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SERIES X: DATA NETWORKS AND OPEN SYSTEM COMMUNICATIONS

Public data networks – Network aspects

User information transfer performance parameters for public frame relay data networks

ITU-T Recommendation X.144

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ITU-T Recommendation X.144

User information transfer performance parameters for public frame relay data networks

Summary

This Recommendation defines speed, accuracy and dependability performance parameters that may be used in specifying and assessing the user information transfer performance of public frame relay data networks. The defined performance parameters are applicable to both PVC and SVC services.

This revision was undertaken to take into account the development of ITU-T Rec. X.147 which specifies network availability objective values together with techniques for assessing frame relay network availability. Information previously pertaining to availability has been moved to ITU-T Rec. X.147. References have been updated to take into account the development of ITU-T Rec. X.146 which specifies performance objectives and classes of service, and of ITU-T Rec. X.148 which defines measurement techniques.

Source

ITU-T Recommendation X.144 was approved on 29 October 2003 by ITU-T Study Group 17 (2001-2004) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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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.

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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.

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

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CONTENTS

ITU-T Recommendation X.144

User information transfer performance parameters for public frame relay data networks

1 Scope

This Recommendation defines speed, accuracy and dependability performance parameters that may be used in specifying and assessing the user information transfer performance of public frame relay data networks. The defined parameters apply to end-to-end and point-to-point frame relay connections[1], and to specified portions of such connections when provided in accordance with ITU-T Recs X.36 and X.76.

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 to ensure that the achieved performance meet user's 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 ITU-T Rec. X.140. Three protocol-independent data communication functions are identified in the matrix: connection set up, 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 service availability (see ITU-T Rec. X.147)

The performance parameters defined in this Recommendation define the speed, accuracy, and dependability of the user information transfer provided by frame relay networks. The user transfer performance parameters are applicable to both PVCs and SVCs.

ITU-T Rec. X.145 defines the speed, accuracy and dependability of the connection set-up and the disengagement phase of frame relay Switched Virtual Connections (SVC).

ITU-T Rec. X.146 specifies performance objectives and quality of service classes applicable to frame relay.

ITU-T Rec. X.147 specifies objectives and methods for assessing network availability of frame relay services.

[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.

ITU-T Rec. X.148 specifies procedures for measuring the performance of public frame relay data networks.

NOTE 1 – The parameters defined in this Recommendation may be augmented or modified based upon further study of the requirements for quantify the performance of frame relay networks.

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

NOTE 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 behaviour 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.

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.

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. Annex C gives some relations between frame-level and ATM-level and performance parameters. Appendix I discusses the performance effects of network indications of congestion and makes general recommendations for controlling these effects. Appendix II discusses performance effects of excessive demand for connection resources. Appendix III gives a method of estimating the FLR from network statistics.

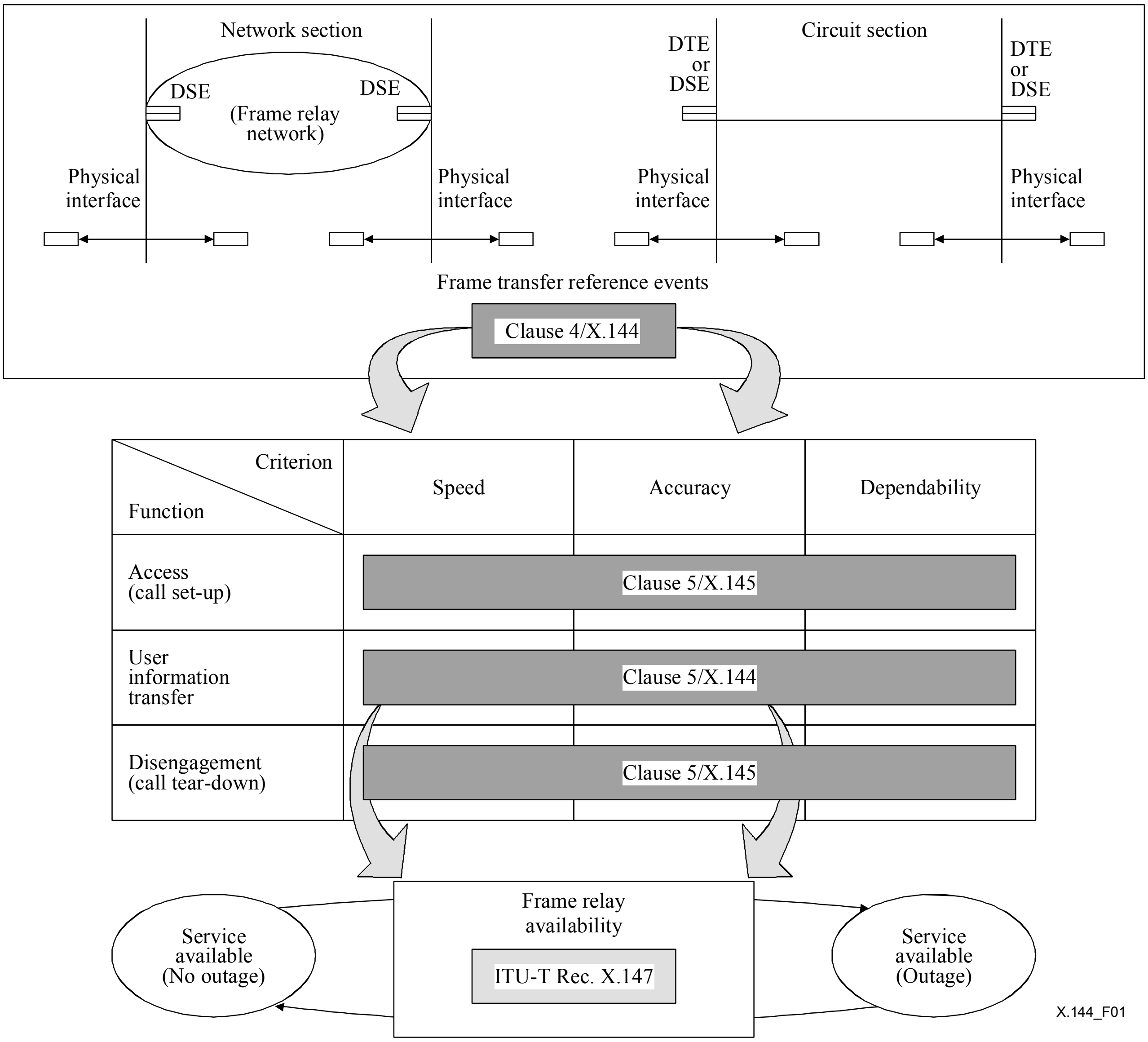


Figure 1/X.144 – Scope of ITU-T Rec. X.144

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 I.356 (2000), *B-ISDN ATM layer cell transfer performance*.

– ITU-T Recommendation I.363 (1993), *B-ISDN ATM adaptation layer (AAL) specification*.

– ITU-T Recommendation I.365.1 (1993), *B-ISDN ATM adaptation layer sublayers: Frame relaying service specific convergence sublayer (FR-SSCS)*.

– ITU-T Recommendation I.370 (1991), *Congestion management for the ISDN frame relaying bearer service*.

– ITU-T Recommendation I.555 (1997), *Frame Relaying Bearer Service interworking*.

– 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.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.147 (2003), *Frame Relay network availability.*

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

– ITU-T Recommendation X.329 (2000), *General arrangements for interworking between networks providing frame relay data transmission services and B-ISDN.*

3 Abbreviations

This Recommendation uses the following abbreviations:

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

FDJ Frame Delay Jitter

FE Frame Layer Reference Event

FECN Forward Explicit Congestion Notification

FLR	Frame Loss Ratio
FTD	Frame Transfer Delay
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.)

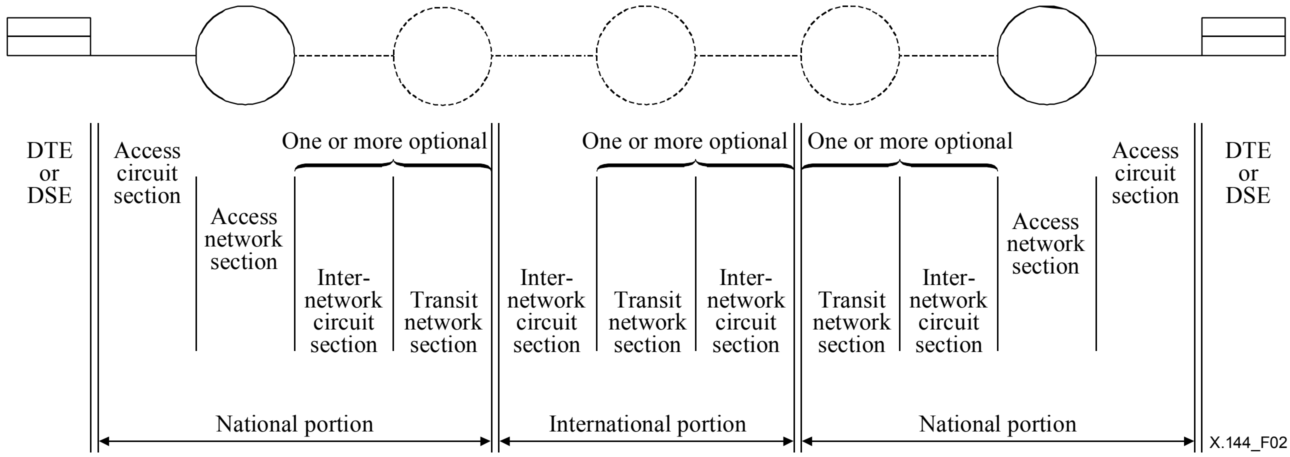


Figure 2/X.144 – Sections of an international virtual connection

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

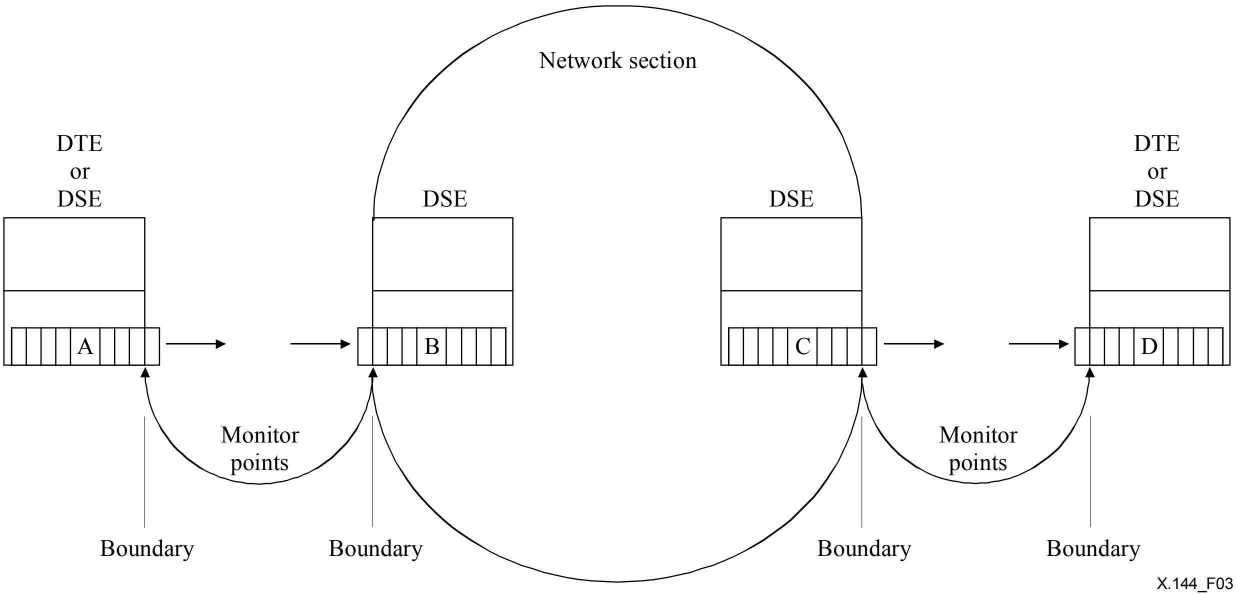
Frame transfer reference events can be observed at the physical boundaries terminating a circuit section.

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

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.



NOTE 1 – Frame exit events for A and C.
NOTE 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.

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[3] Unless otherwise noted, 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] Mis-sequenced 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.

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} (expected to be in the range $5 < T_{max} < 10$ secs) 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 speeds of service, accuracy and dependability parameters associated with the transfer of user information frames:

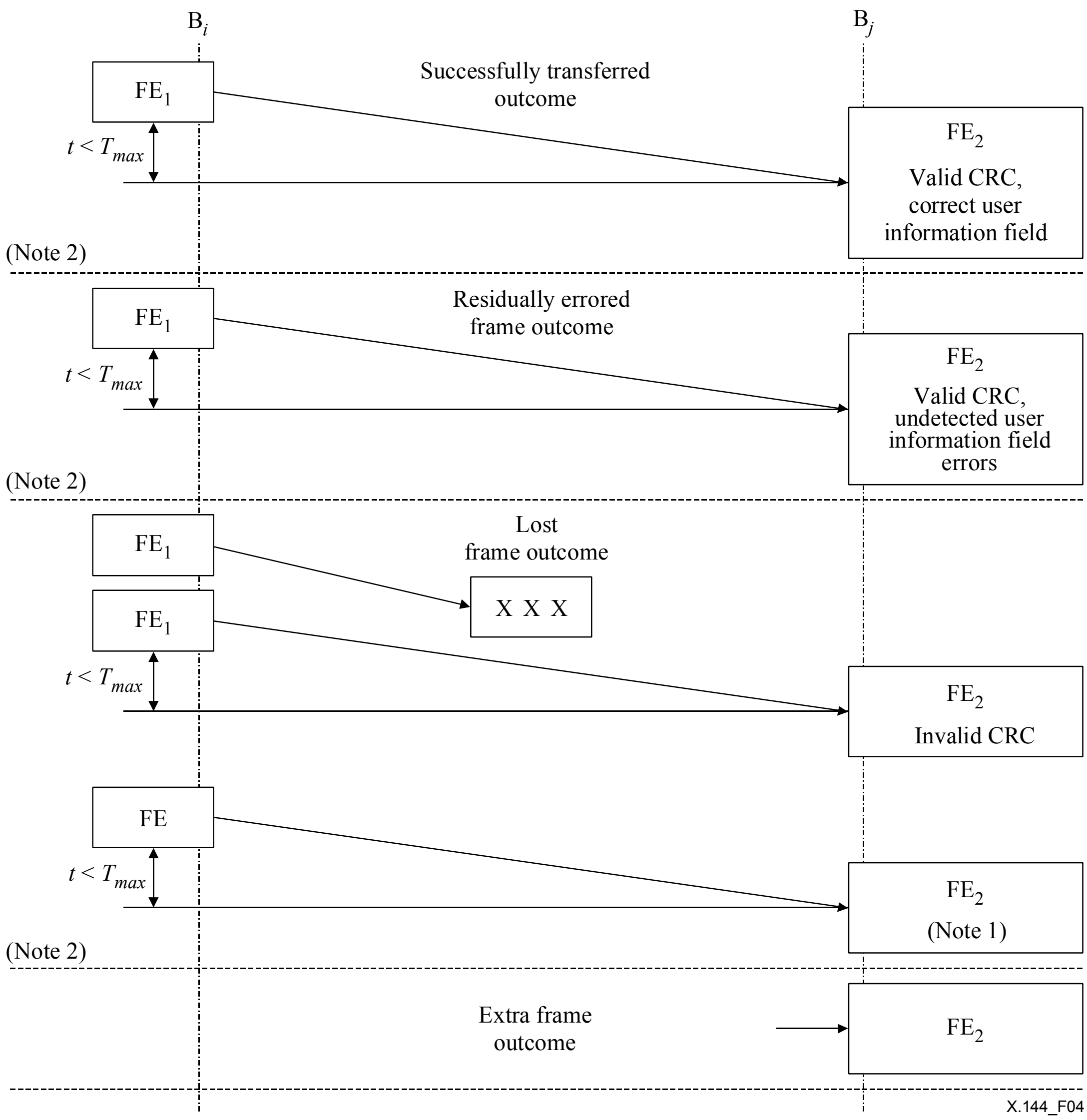
– frame transfer delay;
– user information frame loss ratio;
– residual frame error ratio;
– extra frame rate; and
– frame-based conformant traffic distortion ratio.

These parameters may be used to quantify user information transfer performance for both PVC and SVC services.

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].

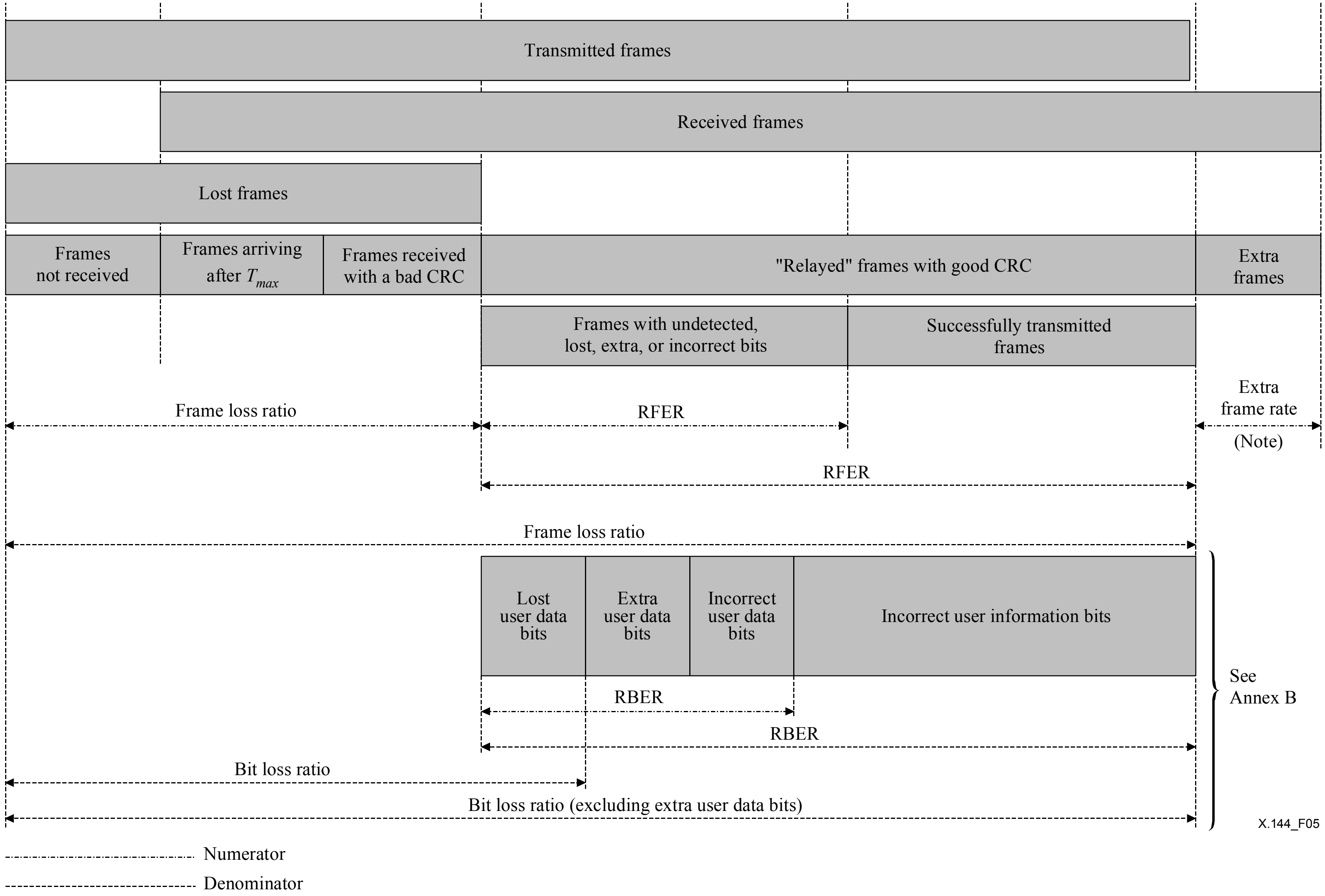
NOTE – Annex B defines three supplementary, bit-based accuracy and dependability parameters associated with the transfer of user information in frame relay services: user information bit loss ratio, residual bit error ratio, and bit-based conformant traffic distortion ratio. These parameters are relatable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

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



NOTE 1 – Outcome occurs independently of CRC validity.
NOTE 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:

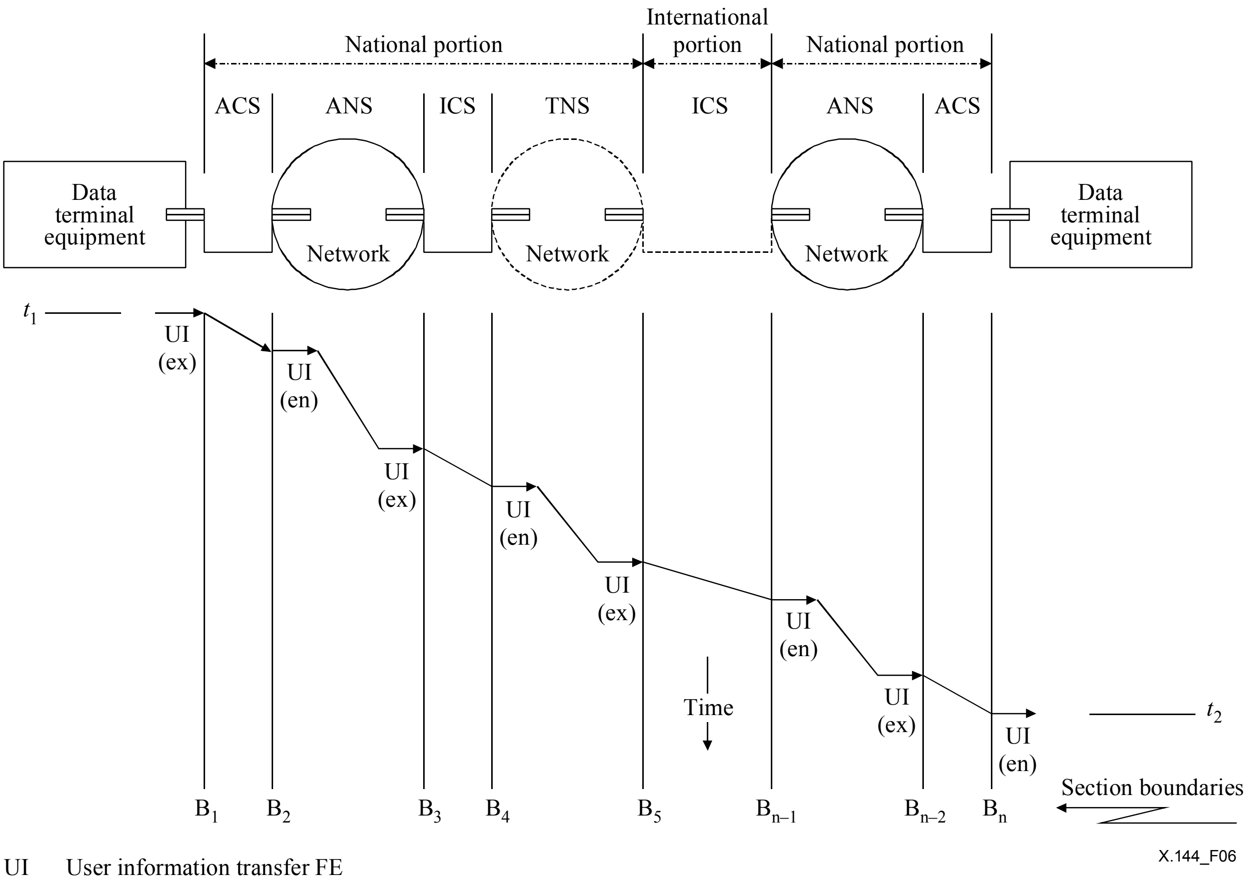
t_1 is the time of occurrence for the first FE;

t_2 is the time of occurrence for the second FE; and

$$t_2 - t_1 \leq T_{max}$$

(where T_{max} is the expected maximum transfer delay across the frame relay connection).

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).



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

5.2 User information frame delay jitter

Frame Delay Jitter (*FDJ*) is defined as the maximum Frame Transfer Delay (FTD_{max}) minus the minimum Frame Transfer Delay (FTD_{min}) during a given measurement interval, consisting of a statistically significant number of delay measurements (*N*).

$$FDJ = FTD_{max} - FTD_{min}$$

where:

FTD_{max} is the maximum *FTD* recorded during a measurement interval of *N* delay measurements;

FTD_{min} is the minimum *FTD* recorded during a measurement interval of *N* delay measurements;

N is the number of *FTD* measurements made to give a statistically significant representation of the *FTD* performance. *N* must be chosen to be at least 1000 (see Note).

NOTE – This number of 1000 observations will ensure that the 99.5 percentile of delay is observed at least 99% of the time. The suggested measurement interval is five (5) minutes. It is desirable that the observations be distributed uniformly across the measurement interval.

5.3 User information frame loss ratio

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

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

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 and FLR_e.

5.3.1 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 conform 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.

5.3.2 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,

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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 ITU-T Rec. I.370 – *Congestion management for the ISDN frame relaying bearer service*, clause 1.2. Their relationships to each other and to the DE bit are illustrated in 1.6/I.370.

some DE = 1 frames may be immediately discarded, possibly increasing the FLR for DE = 1 traffic[8].

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.

5.4 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.

5.5 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]

5.6 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.

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8 See footnote 6.

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.

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.

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:

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

and:

{A_1, A_2, ... , A_N} denotes a sequence of N frames, all input with DE = 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:

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

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.

5.7 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.

Annex A

Conformance test for performance evaluation

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 5.3.1 and 5.3.2), FCTDR (in 5.6) and availability (see ITU-T Rec. X.147) 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:

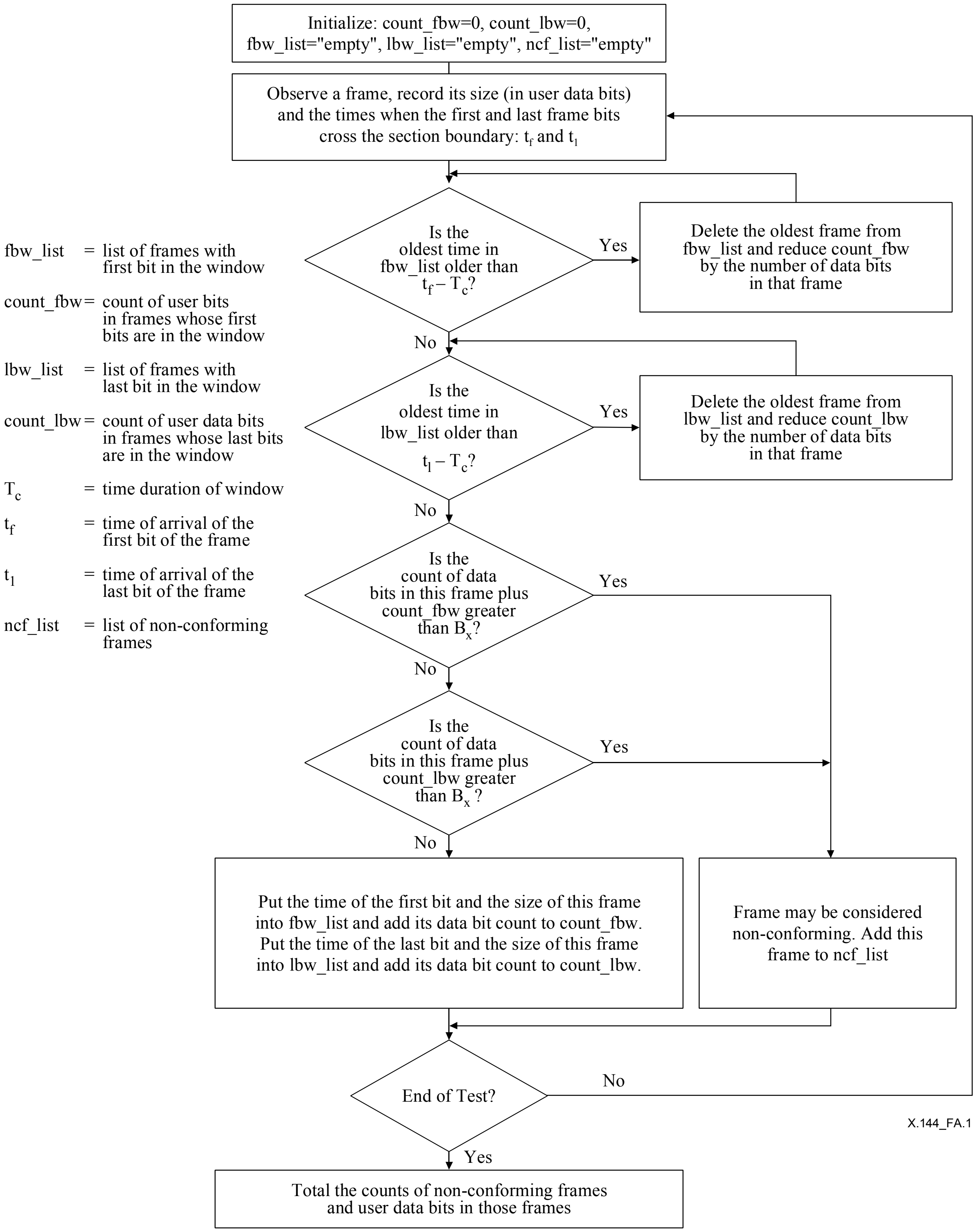
$$\hat{T}_c = T_c - \varepsilon$$

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

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

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

NOTE – The specification of ε is for further study.



NOTE 1 – Other implementations are possible.

NOTE 2 – B_x = Bc or Be.

NOTE 3 – When B_x 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 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 to 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$_c$: 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

The residual bit error ratio (RBER)[11] 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;

[11] 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:

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

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

$\hat{\mathrm{CIR}}$ 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 $\{A_1, A_2, \dots, A_N\}$.

NOTE 1 – 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:

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

and:

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

$\hat{\mathrm{EIR}}$ 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 $\{A_1, A_2, \dots, A_N\}$.

NOTE 2 – The need for objectives for $BCTDR_e$ is for further study.

Annex C

Some relations between frame-level and ATM-level performance parameters

C.1 Scope

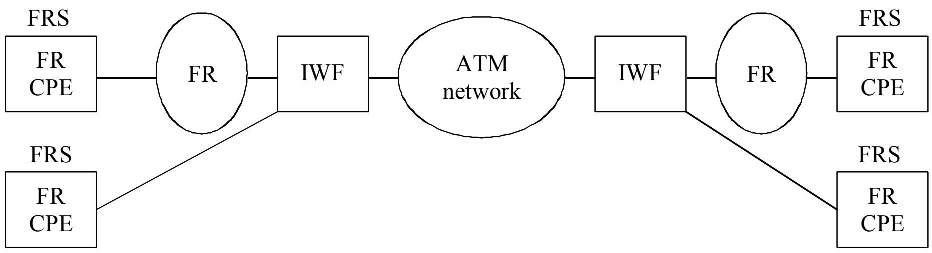
This annex develops some relations between the frame-level performance parameters defined in the main body of this Recommendation and the ATM-level performance parameters defined in the latest version of ITU-T Rec. I.356. These performance relationships are based on the Frame Relay and ATM (FR-ATM) network interworking scenario (see Figure C.1 a) and the FR-ATM service interworking scenario (see Figure C.1 b) identified in ITU-T Rec. I.555 and more fully developed in ITU-T Recs X.329, I.365.1 and clause 6/I.363. The relationships developed in this annex between the ATM-level and frame-level performance parameters may be used as a basis for establishing performance objectives for frame relay when supported over, or interworked with, ATM.

C.2 Motivation for relating frame-level and ATM-level and performance parameters

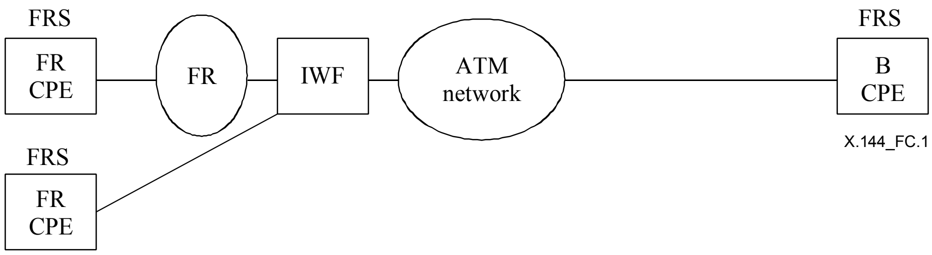
A suitable relation between the network performance parameters for frame transfer and cell transfer should allow determination of end-to-end performance for the two interworking scenarios identified in Figure C.1. Furthermore, for a connection segment that supports frame relay service over ATM technology, such a relation should also allow the estimation of a connection segment's frame-level performance from a measurement of the connection segment's ATM-level performance.

Referring to Figure C.1, an end-to-end (or CPE-to-CPE) virtual connection could be partitioned into two or more "connection segments" by using a Measurement Point (MP) near each IWF. The end-to-end performance of such a virtual connection could be estimated by measuring the performance of each connection segment and then suitably combining the performance impairments measured on each connection segment. Since some of these connection segments use frame-oriented technology and others use ATM-oriented technology, the determination of end-to-end network performance by this approach requires a suitable means for relating the performance parameters based on these two technologies.

On a given connection segment where ATM technology is used to support frame relay service, it can be operationally useful to establish the relation between that segment's ATM-oriented delay, loss and error performance characteristics and their impact on the analogous frame-oriented performance characteristics.



a) Network interworking scenario 1



b) Network interworking scenario 2

ATM	Asynchronous Transfer Mode
B	Broadband
CPE	Customer Premises Equipment
FR	Frame Relay
FRS	Frame Relay Service
IWF	Interworking Function

Figure C.1/X.144 – Some FR-ATM interworking

C.3 Frame relay parameters considered

The relevant frame-level parameters[12] include:

- user information Frame Transfer Delay (FTD);
- user information Frame Loss Ratio (FLR);
- Residual Frame Error Ratio (RFER);
- Extra Frame Rate (EFR).

At least two factors influence correlation of FTD with Cell Transfer Delay (CTD). First, the FR-ATM interworking scenarios provide for the mapping (also called multiplexing) of FR-level Data Link Channel Identifiers (DLCIs) to ATM-level Virtual Channel Identifiers (VCIs). Two types of mapping schemes have been discussed, those which map one DLCI to one VCI (called 1-to-1 multiplexing) and those which map a number of DLCIs to one VCI (called N-to-1 multiplexing).

The type of mapping scheme can influence the relation between CTD and FTD because the N-to-1 mapping scheme could include the buffering of information from several DLCIs before an opportunity exists for their transmission over the one designated VCI. Furthermore, some of a VCI's information transfer capacity can be used to transfer OAM cells in addition to user information cells. If a VCI is transferring both OAM cells and user information cells that bear frame relay service information, some consideration must be given to identifying the capacity that is available for these user information cells even though the impact on FTD of OAM cell transfer is likely to be quite small.

[12] The frame-based conformant traffic distortion ratio and potential frame flow related parameters are not considered in this annex.

The FLR can be related to the Cell Loss Ratio (CLR) and other performance parameters when either the frame size is known or a nominal frame size is assumed. This is discussed further in clause C.4.

The RFER can be related to the Cell Error Ratio (CER) when either the frame size is known or a nominal frame size is assumed. However, development of this relation involves consideration of the frame-level CRC's breakdown during its error detection task. This relationship is for further study.

The EFR is conceptually analogous to the Cell Misinsertion Rate (CMR). The reference events for each of these parameters can be caused by either an undetected/miscorrected error in the channel identifier field (i.e., DLCI or VPI-VCI) or an incorrectly programmed translation of channel identifier labels.

C.4 Relation between FR and ATM user information loss parameters

Consider now the relation between the user information Frame Loss Ratio (FLR), the Cell Loss Ratio (CLR) and other relevant performance parameters. A frame length of F_{cells} or an equivalent F_{bits} is assumed[13].

The FLR is defined over a connection segment delimited by two MPs as the ratio of the number of lost frame outcomes to the number of lost, successfully transferred and residually errored frame outcomes. The denominator of this ratio can be viewed as representing the total number of frames transmitted onto a given connection segment during a time period of interest. Our approach is to first estimate the probability of frame loss under each of several identified mechanisms, next, equate each such probability to the ratio of the number of frames lost under a specific mechanism to the total number of frames transmitted onto the connection segment during a common period of interest, and finally sum the probabilities over all identified mechanisms.

A lost frame outcome occurs on a connection segment either when a frame entry event fails to happen within a specified time interval T_{max} after the corresponding frame exit event, or when the CRC of the received frame corresponding to the frame entry event is invalid. Consistent with this definition, five mechanisms that result in frame loss can be identified:

1) frame loss due to burst impairment events involving multiple bit errors, cell losses and/or misinserted cells;
2) frame loss due to (background) random, single-bit errors;
3) frame loss due to (background) loss of a constituent cell or cells, e.g., cell-level buffer overflow;
4) frame loss due to (background) misinsertion of a cell;
5) frame loss due to frame-level processing failure, e.g., frame-level buffer overflow or frame-level processor saturation.

---

[13] Since one cell requires 53 octets, $F_{bits} = 424 \times F_{cells}$, where F_{bits} represents the total number of bits needed to transport the frame at the ATM level. F_{cells} is determined from the frame length and the fact that AAL 5 is used to transport FR frames. Up to 48 octets of FR information would be contained in each cell used to transport a given frame, and the last cell used for that frame would contain 8 octets of AAL 5-specific information.

Mechanism 1 accounts for the impact of all burst impairments that are visible at the ATM level, while mechanisms 2, 3 and 4 account for the independent impacts of the background impairment types that are visible at the ATM level and that remain after burst impairments are counted and removed. Mechanism 5 accounts for impairments (of both burst and background types) that are caused strictly at the frame level, and hence not visible at the cell level. Take these five mechanisms to be independent. Then applying the approach just cited, the FLR on a particular connection segment during a specific time period is represented as:

$$FLR = FLR_{burst} + FLR_{error} + FLR_{CLR} + FLR_{CMR} + FLR_{frame} \qquad \text{(C-1)}$$

where FLR_{burst} is the FLR due to burst impairment events, FLR_{error} is the FLR due to random, single-bit errors, FLR_{CLR} is the FLR due to loss of constituent cells, FLR_{CMR} is the FLR due to misinserted cells and FLR_{frame} is the FLR due to frame-level processing failure. The remainder of this clause considers the FLR component due to each of these mechanisms.

C.4.1 Burst-type impairments

Consider first the probability of frame loss due to burst-type impairments. The Severely Errored Cell Block Ratio (*SECBR*), as measured on a given connection segment over a time period of interest, can be used to bound the probability of occurrence during that period of burst-type impairments involving bit errors, cell losses and/or misinserted cells. It remains to relate the length of a frame, F_{cells}, to the length of a cell block, B_{cells}[14]. Three cases will be considered here:

- $F_{cells} << B_{cells}$;
- $F_{cells} >> B_{cells}$;
- $F_{cells} \approx B_{cells}$.

NOTE – If only frames of size 512 or less are supported, then only the first case is applicable.

If F_{cells} is significantly smaller than B_{cells}, then the fraction of frames that are impacted by burst-type impairments is approximated by the fraction of cell blocks that are severely errored, i.e., the *SECBR*.

Hence:

$$FLR_{burst} = SECBR \qquad \text{(C-2a)}$$

However, if F_{cells} is significantly larger than B_{cells}, then any one of (F_{cells}/B_{cells}) cell blocks[15] would, if severely errored, impact a given frame. The probability that a frame of such length is not so impacted is:

$$(1 - SECBR)^{F_{cells}/B_{cells}}$$

The FLR due to this mechanism is the logical complement of this, namely the probability that a frame of such length does experience one or more SECBs, which is:

$$FLR_{burst} = 1 - (1 - SECBR)^{F_{cells}/B_{cells}} \qquad \text{(C-2b)}$$

If F_{cells} and B_{cells} are about equal, then a single SECB would generally impact two frames, and so:

$$FLR_{burst} = 2\ SECBR \qquad \text{(C-2c)}$$

---

[14] The length of the cell block identified in ITU-T Rec. I.356 is related to the Peak Cell Rate (PCR). The minimum length is 128 cells and the maximum length is 32 768 cells. Assuming a maximum frame length of 512 octets, 5 octets of overhead, and AAL 5, the number of frames contained in one cell block of 128 cells is (128 × 48 – 8)/(512 + 5) = 12 frames, and the number of frames contained in one cell block of 32 768 cells is 3014 frames.

[15] Or more precisely, $\lceil F_{cells}/B_{cells} \rceil$ where $\lceil x \rceil$ denotes the smallest integer which is greater than or equal to x.

We observe that an alternative approach for estimating the impact at frame level of burst-type impairments would be to use a physical level parameter such as the number of severely errored seconds per day or the time spent per day executing protection switches. The appropriateness of this alternative is for further study.

C.4.2 Single-bit errors

Consider next the probability of frame loss due to independently occurring, single-bit errors. Take the probability of a single-bit error to be as given by the Bit Error Ratio (*BER*). The probability that a frame F_{bits} bits in length does not experience a random, single-bit error is:

$$(1-BER)^{F_{bits}}$$

The FLR due to this mechanism is the logical complement of this, namely the probability that such a frame does experience one or more random, single-bit errors, which is:

$$FLR_{error} = 1-(1-BER)^{F_{bits}} \qquad \text{(C-3)}$$

We observe that relations could in principle be established first between physical level bit error parameters and CER, and then between the CER and this FLR_{error}.

C.4.3 Cell losses

Consider next the probability of frame loss due to independently occurring cell losses. Take the probability of a single cell's loss to be as given by the CLR. The probability that a frame F_{cells} in length does not experience a lost cell is:

$$(1-CLR)^{F_{cells}}$$

The FLR due to this mechanism is the logical complement of this, namely the probability that such a frame does experience one or more cell losses, which is:

$$FLR_{CLR} = 1-(1-CLR)^{F_{cells}} \qquad \text{(C-4)}$$

C.4.4 Misinserted cells

Consider the probability of frame loss due to a randomly occurring misinserted cell. If the Cell Misinsertion Rate (CMR) and the Peak Cell Rate (PCR) applicable to the ATM connection are known, then the fraction of received cells that are misinserted is *CMR*/*PCR*. Take this fraction to be the probability that a single cell is misinserted. The probability that a frame F_{cells} in length does not experience a misinserted cell is:

$$(1-CMR/PCR)^{F_{cells}}$$

The FLR due to this mechanism is the logical complement of this, namely the probability that such a frame does experience one or more cell losses, which is:

$$FLR_{CMR} = 1-(1-CMR/PCR)^{F_{cells}} \qquad \text{(C-5)}$$

C.4.5 Frame-level processing failures

Finally consider the probability of frame loss due to frame-level processing failure. This is dependent upon processes above the physical and ATM levels, and hence is beyond the scope of this Recommendation. The resulting FLR_{frame} would be estimated by frame-based methods and substituted into Equation (C-1), together with the results of Equations (C-2), (C-3), (C-4) and (C-5).

Appendix I

Congestion notification

I.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.

I.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[16];
  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 II for performance effects of excessive demand for connection resources on measured performance.)

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

Appendix II

Performance effects of excessive demand for connection resources

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 behaviour of connection elements outside the pair of boundaries can adversely influence the measured performance of the elements between the boundaries. Two important examples are:

II.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 I) as well as increased FLR, FTD, FCTDR or some combination of these effects.

II.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 I) 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.

Appendix III

A method for estimating the FLR: FLR extraction

As stated in the main body of this Recommendation, any statistically valid method for estimating FLR, or any other of the X.144 performance parameters, is allowed. This appendix specifies a methodology to obtain FLR based on the network data such as accounting records, switch statistics and alarms generated in networks providing frame relay PVC service. Within its limitations, this method provides a cost-effective means of estimating the FLR on a specific PVC.

III.1 FLR extraction methodology limitations

The methodology described in III.2 is appropriate for long-term (of the order of hours, not minutes) estimates of FLR and is not suitable for estimating short-term (of the order of minutes or less) FLR. In particular, this method is not applicable to estimating FLR for the purposes of evaluating FR service availability. The reason for these limitations is the need for negligible discrepancy between the set of frames on which the various statistics are computed. Despite the above, this method is useful in providing a general metric on the health of particular PVCs, and has been validated by network operators using more rigorous methods of FLR estimation.

III.2 FLR extraction methodology

The FLR extraction method explained below depends on statistics gathered on frames at specific network locations as shown in Figure III.1 below.

For all PVC connections in the frame relay network, the following information is collected:

– The total number of ingress frames (A/Figure III.1);
– The number of CIR frames sent to the network (B/Figure III.1);
– The number of EIR frames sent to the network (C/Figure III.1);
– The number of CIR egress frames (D/Figure III.1);
– The number of EIR egress frames (E/Figure III.1);
– The total number of egress frames (F/Figure III.1); and
– The total number of discarded frames (G/Figure III.1).

By using the data collected, the FLR can be estimated as follows:

$$FLR_c = \frac{\text{number of CIR egress frames}}{\text{number of CIR frames sent to the network}} = \frac{\text{D}}{\text{B}} \qquad \text{(III-1)}$$

$$FLR_e = \frac{\text{number of EIR egress frames}}{\text{number of EIR frames sent to the network}} = \frac{\text{E}}{\text{C}} \qquad \text{(III-2)}$$

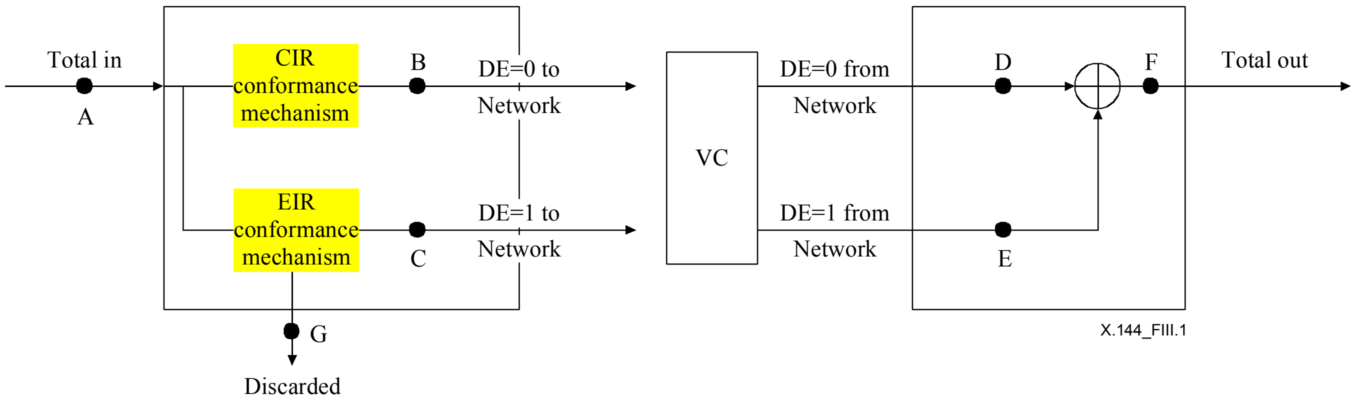


Figure III.1/X.144 – FLR extraction methodology

In Figure III.1 all frames with DE = 0 calculated at B are accepted as conforming and DE = 0 frames calculated at D are those transferred successfully across the network. All frames with DE = 1 calculated at C are accepted as conforming and DE = 1 frames calculated at E are those transferred successfully across the network.

FLR_c in this Recommendation characterizes the degree to which a network transfers the frames with DE = 0 accepted as conforming. FLR_e characterizes the degree to which a network transfers the DE = 1 frames accepted as conforming. In other words, FLR_c corresponds to the probability that a DE = 0 frame accepted as conforming will be subsequently lost. FLR_e is the probability that a DE = 1 frame accepted as conforming will be subsequently lost.

Consequently, given a high correlation between the population of frames for the statistics generated at the specified locations in Figure III.1, Equations (III-1) and (III-2) can be used to accurately estimate FLR as defined in this Recommendation.

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