining conformance.

This annex provides the standard test to be used in determining frame relay traffic conformance for the above performance assessment purposes. The test, Called The Double Dangerous Bridge (DDB), was selected because it is believed to be more stringent than any network's implementation of conformance testing in traffic enforcement.

Since networks are allowed to discard (or mark as DE) all frames in excess of CIR or EIR, it is usually desirable that such frames not be counted against a measurement of FLR or FCTDR. The DDB is believed to be at least as stringent in determining conformance as any reasonable frame relay conformance test. Therefore, any frame stream determined by the DDB to be completely conforming will be accepted as completely conforming by any reasonable network. Every frame in those streams should, in principle, be accepted by the network without discard or marking. Thus, frame streams determined to be completely conforming by the DDB are useful for estimating the frame loss performance within a network while avoiding the allowable effects of traffic enforcement.

For the subscriber's benefit, network providers may carry traffic beyond the negotiated CIR and EIR. However, because there is no standardized way in which this extra capacity is offered, this Recommendation does not include performance measures for such offerings. Users of this capacity should be aware that there may be an accompanying increased probability of FECNs, BECNs, CLLMs, frame loss, delay, and conformance distortion.

A.2 Limited standardized use

The only standardized use for the DDB is for the performance evaluation purposes described above. It is not a standard for implementation within networks. However, designs for traffic enforcement can be compared with the DDB to confirm that they are less stringent and more accepting than the DDB. As defined, the DDB is believed to be so stringent that it is highly unlikely that any practical enforcement policy would reject frames approved by the DDB.

A.3 DDB Definition

The DDB algorithm computes the total number of user data bits in a sliding window of time duration T_c. Two comparisons are made with B_x, where B_x is either Bc or Be, depending on whether the CIR or EIR is being evaluated. The first compares the total number of user data bits included in information frames for which the first bit of the frame is within the current window and the second compares the total number of user data bits included in information frames for which the last bit of the frame is within the current window. If either of these numbers exceeds B_x, a frame in the window is declared non-conforming. It is clear from this description that the DDB never allows more than B_x data bits into any T_c window and this is not true for any (currently) known traffic enforcement policy. Furthermore, with some minimal assumptions about traffic enforcement, the maximally stringent nature of the DDB can be rigorously demonstrated.

An implementation of the DDB is shown in Figure A.1. The DDB can be implemented in alternative ways; however, any such implementation must yield the same decisions about conformance as the algorithm presented here.

Two total counts are calculated for a frame stream at the specified boundary:

1) The variable count_fbw is the total cumulative count of user data bits in frames whose first bits are in the T_c window. The variable fbw_list is the list of frames with their first bits in the current T_c window.

2) The variable count_lbw is the total cumulative count of user data bits in frames whose last bits are in the T_c window. The variable lbw_list is the list of frames with their last bits in the current T_c window.

If B_x is exceeded by either of these two counts, Figure A.1 implementation of the DDB declares the most recent frame into the T_c window as a non-conforming frame.

NOTE – In evaluating FLR_c, FLR_e, and availability, the counts of non-conforming frames and data bits in those frames are not relevant. What is relevant is only whether the DDB determines the entire stream to be conforming.

A.4 Using the DDB in Evaluating FCTDR

FCTDR compares the amount of conforming traffic at a downstream interface with the amount of conforming traffic at an upstream interface. The determination of whether a traffic stream is conformant at a downstream interface should allow for some frame clumping in the upstream elements. A parameter, ε, called the "frame clumping tolerance" can be used to make this allowance.

For a given connection, consider the flow of user information frames between two boundaries delimiting a set of concatenated connection sections. Let T_c refer to the time interval over which B_x (representing Bc for CIR and Be for EIR) is evaluated at the input boundary. To allow for a reasonable amount of frame clumping in evaluating FCTDR, traffic conformance at the output boundary should be compared using a modified T_c, CIR, and EIR:

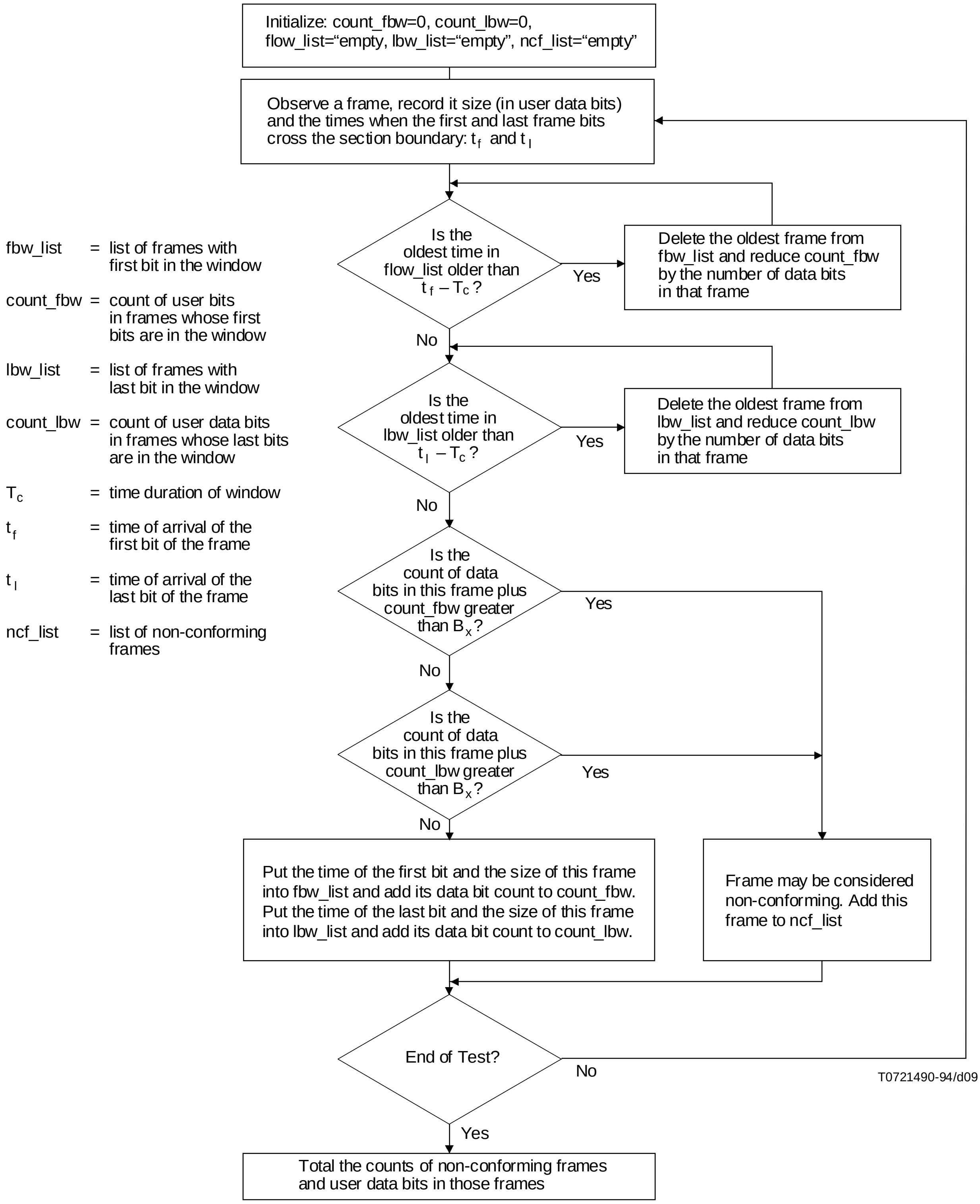
$$\hat{T}_c = T_c - \varepsilon$$

$$\hat{CIR} = Bc / \hat{T}_c$$

$$\hat{EIR} = Be / \hat{T}_c$$

$$(T_c > \varepsilon > 0)$$

NOTE – The specification of ε is for further study.



NOTES

1 Other implementations are possible.

2 Bx = Bc or Be.

3 When Bx is exceeded, this algorithm declares the most recent frame into the T_c window as the non-conforming frame. Reasonable algorithms should either do this or identify a shorter frame in the current window.

FIGURE A.1/X.144

Double dangerous bridge implementation

Annex B

Bit-based accuracy and dependability parameters

(This annex forms an integral part of this Recommendation)

This annex defines three bit-based protocol-specific accuracy and dependability parameters associated with the transfer of user information in frame relay services:

- user information bit loss ratio;
- residual bit error ratio; and
- bit-based conformant traffic distortion ratio.

These parameters supplement the corresponding frame-based parameters (user information frame loss ratio, residual frame error ratio, and frame-based conformant traffic distortion ratio) defined in clause 5. Figure 5 shows the statistical populations used to calculate these accuracy and dependability parameters.

NOTE – Unless otherwise stated, the relevant conditions stipulated in clauses 1-5 apply in Annex B.

B.1 User information bit loss ratio

The **user information bit loss ratio (BLR)** is defined as:

$$BLR = \frac{B_L + B_M}{B_S + B_R + B_L + B_M}$$

where, in a specified population:

- B_S is the total number of user information bits in successfully transferred frame outcomes;
- B_R is the total number of user information bits in residually errored frame outcomes;
- B_L is the total number of user information bits in lost frame outcomes; and
- B_M is the total number of residually lost (i.e. missing) user information bits in residually errored frame outcomes.

Two special cases are of particular interest.

B.1.1 BLR_c: BLR_c is defined as the BLR for a population of frames with DE = 0 when all DE = 0 frames conform with the CIR.

B.1.2 BLR_e: BLR_e is defined as the BLR 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.

B.2 Residual bit error ratio

residual bit error ratio (RBER)[12] is defined as:

$$RBER = \frac{B_M + B_E + B_X}{B_C + B_M + B_E + B_X}$$

where, in a specified population:

- B_C is the total number of correct user information bits in either successfully transferred or residually errored frame outcomes;

[12] This accuracy parameter refers to the residual (i.e. undetected) user information bit errors caused by transmission or switching impairments introduced on a specified virtual connection.

– B_M is the total number of residually lost (i.e. missing) user information bits in residually errored frame outcomes;

– B_E is the total number of residually incorrect (i.e. inverted) user information bits in residually errored frame outcomes; and

– B_X is the total number of residually extra (i.e. additional) user information bits in residually errored frame outcomes.

In practice, it is not possible in all cases to distinguish residually incorrect, residually lost, and residually extra user information bit occurrences without comparison of the data bits seen at the boundaries.

B.3 Bit-based conformant traffic distortion ratio: The bit-based conformant traffic distortion ratio for DE = 0 traffic is defined as:

$$BCTDR_c = \frac{1}{N_A} \sum_{n=1}^{N} F_n \, b_n$$

where

$$F_n = \begin{cases} 1 \text{ if frame } A_n \text{ is non-conforming to } \hat{CIR} \text{ at } B_j, \\ \text{or is marked DE = 1 at } B_j, \\ 0 \text{ otherwise} \end{cases}$$

$\{A_1, A_2, ..., A_N\}$ denotes a sequence of N frames, all input with DE = 0, conforming to CIR at B_i, and are all relayed to B_j.

CÎR is the modification of CIR as described in Annex A,

b_n is the number of user information bits in frame A_n (n = 1, 2, ..., N), and

$$N_A = \sum_{n=1}^{N} b_n$$

is the total number of user information bits in frames $\{A_1, A_2, ..., A_N\}$.

NOTE – The need for objectives for $BCTDR_c$ is for further study.

The bit-based conformant traffic distortion ratio for DE = 1 traffic is defined as:

$$BCTDR_e = \frac{1}{N_A} \sum_{n=1}^{N} F_n \, b_n$$

where

$$F_n = \begin{cases} 1 \text{ if frame } A_n \text{ is non-conforming to } \hat{EIR} \text{ at } B_j, \\ 0 \text{ otherwise} \end{cases}$$

$\{A_1, A_2, ..., A_N\}$ denotes a sequence of N frames, all input with DE = 1, conforming to EIR at B_i, and are all relayed to B_j..

EÎR is the modification of EIR as described in Annex A,

b_n is the number of user information bits in frame A_n (n = 1, 2, ..., N), and

$$N_A = \sum_{n=1}^{N} b_n$$

is the total number of user information bits in frames $\{A_1, A_2, ..., A_N\}$.

NOTE – The need for objectives for $BCTDR_e$ is for further study.

Appendix I

Sampling estimation of PVC availability parameters

(This appendix does not form an integral part of this Recommendation)

I.1 A minimal test for PVC service availability

The definition of Permanent Virtual Circuit (PVC) service availability 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 5 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 N_1;

1b) (CIR = 0) – The test fails if the FLR_e is greater than N_2;

2) The test fails if the RFER is greater than N_3;

3) The test fails if the extra frame rate is greater than N_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.

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 size s, not less than 300. Choose s testing times during scheduled service time and distribute them across a long measurement period (for instance, 6 months). Because of the expected durations of service outages, choose no two testing times closer together than 7 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 nor more than 3 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*[13)].

13) Each counter is initially set to zero.

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 5 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 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, will not bias the result[14)]. 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 3 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 5-minute availability samples.

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.

---

14) 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.

Appendix II

Congestion notification

(This appendix does not form an integral part of this Recommendation)

II.1 The effects of FECN, BECN and CLLM on performance

Network providers can use FECN and BECN bits and/or CLLM frames to signal information about the utilization of network resources, thus helping users avoid or mitigate the effects of congestion. For this reason, some DTEs or applications may automatically respond to FECNs, BECNs, and/or CLLMs by reducing or smoothing the offered frame traffic more than the *a priori* traffic descriptors require. Thus, a network's use of FECN, BECN, and CLLM may impact directly on the throughput and performance observed by end users.

II.2 Controlling the effects on performance

Neither the network's use of FECN, BECN, and CLLM nor the appropriate user response is standardized. Thus, at the current time there is no mutually acceptable way to standardize limits on the use of these performance significant signals. In the meantime, the following recommendations can be made:

– If a network provider expects its users to respond to FECN, BECN, or CLLM by temporarily reducing or smoothing their offered traffic more than the *a priori* descriptors require, these network providers should:

  1) precisely define how users should respond[15];

  2) establish limits for the frequency and duration of such periods; and

  3) explain what additional risk the user is facing by ignoring these periods.

– Users should determine their network provider's interpretation of FECN, BECN, and CLLM, and then they should attempt to optimize their responses to these signals.

– In lieu of specific information about how to respond to FECN, BECN, and CLLM or in lieu of limits on their use, users completely conforming to their *a priori* traffic descriptors may assume that network performance objectives (FTD, FLR, etc.) will be met independently of FECNs, BECNs, and CLLMs.

(See also Appendix III for performance effects of excessive demand for connection resources on measured performance.)

Appendix III

Performance Effects of Excessive Demand for Connection Resources

(This appendix does not form an integral part of this Recommendation)

The parameters of this Recommendation are designed to measure the performance of network elements between pairs of section boundaries. However, users of this Recommendation should be aware that the behavior of connection elements outside the pair of boundaries can adversely influence the measured performance of the elements between the boundaries. Two important examples are:

---

[15] Note that some network providers also ask that users respond to lost frames by initiating or extending periods of load reduction.

III.1 Unanticipated Simultaneous Access Line Bursting

There may be occasions where simultaneous bursts from the set of connections on an access circuit section exceed the physical capacity of the line. In accepting this set of connections, the network provider and subscriber had anticipated a limited or negative time correlation among bursts of frames, but for unanticipated reasons this assumption does not hold true. During such events, the apparent performance of the network between the specified section boundaries will be degraded and, in particular, this may result in increased numbers of FECNs, BECNs, and CLLMs (see Appendix II) as well as increased FLR, FTD, FCTDR, or some combination of these effects.

III.2 Full Utilization of Over Subscribed Access Lines

Particularly when PVCs are involved, network providers may allow a subscriber to establish multiple connections on an access circuit section with a total CIR greater than the access circuit's physical capacity. This allows the subscriber to take advantage of the fact that not all of these connections will be active simultaneously. However, the apparent performance of the network will be degraded if the subscriber attempts to make use of this overbooked commitment. In particular, attempts to fully utilize this overbooking will result in increased numbers of FECNs, BECNs, and CLLMs (see Appendix II) as well as increased FLR, FTD, FCTDR, or some combination of these effects. In the worst case, attempts to fully utilize such overbooked commitments may appear as unavailability.