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SERIES X: DATA NETWORKS AND OPEN SYSTEM COMMUNICATIONS

Public data networks – Network aspects

Performance objectives and quality of service classes applicable to frame relay

ITU-T Recommendation X.146

(Formerly CCITT Recommendation)

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ITU-T Recommendation X.146

Performance objectives and quality of service classes applicable to frame relay

Summary

This Recommendation defines the reference model, national/international apportion model, frame relay service classes and their associated delay and loss objectives, applicable to networks providing frame relay PVC or SVC service and supporting frame relay service classes.

Source

ITU-T Recommendation X.146 was revised by ITU-T Study Group 7 (1997-2000) and approved by the World Telecommunication Standardization Assembly (Montreal, September 27 – October 6 2000).

FOREWORD

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

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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

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ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

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

CONTENTS

ITU-T Recommendation X.146

Performance objectives and quality of service classes applicable to frame relay

1 Scope

The purpose of this Recommendation is to define frame relay service classes with their associated delay and loss parameters, together with allocations to national and international portions applicable to international frame relay services in accordance with ITU-T Recommendations identified herein. This Recommendation defines frame relay service classes that may be used to describe the information transfer phase of data networks when providing international frame relay service (either permanent virtual connection service or switched virtual connection service). Two frame relay performance parameters of ITU-T X.144 – frame transfer delay and committed frame loss ratio – are used to characterize the various frame relay service classes. This Recommendation applies only to those networks supporting the service class options of X.36 and X.76. Signalling and service class interworking issues are covered in ITU-T X.36 and X.76.

The 3 × 3 performance matrix defined in ITU-T X.134 (see Figure 1) is used as a guide to identify the applicability of this Recommendation. As mentioned above, this Recommendation applies to the information transfer phase of a frame relay virtual connection.

The parameters defined in this Recommendation may be allocated to specify the performance of end-to-end frame relay connections or connection portions as specified in ITU-T X.144.

The frame relay service classes defined in this Recommendation describe specific design objectives for the information transfer phase of the national and international portions of an international virtual connection. In the context of this Recommendation, the term "service class" is equivalent to the terms "quality of service class" or "QoS class" as used in ITU-T I.356.

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

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

This Recommendation is organized as follows:

– clause 2 presents references;

– clause 3 presents abbreviations;

– clause 4 reviews the performance model of ITU-T X.144 and its national and international portions that provide the basis for the allocations given in clause 5;

– clause 5 defines frame relay service classes applicable to the user information transfer phase of a frame relay virtual connection, based primarily on the two performance parameters of frame transfer delay (FTD) and committed frame loss ratio (FLR_c);

– clause 6 defines allocations of the service classes defined in clause 5 to the national and international portions described in clause 4.

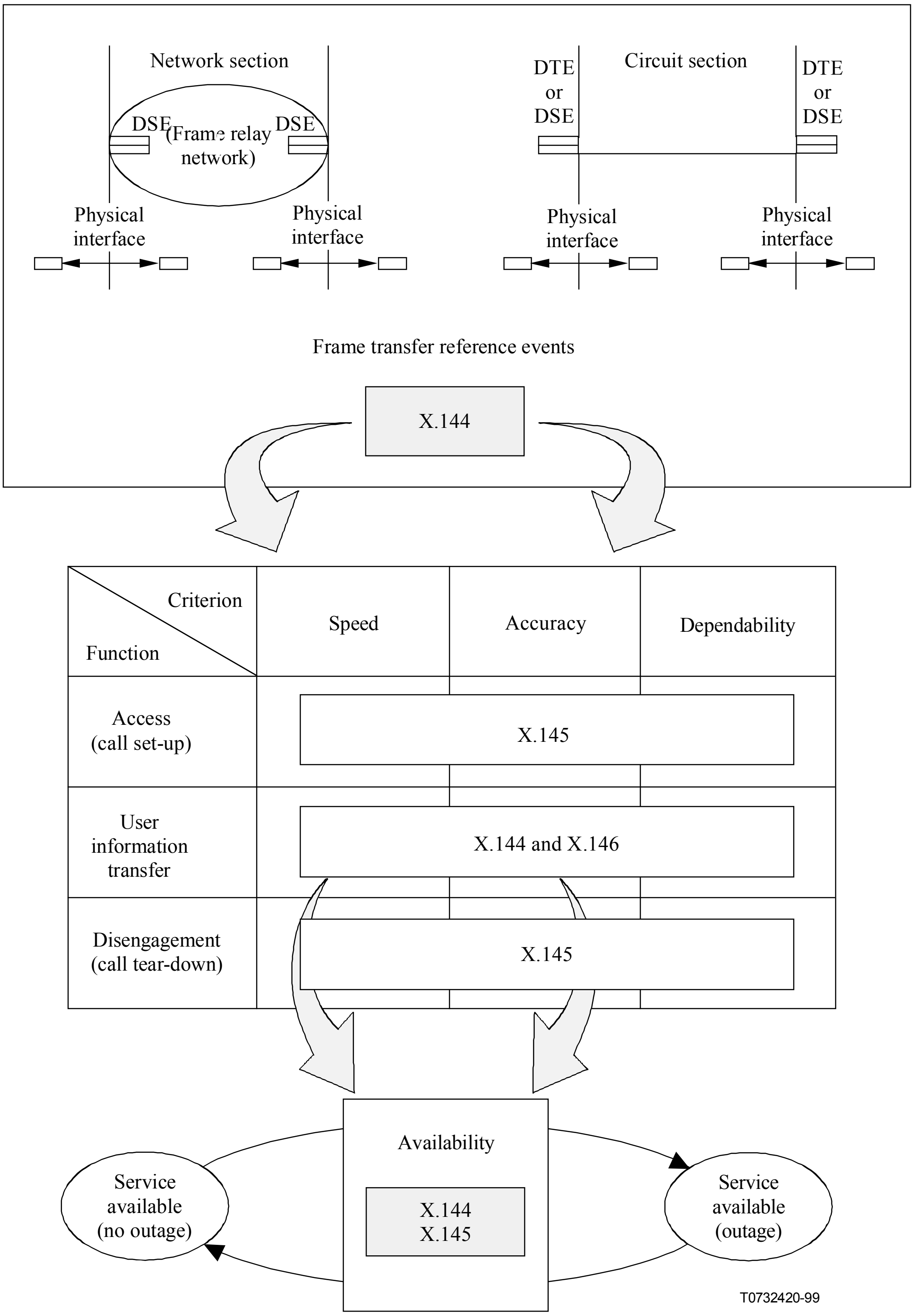

Figure 1/X.146 – Scope of this Recommendation

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; 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.

- ITU-T G.114 (2000), *One-way transmission time*.
- ITU-T X.36 (2000), *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 X.76 (2000), *Network-to-network interface between public networks providing PVC and/or SVC frame relay data transmission service*.
- ITU-T X.140 (1992), *General quality of service parameters for communication via public data networks*.
- ITU-T X.144 (2000), *User information transfer performance parameters for data networks providing international frame relay PVC service*.
- ITU-T X.145 (1996), *Performance for data networks providing international frame relay SVC service*.

3 Abbreviations

This Recommendation uses the following abbreviations:

AR Access line Rate for the access circuit section

CPE Customer Premises Equipment

DCE Data Circuit-terminating Equipment

D_{km} Air route distance

DSE Data Switching Equipment

DTE Data Terminal Equipment

FDJ Frame Delay Jitter

FLR_c Committed frame loss ratio

FTD Frame Transfer Delay

FTD_a Access circuit section frame transfer delay

FTD_I International portion frame transfer delay

FTD_N National portion frame transfer delay

FTD_O Edge-to-edge frame transfer delay objective

NNI Network-to-Network Interface

PVC Permanent Virtual Connection

QoS Quality of Service

R_a Access circuit section route length

R_I Route length of the international portion

R_{km} Route length

SVC Switched Virtual Connection

UNI User-to-Network Interface

4 Reference model

The performance model for this Recommendation is that of ITU-T X.144 (as presented in clause 4/X.144). For completeness, this performance model is illustrated by Figure 2. The national and international portions of this frame relay performance model are those used in clause 6.

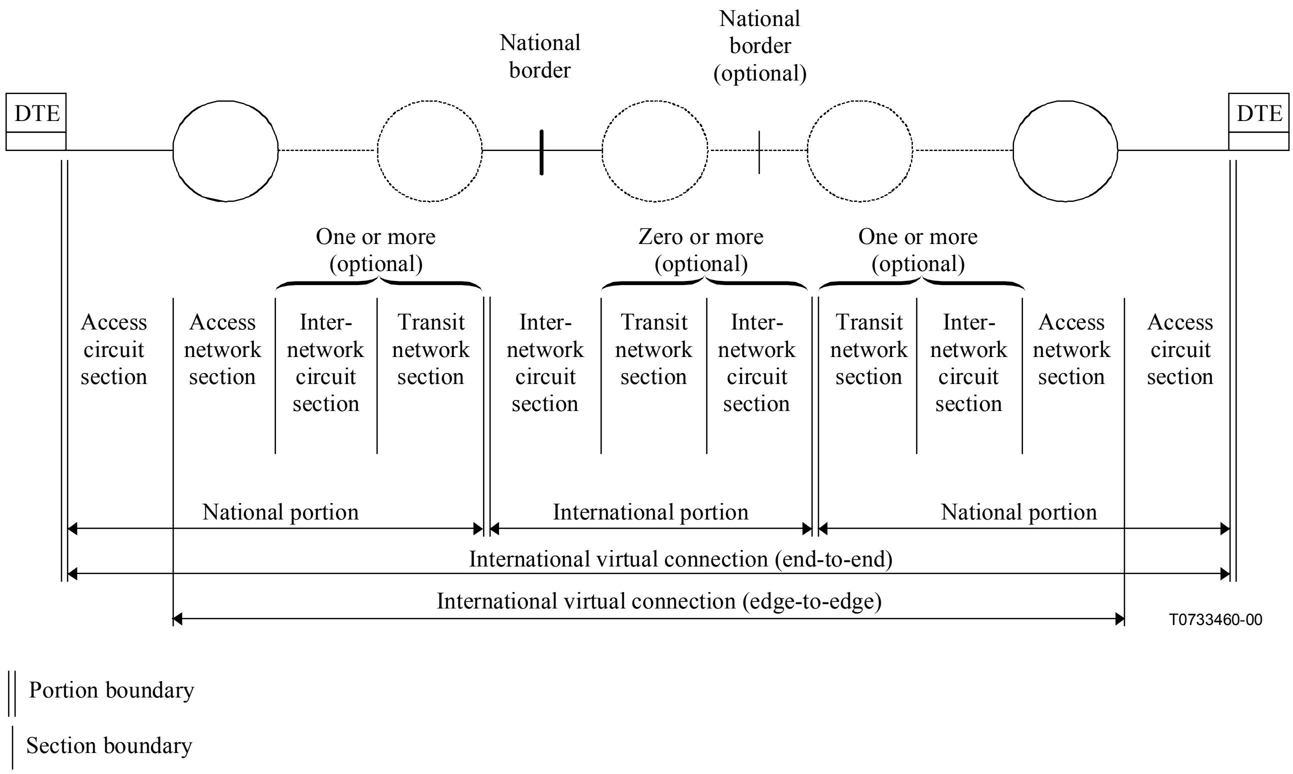

Figure 2/X.146 – Reference model for the apportionment of national and international portions of a multiple-network international virtual connection

Note that an end-to-end international virtual connection consists of two national portions and one international portion. In certain cases, the international portion could consist solely of an internetwork circuit section. In this Recommendation, the term edge-to-edge denotes the performance of the end-to-end connection excluding the two access circuit sections. This model applies to the information transfer phase of a frame relay connection, and is applicable to either a switched virtual connection (SVC) or a permanent virtual connection (PVC).

The Data Terminal Equipment (DTE) is not part of the end-to-end international virtual connection; hence, its contribution to the user experience is not considered in this Recommendation. Private frame relay networks are considered as DTE, and thus neither is their performance contribution considered in this Recommendation. The subject of quantifying the degree to which a private frame relay network contributes to the overall user experience is a subject for further study.

5 Network performance objectives and frame relay quality of service classes

This clause discusses the general nature of per-connection frame relay network performance objectives and the specific quality of service (QoS) classes of Table 1 through which they are supported. Issues of estimating these network objectives are also discussed, as is the weighting referred to in Table 1.

With respect to the frame relay QoS classes in Table 1, the user has the option of requesting a different QoS class for each new SVC or PVC. While three of the four QoS classes in Table 1 have numeric objectives for both FLR_c and FTD, there is one class (class 0) for which no objectives are specified. Class 0 is therefore sometimes referred to as the unspecified class.

Table 1/X.146 – Frame relay service classes

Class	Network support	FLR_c	FTD (ms)	FDJ (ms)
0	Mandatory, default class	No upper bound specified on FLR_c. But FLR_c will have a practical upper bound and will not be arbitrarily bad.	No upper bound specified on FTD. But delay will have a practical upper bound and will not be arbitrarily large.	Not Applicable
1	Mandatory	Value $< 1 \times 10^{-3}$, and 95th percentile of weighted 15-minute values $< 3 \times 10^{-3}$.	95th percentile < 400 ms.	95th percentile < 52 ms (see Notes 9, 11 and 12)
2	Optional	Value $< 3 \times 10^{-5}$, and 95th percentile of weighted 15 minute values $< 1 \times 10^{-4}$.	95th percentile < 400 ms.	95th percentile < 17 ms (see Notes 10, 11 and 13)
3	Optional	Value $< 3 \times 10^{-5}$, and 95th percentile of weighted 15-minute values $< 1 \times 10^{-4}$.	95th percentile < 150 ms (see Note 6).	95th percentile < 17 ms (see Notes 10, 11 and 13)

NOTE 1 – All values are provisional and they need not be met by networks until they are revised (up or down) based on real operational experience.

NOTE 2 – The FTD objectives apply edge-to-edge.

NOTE 3 – Basic frame relay service guarantees apply to all service level classes (i.e. minimum service availability requirements).

NOTE 4 – For FTD performance, all service classes apply to frames of size 256 (i.e. to frames with user information fields of 256 octets). If frames of size 128 are used to estimate compliance with these objectives, then the following tighter 95th percentile objectives for FTD should be used; 380 ms for classes 1 and 2, and 130 ms for class 3.

NOTE 5 – Classes 2 and 3 may be characterized by service availability levels higher than those of basic frame relay service.

NOTE 6 – In the case of service class 3, if the international portion route length exceeds 9300 km, an allowance of 6.25 ms per 1000 km of route length is allocated to the international portion.

NOTE 7 – For frame relay PVC connections, a one-month interval should be used to evaluate the FLRc objective.

Table 1/X.146 – Frame relay service classes *(concluded)*

NOTE 8 – Methods for estimating network performance for frame relay SVCs is for further study. See Appendix I.
NOTE 9 – The FDJ allocated for the national portion of class 1 service is 30 ms. The FDJ allocated for the international portion of class 1 service is 30 ms.
NOTE 10 – The FDJ allocated for the national portion of a class 2 and class 3 service is 10 ms. The FDJ allocated for the international portion of a class 2 and class 3 service is 10 ms.
NOTE 11 – The allocated FDJs sum to more than the end-to-end FDJ because FDJ accumulates similarly to the standard deviation of roughly independent random variables. When independently random variables are summed, the resulting standard deviation is roughly the square root of the sum of the squares.
NOTE 12 – Certain applications, e.g., voice, need a FDJ requirement and therefore such a requirement is included in Class 1. However, it is recognized that there are other applications that could use class 1, e.g. file transfer, that do not need a FDJ requirement.
NOTE 13 – Since the inclusion of a satellite does not impact on the end-to-end jitter, class 2 and class 3 FDJ requirements are the same.

5.1 Nature of the network performance objectives

FLR_c objectives are expressed as upper bounds on the mean and 95th percentile of weighted 15-minute averages. These FLR_c objectives apply to all offered frame relay frames within the CIR (regardless of size). FTD objectives are expressed as an upper bound on the 95th percentile of FTD. These objectives do not include the performance of DTEs or private networks. The performance of private networks and DTEs is a subject for further study.

5.2 Statistical estimation of network performance

Estimation of performance to assess compliance with the FLR_c and FTD 95th percentile objectives can be accomplished through either continuous monitoring or via statistical estimation. Any statistically valid method for verifying that these network objectives have been met is acceptable. Such a method could be sampling a fifteen-minute interval every three hours and producing weighted estimates – as long as this method produces unbiased estimates of either FLR_c or FTD.

Among others, the following points should be covered:

- aggregation period, the period of time over which the objective value is finally computed (default is one month);

and, if continuous monitoring is not used, use a sampling policy that:

- Determines the frequency of the measurement interval;
- Determines the duration of the measurement interval (time or number of frames);
- For each measurement interval, compute the relevant statistics (e.g. average or ratio, 95th percentile);
- Compute corresponding weighted statistics based on number of frames (offered for FLR_c and delivered for FTD) if needed.

For example, to estimate FLR_c, a 15-minute interval (interval A with an FLR_c of 1%) in which 400 frames were offered to the network should receive four times the weight of a 15-minute interval (interval B with an FLR_c of 2%) in which 100 frames were offered. This would produce a weighted average FLR_c of $\{(400/500) \times 1\%\} + \{(100/500) \times 2\%\} = 1.2\%$.

When estimating the 95th percentile of the 15-minute values of FLR_c, the 15-minute values should be weighted by the number of offered frames. For estimating the 95th percentile of FTD, all observations of FTD should be considered.

When performing any statistical estimation, a sufficiently large sample (to ensure statistical validity) must be present. In the case of SVC-connections, sometimes either the number of frames or duration of time may be less than sufficient to compute valid statistics to determine network compliance with the stated frame relay QoS classes. Should this occur, collections of like SVCs may be aggregated to obtain a sufficiently large sample to allow the statistically valid determination of the extent to which a network is meeting its QoS obligations. Examples of collections of like SVC connections include those between the same pair of end users, or those between the same called and calling party numbers. When such aggregation of SVCs occurs, isolated instances of failure to meet QoS objectives on individual SVCs that have an insufficient number of frames cannot by themselves be taken as proof that the network has failed in its obligations – only an analysis of the entire aggregate collection of data can make that determination.

Although the precision of any statistical estimate should be reported with the estimate itself, the specification of the precision of statistical estimates of FLR_c or FTD is for further study.

5.3 Unspecified performance

Despite not having any numeric network objectives set in class 0, there is no implication that the performance of a connection supporting QoS class 0 will be arbitrarily poor, some operational bounds on performance will exist even in this case. Indeed, some network operators may unilaterally elect to support a minimal level of FLR_c or FTD even for connections supported by class 0.

5.4 Standardized Frame Size for FTD performance measurement

Clocking delay of both access circuit sections and inter-network circuit sections can be a significant component of the end-to-end frame transfer delay, in particular if large frames or low-speed circuit sections are in place.

A standardized frame size (length of information field in frame relay frame) of 256 octets is to be used for making FTD performance measurements. This ensures that the clocking delay component is not significant and that the clocking delay contribution is not variable between different performance measurement implementations.

NOTE – It is recognized that FTD performance measurements might be made using a frame size of 128 octets, in which case the objective values are modified accordingly (see Note 4 of Table 1).

5.5 Frame relay service classes

Table 1 specifies four frame relay service classes. For each QoS class these three items are specified. First, the level of network support, either mandatory or optional, is specified. Next, the committed frame loss ratio, FLR_c, if applicable, and its mean value and 95%-tiles. Finally, the requirements on the frame transfer delay and frame delay jitter, FTD and FDJ (both in milliseconds), is given for each QoS class. These frame relay QoS classes apply to both frame relay PVC and frame relay SVC. User signalling of frame relay service class at a UNI is contained in ITU-T X.36. Signalling of frame relay service class at the NNI is contained in ITU-T X.76.

The notations of mandatory, default class, and optional in the network support column have the following interpretations. Any network supporting these frame relay service classes must support both class 0 and class 1. Class 0 corresponds to current frame relay implementations and is thus denoted as the default class. Use of the default service class is defined in ITU-T X.36 and X.76. Lastly, networks supporting these frame relay service classes may, at their discretion, elect to support the optional classes 2 or 3. Users selecting class 2 or class 3 may be subject to additional restrictions of the service provider not explicitly mentioned in this Recommendation.

6 Service class allocation methods

This clause defines methods for allocating the performance specified in the QoS classes of clause 5 to the national and international portions of clause 4. As the objectives in the QoS classes in clause 5 exclude the performance of the access circuit section, this aspect is discussed first in 6.2 after the introduction of route length in 6.1. Subsequently, 6.3 and 6.4 discuss the means by which the QoS class objectives of clause 5 for FTD and FLR_c, respectively, are to be allocated to national and international portions. Clause 6.3 also contains the end-to-end formula for FTD.

When allocating frame transfer delay on an edge-to-edge basis, a percentage allocation (modified when a satellite is present) is utilized. The effects of both "complexity" and "distance" when allocating FTD are for further study. The term "complexity" denotes network effects that increase delay as more switching and queuing stages are encountered. By "distance" is meant those networks effects not directly related to additional switching or queuing. These are typically less controllable, and route length estimates and allocations are used for these effects.

It should be noted that as the levels of the various FLR_c objectives in the frame relay QoS classes are in the range of 10^{-5} to $3*10^{-3}$, the major effect on FLR_c is due to buffer management (i.e. complexity). Thus, route length is not used as a factor in the allocation of FLR_c.

It is not anticipated that there will be more than one geostationary (or high orbit) satellite in a particular frame relay virtual connection. The presence of a geostationary or high orbit satellite is anticipated to reduce the number of switching nodes encountered by a virtual connection. However, the presence of more than one geostationary (or high orbit) satellite will cause the end-to-end objective for FTD to be exceeded, for all defined service classes except for the default class 0.

Performance allocations for multiple geostationary or high orbit satellites are for further study. Refinements to these allocations that reflect variations in connection segment length and/or complexity among national portions are for further study. Also for further study are performance allocations for portions containing low or medium orbit satellites.

6.1 Route length calculation

Route length (R_{km}) is used in place of "distance" in allocating some of the FTD performance objectives. If D_{km} is the air-route distance between the portion boundaries, then the route length is calculated as follows (this is the same calculation as found in ITU-T G.826):

- if $D_{km} < 1000$ km, then $R_{km} = 1.5 \times D_{km}$;
- if 1000 km $\leq D_{km} \leq$ 1200 km, then $R_{km} = 1500$ km;
- if $D_{km} > 1200$ km, then $R_{km} = 1.25 \times D_{km}$.

This rule does not apply if there is a satellite in the portion.

6.2 Access circuit section allocations

An access circuit section is part of a national portion.

As noted above, the major contribution to FLR_c performance is complexity. The apportionment of the national portion FLR_c allocation to the access circuit section is a national matter. Hence, this Recommendation makes no allocation to the access circuit section for FLR_c.

For FTD, the contribution of the access circuit section could be significant, depending on both its length and its nominal access line rate. The following formula quantifies the access circuit section's contribution to FTD.

The following notation is used:

- AR stands for the access line rate of the access circuit section in bits per second;
- FTD_a is the respective contribution of an access circuit section to the end-to-end frame transfer delay in milliseconds;
- R_a stands for the calculated route length of the access circuit section in kilometres.

The multiplier of 0.005 ms/km comes from Table A.1/G.114, and allows for delay in repeaters and regenerators. Additionally, a frame size of 256 octets, with 5 octets of overhead (a two-octet address field, a 16-bit cyclic redundancy check, and one flag) and 40 insertion bits for transparency is assumed.

The FTD associated with an access circuit section is:

$$\mathrm{FTD_a\,ms} = \frac{(256\times 8+5\times 8+40)\,\mathrm{bits}}{(\mathrm{AR}/1000)\,\mathrm{bit\cdot s^{-1}}} + \mathrm{R_a\,km}\times 0.005\,\mathrm{ms\cdot km^{-1}}$$

6.3 Frame delay allocations to national and international portions

For the allocation of FTD to national and international portions, the following formulas are used when no satellite is present. For the national portion, the route length, R_{km}, excludes the length of the access circuit section.

The following notation is used:

- FTD_N is the FTD of the national portion:

  The FTD_N is applicable to international virtual connections only. FTD for national virtual connections is outside the scope of this Recommendation.
- FTD_I is the FTD of the international portion;
- FTD_O is the FTD edge-to-edge objective from Table 1;
- FTD_a is the FTD of the access circuit section associated with the national portion;
- R_I is the calculated route length of the international portion.

The formula for end-to-end FTD (in milliseconds) of the national portion is:

$$FTD_N = FTD_a + 0.345 \times FTD_O$$

The formula for FTD (in milliseconds) of the international portion is:

$$FTD_I = 0.31 \times FTD_O, \text{ when } R_I \text{ is less than 9300 km}$$

$$FTD_I = 0.00625 \times R_I, \text{ when } R_I \text{ is at least 9300 km}$$

NOTE – 0.345 and 0.31 are the allocation factors defined in 6.4.

If a satellite is present in any portion, that portion is allocated a fixed FTD of 320 milliseconds. The value of 320 milliseconds takes into account factors such as low earth station viewing angles, and forward error correction encoding. Most portions that contain a satellite are not expected to exceed

290 milliseconds of delay. In the case of a satellite in one of the three portions, the remaining two portions are allocated 40 ms of delay each for their FTD objective.

6.4 Frame loss allocations to national and international portions

This clause provides allocations of the FLR_c objectives. As noted above, this allocation does not use the route length of a portion due to the levels of the FLR_c objectives. Since national portions often have somewhat more complexity than international portions, this allocation slightly favours national portions. The allocation is as follows:

- For a national portion, take 34.5% of the objective in Table 1.
- For an international portion, take 31% of the objective in Table 1.

These rules apply regardless of the presence or absence of a satellite in the portion.

The allocation is applicable to international virtual connections only. FLR_c for national virtual connections is outside the scope of this Recommendation.

APPENDIX I

Illustration of the weighted distribution concept for X.146 with possible application to frame relay SVC connections and measurement methods to estimate the 95th percentile of FTD

I.1 Weighted distributions and SVC performance estimation

Various questions arise when examining the possible means by which the design objectives in Table 1 could be applied to frame relay SVC connections:

1) Do the objectives of Table 1 really apply to all frame relay SVC connections regardless of the number of offered frames or time duration?
2) Will the objectives apply only to SVC connections with some minimal duration or number of offered frames?
3) How can frame relay SVC connections with different numbers of offered frames and durations be used in estimating the network design objectives?
4) Will the same methodology that is used for frame relay SVC connections also be applicable to PVC connections?
5) How can both PVC and SVC connections be used to estimate the FLR_c and FTD objectives in Table 1?

In order to answer the above questions with respect to FLR_c, this appendix presents a methodology for describing a weighted distribution of FLR_c applicable to both PVCs and SVCs. Both long- and short-time duration Frame Relay connections are amenable to this methodology.

Key to this methodology is the notion of a basic time duration, τ. The basic time durations can correspond to individual short calls (e.g. SVCs) or to portions of longer calls (e.g. portions of PVCs). Based on the observations of FLR_c over both time intervals of a basic time duration, and intervals of time less than the basic time duration, a weighted distribution of FLR_c is defined. The definition of the weighted distribution given here does not require that the same number of frames be sent in each time interval. Various statistics of the distribution (e.g. mean, variance, quantile) are easily obtained.

Let there be M time intervals, and let the duration of the jth interval be T_j. T_j is defined as follows:

1) If the duration of a connection is less than or equal to τ, set T_j equal to τ.
2) If the duration of a connection is greater than τ, break the connection into a number of intervals of length τ and a final interval whose duration is less than or equal to τ.

As an example, setting τ equal to 15 minutes means that connections longer than 15 minutes will be divided into 15-minute intervals, and connections shorter than 15 minutes will not be divided.

Next, define the following quantities:

N_j = number of frames sent during interval j;

n_j = number of frames lost during interval j;

$p_j = n_j/N_j$ = FLR for interval j;

$N = \sum_{j=1}^{M} N_j$ = total number of frames sent during all M time intervals;

$w_j = MN_j/N$ = weight for interval j.

The weights w_j are defined to handle the case where a different number of frames is sent during each interval j. Note that the weights are normalized to M, i.e.:

$$\sum_{j=1}^{M} w_j = M$$

In addition, in the case where all the N_j are equal, i.e. the same number of frames is sent in each interval, the w_j are all equal to 1 (and they sum to M).

Using the above, a distribution for FLR (the p_j) can be defined as follows. Note that FLR is a number between 0 and 1, and divide the interval [0,1] into K bins for FLR. The boundaries for these bins are defined by quantities P_k.

$$P_0 \le P_1 \le P_2 \le \cdots \le P_K$$

The jth bin is given by the interval $[P_{j-1}, P_j]$. Note that number of bins and the P_j are chosen to correspond to the granularity for which FLR estimates are desired.

The total weight for all the intervals whose FLR falls in bin k is given by:

$$w_k = \sum_{j:P_{k-1} \le p_j \le P_k} w_j$$

i.e. for bin k, the weights for all the intervals whose FLR falls within the bin (i.e. is between P_{k-1} and P_k) are summed. Using these weights, a histogram (FLR distribution) may be plotted with FLR bin on the horizontal axis and total weight for the bin (w_k) on the vertical axis. Figure I.1 illustrates such a distribution.

Once the distribution of FLR is defined, statistics may be defined in the usual way. For example, the mean μ and variance σ^2 are given by:

$$\mu = \frac{1}{M}\sum_{j=1}^{M} w_j\, p_j \quad \text{and} \quad \sigma^2 = \left[\frac{1}{M}\sum_{j=1}^{M} w_j\, p_j^2\right] - \mu^2$$

An estimate of the α-quantile may be obtained as the value p such that the cumulative distribution between 0 and p (i.e. the area under the histogram between 0 and p) is equal to αM (note that the factor of M is present because the weights are normalized to M rather than 1). Note that, in practice, the α quantile would be determined to the granularity of one bin $[P_{k-1}, P_k]$, with the area up to P_{k-1} being less than or equal to αM and the area up to P_k being greater than or equal to αM.

Finally, note that when the mean and variance above are obtained from measurement data, they are point estimates of the true mean and variance; the question of statistical confidence (and associated confidence intervals) is not addressed here. In addition, the α-quantile is an interval estimate, though the degree of statistical confidence is not addressed.

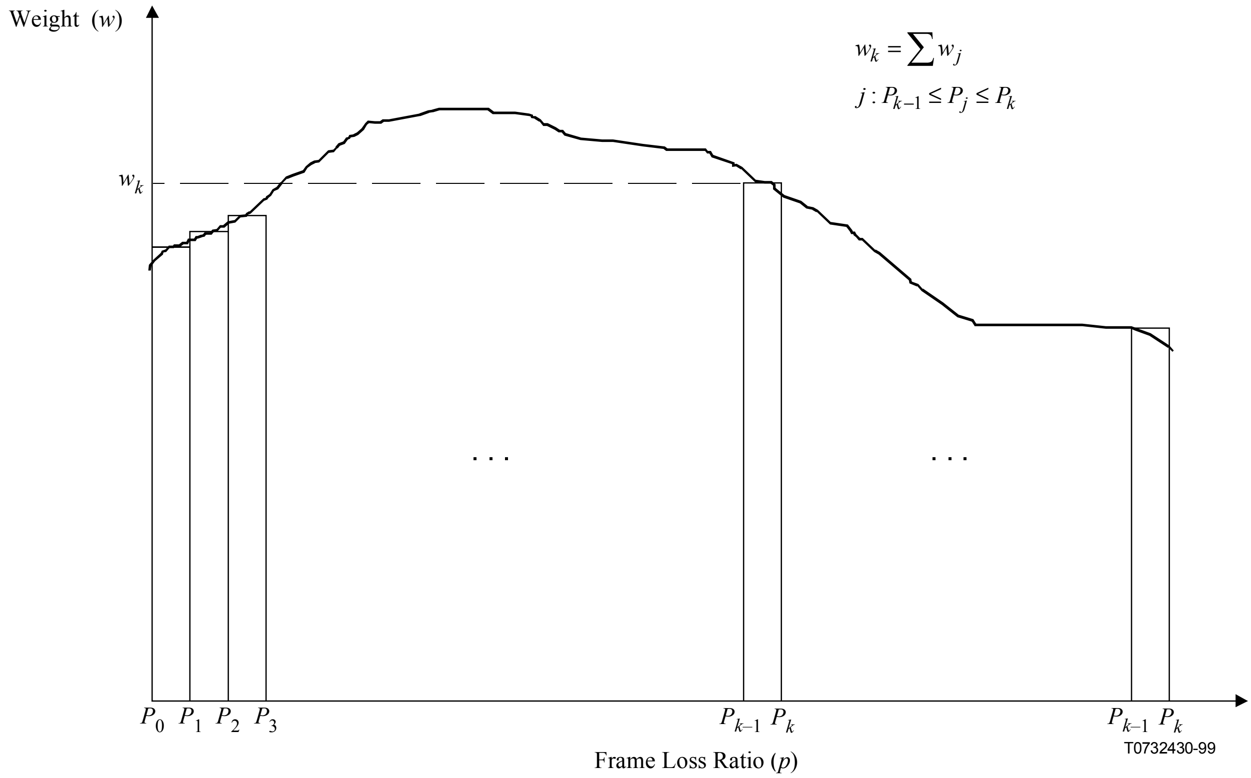

Figure I.1/X.146

I.2 Methods to estimate the 95th percentile of FTD

One method to estimate the 95th percentile value is to sample the FTD with a sufficiently large number of measures, and compute the 95th percentile from all the measures of FTD in the sample. This estimate of the 95th percentile would then be compared to the objective in Table 1 for the 95th percentile of FTD.

Another way is to verify that no more than 5% of the measures are above the target threshold. When this method is used, the actual ratio above the predetermined threshold (be it 1% or 4%) and its evolution provide useful information on how good or bad the service is and will be.

From a pure performance perspective, the two methods are equivalent, but from an implementation point of view, one requires that all the measures be captured, while the other requires that only in the order of 5% of the measurements be captured.

APPENDIX II

Effect of transmission delay and frame size on FTD

This appendix presents information to illustrate the effects which the choice of frame size and transmission trunk speed have on FTD performance. These effects occur in both the access circuit section, and also in the inter-node trunk transmission link.

Clocking delays of inter-node trunk transmission link clearly contribute towards the end-to-end frame transfer delay. Although it is a small component for frame sizes below 512 octets, this component can become more significant for larger frame sizes and low speed transmission links. This can be seen by observing the clocking delay components calculated for various transmission speeds, as shown in Table II.1 below.

Table II.1/X.146 – Clocking delay for various transmission rates and frame sizes

Transmission speeds	Frame size (FR information field)					
	64 bytes	128 bytes	256 bytes	512 bytes	1024 bytes	2048 bytes
64 kbit/s	8 ms	16 ms	32 ms	64 ms	128 ms	256 ms
128 kbit/s	4 ms	8 ms	16 ms	32 ms	64 ms	128 ms
256 kbit/s	2 ms	4 ms	8 ms	16 ms	32 ms	64 ms
512 kbit/s	1 ms	2 ms	4 ms	8 ms	16 ms	32 ms
1 024 kbit/s	0.5 ms	1 ms	2 ms	4 ms	8 ms	16 ms
1 544 kbit/s	0.35 ms	0.68 ms	1.35 ms	2.67 ms	5.3 ms	10.6 ms
2 048 kbit/s	0.25 ms	0.5 ms	1 ms	2 ms	4 ms	8 ms
34 368 kbit/s	16 µs	31 µs	61 µs	120 µs	240 µs	480 µs
44 736 kbit/s	12 µs	24 µs	46 µs	92 µs	184 µs	367 µs
155 520 kbit/s	3.5 µs	7 µs	13 µs	27 µs	53 µs	106 µs
NOTE – The frame size refers to the size of the FR information field. Also a 2-byte FR header size plus a 2-byte FCS are assumed.						

Consider a national network which has a geographic span of 4000 km, consisting of 8 switching stages and inter-trunk transmission speeds of 2 Mbit/s. Each switch contributes 1 ms of queuing delay.

– For a 512-octet test frame, each trunk will contribute a clocking delay of 2 ms (see Table II.1). The total FTD is calculated as 8 × 1 ms + 4000 km × 0.005 + 8 × 2 ms = 44 ms. This network meets the national portion FTD objective allocation of 51.75 ms for class 3 FR services.

– For a 256-octet test frame, each trunk will contribute a clocking delay of 1 ms (see Table II.1). The total FTD is calculated as 8 × 1 ms + 4000 km × 0.005 + 8 × 1 ms = 36 ms. This network meets the national portion FTD objective allocation of 51.75 ms for class 3 FR services.

Now consider a national network which has a geographic span of 4000 km, consisting of 8 switching stages but whose inter-trunk transmission speed is 1.544 Mbit/s. Each switch contributes 1 ms of queuing delay.

– For a 512-octet test frame, each trunk will contribute a clocking delay of 2.67 ms (see Table II.1). The total FTD is calculated as 8×1 ms + 4000 km $\times$ 0.005 + 8×2.67 ms = 50.36 ms. This network meets the national portion FTD objective allocation of 51.75 ms for class 3 FR services.
– For a 256-octet test frame, each trunk will contribute a clocking delay of 1.35 ms (see Table II.1). The total FTD is calculated as 8×1 ms + 4000 km $\times$ 0.005 + 8×1.35 ms = 38.8 ms. This network meets the national portion FTD objective allocation of 51.75 ms for class 3 FR services.

Thus, it can be seen that only in the case where the number of switching stages exceeds eight (8), and the inter-node trunk transmission speed is 1.544 Mbit/s, will the national portion FTD objective be exceeded when the test frame size is 512 octets.

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