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Public data networks – Network aspects

Procedures for the measurement of the performance of public data networks providing the international frame relay service

ITU-T Recommendation X.148

ITU-T X-SERIES RECOMMENDATIONS

DATA NETWORKS AND OPEN SYSTEM COMMUNICATIONS

For further details, please refer to the list of ITU-T Recommendations.

ITU-T Recommendation X.148

Procedures for the measurement of the performance of public data networks providing the international frame relay service

Summary

This Recommendation defines procedures for the measurement and assessment of the user information transfer performance parameters of Frame Relay virtual connections. Use is made of OAM Frames and methods for measuring Frame Transit Delay, Frame Delay Jitter and Frame Loss Ratio are specified. The techniques are applicable to both PVCs and SVCs. The techniques defined enable in-service real time performance estimation.

Source

ITU-T Recommendation X.148 (2003) was prepared by ITU-T Study Group 17 (2001-2004) and approved under the WTSA Resolution 1 procedure on 13 February 2003.

FOREWORD

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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-T Recommendation X.148

Procedures for the measurement of the performance of public data networks providing the international frame relay service

1 Scope

This Recommendation describes a methodology for measuring, in near real time, the performance parameters of virtual connections established over public frame relay data networks. The preferred measurement procedures are based on the use of FR-OAM Frames as defined by FRF.19.

Clause 5 provides a general overview of the measurement methodologies that may be used to measure the Quality of Service parameters. The use of test traffic, and the associated measurement architectures, is based on methods specified in ITU-T Rec. X.l38. Clauses 6 through 10 present estimation procedures for frame transfer delay, frame delay jitter, frame loss ratio (derived from frame delivery ratio), and data delivery ratio based on the use of OAM Frames. Methods for estimating service availability are for further study.

Annex A provides information on the use of test traffic in conjunction with dedicated monitoring equipment. Note that other measurement devices and procedures that adhere to the performance parameter definitions in ITU-T Recs X.144, X.145 and X.146 are also acceptable for estimating the performance of frame relay public data networks.

1.1 General

The network performance of Frame Relay networks may need to be measured for the following reasons:

- network performance objectives may be included in service level agreements or other contractual arrangements;
- ongoing measurement/assessment of network performance as part of operational procedures;
- to assist network planning: collection of data for network dimensioning purposes;
- network operators may require ongoing knowledge of their network's capabilities as defined by the primary performance parameters;
- Quality of Service parameters may need to be measured for use in other Recommendations;
- National Regulatory Requirements

1.2 Parameters to be measured

ITU-T Recs X.144 and X.145 define performance parameters which specify the Quality of Service of a Frame Relay virtual connection. ITU-T Rec. X.146 defines various QoS classes. The QoS classes are characterized by distinct combinations of objective values for the following primary performance parameters:

- Frame Transfer Delay (FTD);
- Frame Delay Jitter (FDJ);
- Frame Loss Ratio (FLR) (derived from Frame Delivery Ratio).

These primary parameters, when taken together with the derived parameter of service or network availability, define the overall quality of the data transfer phase of a frame relay connection.

The measurement techniques defined in this Recommendation are applicable to both PVCs and SVCs since in both cases measurement of the performance parameters is related to the data transfer phase of a FR connection.

1.3 Accuracy requirements of measurements

1.3.1 Measurement objectives

In measuring network performance, there is always a cost versus sample size tradeoff which must be resolved when attempting to estimate a given performance parameter. As the cost of taking an observation can have a considerable effect on the final estimate achieved, this Recommendation does not recommend a minimum number of observations. However, a sufficient number of measurements must be made in order to obtain statistical significance. Additionally, in certain situations, estimating the parameter with a high level of precision may not be required. For example, estimating Frame Transfer Delay to within between 2 ms may be adequate for most planning and monitoring purposes.

Estimates of means, variances, percentile, modes, maxima and minima are all examples of statistical descriptors which may be used to quantify the performance achieved by a specific parameter. In reporting any such estimated parameters, it is always recommended that a measure of the precision of the estimate be included. The variance of the estimate, or a confidence interval about the estimate, are two common methods of expressing the estimate's precision.

1.3.2 Reference events

The time of occurrence of various reference events is the basis for the definitions of the speed of service parameters (i.e, FTD and FDJ) listed above. In this Recommendation, times are specified with respect to exit and entry events relative to the test equipment. Thus, the time of occurrence of an entry event into such a DTE is the time at which the last bit of the closing flag of the frame enters the DTE from a circuit section, and the time of occurrence of an exit event from such a DTE is the time at which the first bit of the address field of the frame enters the circuit section from the DTE.

The exact definition of a Frame Reference Event for the user information transfer parameters is given in ITU-T Rec. X.144.

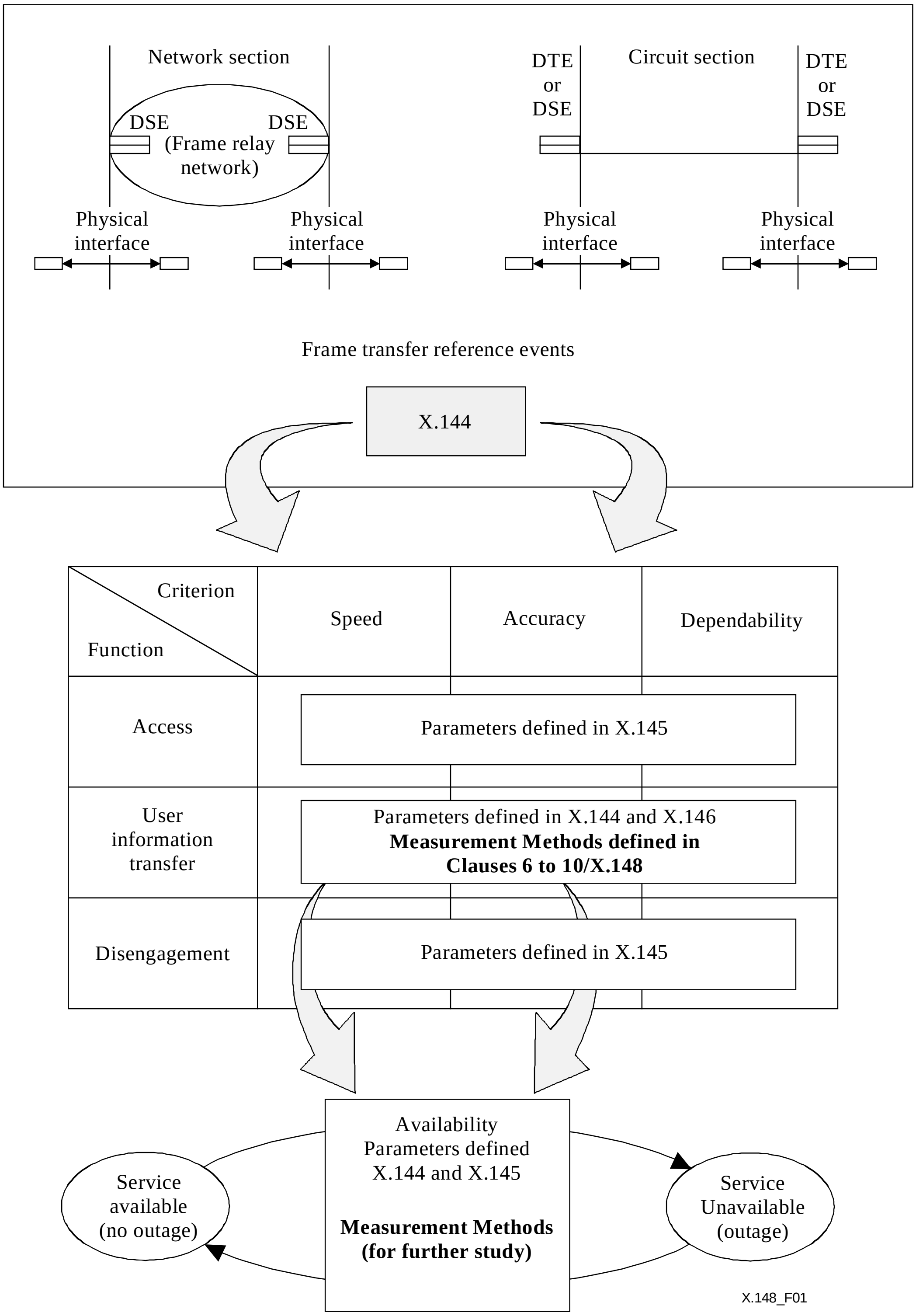


Figure 1/X.148 – Scope of ITU-T Rec. X.148

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 G.114 (2003), *One-way transmission time*.

– ITU-T Recommendation I.610 (1999), *B-ISDN operation and maintenance principles and functions*.

– ITU-T Recommendation I.620 (1996), *Frame relay operation and maintenance principles and functions*.

– 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.138 (1997), *Measurement of performance values for public data networks when providing international packet-switched services*.

– ITU-T Recommendation X.139 (1997), *Echo, drop, generator and test DTEs for measurement of performance values in public data networks when providing international packet-switched services*.

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

– ITU-T Recommendation X.144 (2000), *User information transfer performance parameters for data networks providing international frame relay PVC service*.

– ITU-T Recommendation X.145 (1996), *Performance for data networks providing international frame relay SVC service*.

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

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

3 Definitions

The terms and definitions used in this Recommendation are consistent with those defined in ITU-T Recs X.36, X.76, X.138, X.139, X.144, X.145, X.146, I.620, I.610 and Frame Relay Forum Implementation Agreement FRF.19.

4 Abbreviations

This Recommendation uses the following abbreviations:

CIR Committed Information Rate

DCE Data Circuit Terminating Equipment

DDR Data Delivery Ratio

DE	Discard Eligibility
DLCI	Data Link Connection Identifier
DSE	Data Switching Exchange
DTE	Data Terminal Equipment
EFR	Extra Frame Rate
EIR	Excess Information Rate
FDJ	Frame Delay Jitter
FDR	Frame Delivered Ratio
FE	Frame Layer Reference Event
FLR	Frame Loss Ratio
FR	Frame Relay
FRF	Frame Relay Forum
FROMP	Frame Relay OAM Maintenance Point
FTD	Frame Transfer Delay
IF	Information Field
ISDN	Integrated Services Digital Network
MP	Maintenance Point
MTBSO	Mean Time Between Service Outages
MTTSR	Mean Time To Service Restoral
NLPID	Network Layer Protocol ID
OAM	Operations, Administration and Maintenance
PVC	Permanent Virtual Connection
RFER	Residual Frame-Error Ratio
RTD	Round Trip Delay
SA	Service Availability
SLA	Service Level Agreement
SVC	Switched Virtual Connection
TE	Terminal Equipment
TNS	Transit Network Section

5 Measurement Methodologies

This clause provides an overview of the measurement methodologies that may be used to measure the Quality of Service parameters for public Frame Relay data networks as specified in ITU-T Recs X.144, X.145 and X.146, together with general considerations for measuring the performance parameters. In general, two approaches may be used to estimate/monitor the network performance:

a) use of test traffic;

b) use of OAM frames.

5.1 Use of test traffic to estimate performance parameters

The use of test traffic is a simple measurement methodology that can be used to estimate the values of the performance parameters for a specific virtual connection.The method involves setting up an SVC or PVC between a source and a data sink and generating a known and sufficient quantity of test traffic. The protocol and user information signals transferred across the user/network (DTE/DCE) interfaces are observed in real time and a chronological event history is compiled. This event history can then be analysed to provide a measurement of the primary performance parameters. The use of test traffic is particularly suited to use by customers for testing the performance of their Frame Relay connections. Network operators can also use this method to measure specific test connections within their networks in order to obtain an indication of network performance.

ITU-T Recs X.138 and X.139 specify measurement methods for assessing the performance parameters of PSPDNs (X.25 networks) using test traffic. These techniques are also applicable to Frame Relay Networks. Annex A provides an overview of various measurement architectures which are applicable to the use of test traffic for measuring FR performance.

5.2 Use of OAM Frames to estimate performance

OAM frames provide a means to test, measure and diagnose the overall Quality of Service being provided by a Frame Relay Network. The key benefit in using OAM frames to measure performance is that it can be readily applied across a Network. Accordingly it is considered to have better scalability than the test traffic method.

OAM provides functions which can assist in the operation and maintenance of the physical layer and FR layer aspects of a Frame Relay Network. The OAM functions may be applied to the Virtual Connections (PVC and SVC) that are routed through a Frame Relay Network.

OAM has been defined to enable fault and performance management by providing the following general functionality:

a) *Performance monitoring*

   Performance monitoring of the network is monitored by continuous or periodic checking of functions. As a result, maintenance event information will be produced. Analysis of the maintenance event information for a specific connection allows estimation of the transport integrity.

b) *Defect and failure detection*

   Defect/failures affecting the transport of user information are detected by continuous or periodic checking. As a result, maintenance event information or various alarms will be produced.

c) *Defect information*

   Defect information is given to other management entities. As a result, alarm indications are given to other management planes. Response to a status report request will also be given.

d) *Fault localization*

   Determination by internal or external test systems of a failed entity if failure information is insufficient.

e) *Status and failure information*

   Notification of availability (active) or unavailability (inactive) as well as failure information is provided for configured connections among layer management entities. Response to status report requests will also be given.

These functions result in a bidirectional information flow known as FR-OAM flows. Information within the FR-OAM messages can be used to assess network performance and assist in determining maintenance actions.

6 Use of FRF.19 OAM Frames to measure the Frame Relay performance parameters

Frame Relay OAM messages are carried in standard FR frames. The measurement methodology specified in this Recommendation is based on the use of FR-OAM Frames as defined by Frame Relay Forum Implementation Agreement 19, FRF.19 (2001) – Frame Relay Operations, Administration, and Maintenance.

Three basic OAM Message Types are defined: Hello Frames, Service Verification Frames and Loopback Frames. For each OAM Message Type, a number of specific functions, as specified by the "Information Field Type" have been defined.

- Capabilities
- Frame Transfer Delay
- Frame Transfer Delay Results
- Frame Delivery Ratio Sync
- Frame Delivery Ratio Results
- Data Delivery Ratio Sync
- Data Delivery Ratio Results
- Non-Latching Loopback
- Latching Loopback
- Diagnostic Indication

Service Verification Frames support the measurement of the following primary performance parameters:

– Frame Transfer Delay;

– Frame Delay Jitter and;

– Frame Loss Ratio or Frame and Data Delivery Ratio.

Clauses 7 to 10 describe the way in which specific OAM Messages (as defined by the Message Type and the Information Field Type) can be used to measure Frame Transfer Delay, Frame Delay Jitter and Frame Loss Ratio and Data Delivery Ratio.

6.1 Measurement duration, frequency and sampling rates

It is important that the primary performance parameters are measured on a regular basis. The duration, frequency and sampling rates should be such that both short-term and long-term performance degradation can be detected. For example, the duration and frequency at which Frame Loss is measured should be such that burst losses can be distinguished from long-term periodic losses.

In using OAM Frames to assess performance, the measurement duration should be such that problems due counter wrap and the effects of lost OAM frames are avoided.

FRF.19 uses a timing technique (see 6.1.1) to send OAM frames at specified time intervals.

NOTE – The specific definition of measurement periods, sample rates and the frequency at which OAM frames are to be injected into the user traffic flows for the purpose of assessing network performance are for further study.

6.1.1 Periodic transmission interval for measurement initiations – use of TIMER_SLV

FRF.19 provides that each type of service measurement may use an independent timer (designated TIMER_SLV_*), or share a single timer (designated TIMER_SLV). FRF.19 recommends that the default interval for TIMER_SLV is 900 seconds. Network operators may choose other values.

6.2 OAM frame format

The basic structure of a Frame Relay OAM frame as specified by FRF.19 is shown in Figure B.1. For reference and to aid understanding, Annex B also provides information on the structure of the OAM Service Verification Messages and the Information Fields used in measuring the performance parameters.

6.3 Network initialisation and awareness of OAM capabilities within a network

Any measurement using FRF.19 OAM frames requires that the nodes at both ends of the connections under measurements (known as Frame Relay OAM Maintenance Points (FROMPs)) to be OAM compliant. FRF.19 outlines a method by which all OAM compliant Maintenance Points (MPs) can be made aware of other MP's compliance. This is achieved through the use of "hello" messages. All FROMPs periodically send "hello" messages, which are then processed by all other FROMPs. Each Maintenance Point thus becomes aware of all other Maintenance Points within a maintenance domain.

Likewise each FROMP sends capability messages. These capability messages are specific OAM frames that carry information regarding the capabilities of a particular FROMP (e.g, the ability to measure loss or RTD). The hello messages and the capabilities message allow all maintenance points to know which other points are OAM compliant and which capabilities they possess.

An example of "hello" message flows between the initiator and receiver devices is shown in Figure I.1.

6.4 Measurement of frame loss in both directions

The methods specified in clauses 9 and 10 only provide a measurement of delivery or loss ratio on the forward path of the Frame Relay connection. In order to measure the performance on the return path, it is necessary to initiate a measurement session from the receiving maintenance point.

The remote maintenance point initiates the measurement by sending an OAM message with a Frame Delivery Ratio Sync Information Field to the initiating maintenance point. The measurement period is terminated when a second Delivery Ratio Sync Information Field is sent by the remote MP. If required, the results of the measurement can be reported back to the remote MP via an OAM frame with the Frame Delivery Ratio Results Information Field.

7 Procedures to estimate frame transfer delay

7.1 Measurement procedure description

To overcome the need to synchronize the real time clocks located at the two maintenance points, an estimate of the Frame Transfer Delay between two MPs in a Frame Relay network, can be made by making a measurement of the Round Trip Delay (RTD). This measurement is divided in half to obtain an estimate of the one-way FTD measurement.

A Frame Transfer Delay measurement requires a two-way exchange between initiator and receiver FROMPs. The initiator begins the measurement by sending an OAM Service Verification message containing the Frame Transfer Delay Information Field, (see Figure B.2) from an initiating MP to a receiving MP. The Frame Transfer Delay Information Field contains subfields that carry information relating to when the frame was sent from the initiating MP, and when it was received and returned by the receiving MP. On receipt of the message, the receiving FROMP loops the message back after filling in additional time-stamps. On receipt of the frame at the initiating MP the arrival time is inserted. The timestamp values can be used in conjunction with the Initiator R_x time-stamp (which is inserted on receipt of the frame) to determine the round trip delay and subsequently to estimate the Frame Transfer Delay.

The measurement technique is summarized in Figure 2. (Optionally, the initiator may then deliver a copy of the results back to the receiver using the Frame Transfer Delay Results Information Field. See Figure B.3.)

This procedure uses the Frame Transfer Delay IF, the Frame Transfer Results IF, and the Pad IF An example of message flows between the initiating MP and the receiving MP is shown in Figure I.2.

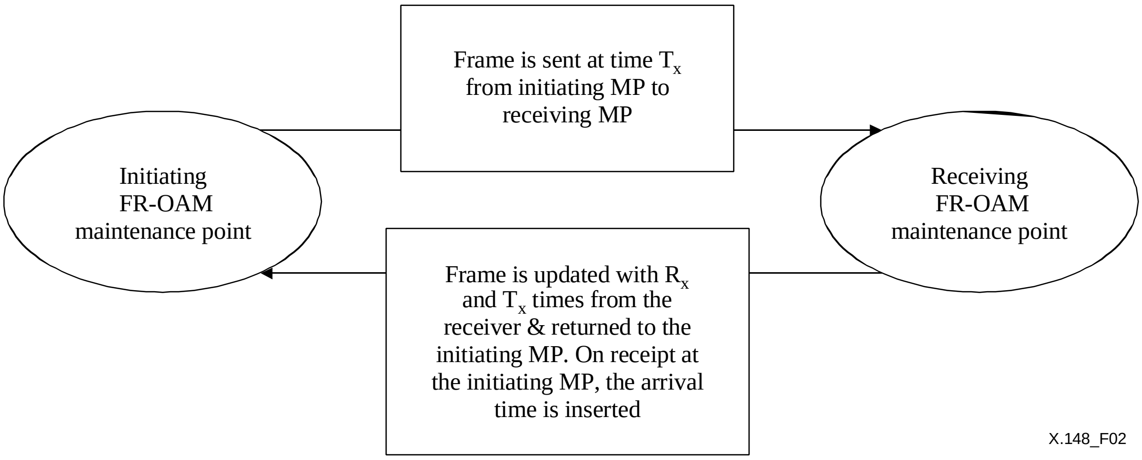


Figure 2/X.148 – Measurement of RTD using OAM frames

7.2 Delay measurement initiation

On the initiation of a delay measurement, the initiator device transmits the Frame Transfer Delay IF using the short form (6 octets). The initiator shall fill in the initiator T_x time-stamp with a value representing the time that the opening bit of the frame will begin transmission.

7.3 Transfer delay information frame turnaround

Upon receiving a Frame Transfer Delay IF of the short form, the receiving device responds to the initiator with the Frame Transfer Delay IF long form (12 octets). The responder shall copy the initiator T_x time-stamp, fill in the responder R_x time-stamp with a value representing the arrival time of the closing bit of the frame, and fill in the responder T_x time-stamp with a value representing the time that the opening bit of the frame will begin transmission. This response shall be sent in an OAM message padded to the same length as was received. The pad information field is available to be used for this purpose.

7.4 Calculation of frame transfer delay

7.4.1 Use of round trip delay times

Upon receiving a Frame Transfer Delay IF of the long form, the initiator device shall record a time-stamp with a value representing the arrival time of the closing bit of the frame. The Frame Transfer Delay is calculated from the time stamps in the Frame Transfer Delay Information Field as follows:

$$\text{Round Trip Delay } (RTD) = (Initiator\_R_x - Initiator\_T_x)$$

$$\text{Hence } FTD = ((Initiator\_R_x - Initiator\_T_x) - (Responder\_T_x - Responder\_R_x))/2$$

It is expected that $(Responder\_T_x - Responder\_R_x)$ will be small compared with the end-to-end delay. Hence a practical approximation for Frame Transfer Delay will be given by:

$$FTD = (Initiator\_R_x - Initiator\_T_x)/2$$

NOTE 1 – Since the Frame Transfer Delay times on the forward and backward paths may vary due to changing traffic conditions, a sufficient number of measurements should be made to ensure a statistically convergent result.

NOTE 2 – The above method for measuring FTD is more accurate than the method currently outlined in ITU-T Rec. I.620. This is because the FRF.19 method subtracts the processing delays of the remote maintenance point. This delay is not accounted for by ITU-T Rec. I.620.

7.4.2 Direct estimate of frame transfer delay

If the time clocks at the initiating and receiving MPs are synchronized, the Frame Transfer Delay could be directly estimated from the $Initiator\_T_x$ and $Responder\_R_x$ time stamps:

$$FTD = Responder\_R_x - Initiator\_T_x$$

7.5 Delivery of delay results

Dependent upon provisioning, the initiator device may forward the calculated one-way FTD results to the receiver device using the Frame Transfer Delay Results I.F. Such forwarding may be done immediately, or held for inclusion in the next measurement interval.

7.6 Error handling

A lost or damaged FTD request or response message can result in a missed measurement period. Implementations may optionally time-out and retransmit to recover the period.

8 Procedures for the estimation of frame delay jitter

Clause 5.2/X.144 defines Frame Delay Jitter (FDJ) 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.

Accordingly, a running estimate of FDJ can be obtained from an analysis of the collected values of a statistically significant number of transfer delay measurements.

9 Procedures for estimation of frame loss ratio/frame delivered ratio

ITU-T Rec. X.144 specifies Frame Loss Ratio as the primary parameter used to quantify the dependability of the transfer of user information frames. The OAM frames defined by FRF.19 enable the calculation of the parameter Frame Delivered Ratio (FDR). The FDR parameter is the complement to the Frame Loss Ratio.

9.1 Procedures for frame delivery ratio measurement

In this procedure, a one-way measurement is made of the delivery ratio from the initiating MP to the receiving MP. This measurement also satisfies the requirements for calculating the FLR as defined by ITU-T Rec. X.144.

A complete Frame Delivery Ratio (or FLR) measurement requires multiple exchanges between the initiating and receiving MPs. The measurement using FR-OAM frames is a three-step process.

To initiate the measurement sequence an OAM message frame containing the Frame Delivery Ratio Sync Information Field (See Figure B.4) is sent from the initiator MP with the VC time value set to zero. This tells the receiving MP to count frames received from this point in time onwards.

After the period of time over which the measurement is to made has elapsed, the initiating MP sends a second OAM message also containing the "Frame Delivery Ratio Sync Information Field" to the receiving MP. This field contains a count of the number of CIR and EIR frames transmitted (offered) on the FR connection. When this frame arrives at the receiving MP, it also signals the receiving MP to terminate the frames received count. The counts for the number of frames transmitted count are then compared with the number of frames actually received (delivered) at the MP. This creates a one-way measurement of the FDR (or FLR) parameter.

Finally, the receiving MP then sends back a "Frame Delivery Ratio Results Information Field" (See Figure B.5) which contains calculated values for the number of frames delivered and frames lost for both CIR and EIR traffic. Either the Frame Delivered Ratio or the Frame loss Ratio can then be calculated from values for $FramesDelivered_{Committed}$, $FramesDelivered_{Excess}$, $FramesLost_{Committed}$ and $FramesLost_{Excess}$.

An independent measurement session may also be established in the reverse direction.

This procedure uses the Frame Delivery Ratio Sync IF, and the Frame Delivery Results IF.

An example of message flows between the initiating MP and the receiving MP is shown in Figure I.3. An example of the use of this method to calculate the FDR for across a FR end-to-end connection is described in Appendix II.

9.2 Frame delivery ratio initiation

The Frame delivery ratio sync IF is used to initialize (or re-initialize) an FDR measurement session.

The initiator of this message shall fill in the VC Time (in milliseconds) to ensure that the receiver interprets the message to indicate an initialization or a re-initialization. A VC Time of zero is used to indicate initiation or re-initialization.

The initiator of this message shall also fill in the current counters for this VC ($FramesOffered_{Committed}$ and $FramesOffered_{Excess}$) prior to this message being transmitted. OAM messages must be included in these frame counts.

When a Frame Delivery Ratio Sync IF is received with the VC Time value set to zero or less than the previous received value (taking into account normal counter-wrapping), the receiver shall terminate any previous session and restart a new session. A FROMP receiving this information field (regardless of the VC Time indicated) shall record the receiver frame counts representing the counters for this VC ($FramesReceived_{Committed}$ and $FramesReceived_{Excess}$) as they were prior to the reception of this frame.

9.3 Frame delivery ratio measurement

The Frame Delivery Ratio Sync IF is also used to complete a one-way measurement of the ratio of frames delivered to frames offered. The initiating MP of this message shall fill in the current counters for this VC ($FramesOffered_{Committed}$ and $FramesOffered_{Excess}$) prior to this message being transmitted. When wrapping of the VC Time occurs, the initiating MP shall ensure that a value of zero is not sent.

A FROMP receiving the frame delivery ratio sync IF shall record the receiver frame counts representing the counters for this VC ($FramesReceived_{Committed}$ and $FramesReceived_{Excess}$) as they were prior to the reception of this frame. The value of the VC Time shall be inspected for indications of a restart as described in clause 9.2.

The receiving MP shall determine if the recorded maximum interval has been exceeded.

- If the interval has been exceeded, the MP shall not use the previous counters to calculate the FDR for the interval terminated by this message. The counters from this poll shall be stored such that the next poll in this measurement session will be valid if it is received within the allowable interval.
- If the interval has not been exceeded, the MP shall use these counters to calculate the FDRs for the interval. FDRs for the receive direction are calculated using the following formulae:

$$\Delta\, FramesOffered_{Committed} = FramesOffered_{Committed}2 - FramesOffered_{Committed}1$$

$$\Delta\, FramesOffered_{Excess} = FramesOffered_{Excess}2 - FramesOffered_{Excess}1$$

$$\Delta\, FramesDelivered_{Committed} = FramesReceived_{Committed}2 - FramesReceived_{Committed}1$$

$$\Delta\, FramesDelivered_{Excess} = FramesReceived_{Excess}2 - FramesReceived_{Excess}1$$

$$\Delta\, FramesLost_{Committed} = \Delta FramesOffered_{Committed} - \Delta FramesDelivered_{Committed}$$

$$\Delta\, FramesLost_{Excess} = \Delta FramesOffered_{Excess} - \Delta FramesDelivered_{Excess}$$

$$FDR_C = \Delta FramesDelivered_{Committed}/\Delta FramesOffered_{Committed}$$

$$FDR_E = \Delta FramesDelivered_{Excess}/\Delta FramesOffered_{Excess}$$

Hence

$$FDR = \frac{(\Delta FramesDelivered_{Committed} + \Delta FrameDelivered_{Excess})}{(\Delta FramesOffered_{Committed} + \Delta FrameOffered_{Excess})}$$

The MP shall record the counters for use by the next "FDR Sync" message.

9.3.2 Frame loss ratio calculation

Also it should be noted that an estimate of the FLR can be readily calculated from the values (frame counts) in the Frame Delivery Ratio Results Information Field.

Clause 5.3/X.144 defines user information frame loss ratio (FLR) 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.

Assuming $F_E = 0$

$F_L = (FramesLost_{Committed} + FramesLost_{Excess})$

$F_S = (FramesDelivered_{Committed} + FramesDelivered_{Excess})$

$$FLR = \frac{(FramesLost_{Committed} + FramesLost_{Excess})}{(FramesDelivered_{Committed} + FrameDelivered_{Excess}) + (FramesLost_{Committed} + FramesLost_{Excess})}$$

9.4 Delivery of frame delivery ratio results

Dependent upon provisioning, the receiver device may forward the calculated one-way FDR results to the initiator device using the Frame delivery ratio results IF Such forwarding may be done immediately, or held for inclusion in the next measurement interval.

9.5 FDR error handling

A lost or damaged FDR Sync message may result in one or more missed measurement intervals.

- If the maximum interval for counter-wrap (advertised by the peer in the capabilities information field) does not expire prior to the next successful FDR Sync message, this next complete measurement will span the period between the two received messages.
- If the maximum interval for counter-wrap occurs, the next successful FDR Sync message is treated as if it were a restart. In this case, the prior interval(s) are lost and FDR Results shall not be sent.

10 Procedures for data delivery ratio measurement

In this procedure, a one-way measurement is made of the delivery ratio from the initiator to the receiver.

NOTE – Although the Data Delivery Ratio parameter is not defined in ITU-T Rec. X.144, information on making a measurement is included as it is considered that this parameter provides information that customers of Frame Relay Networks would find useful.

A complete Data Delivery Ratio measurement requires multiple exchanges between the initiating MP and the receiving MP. The beginning of a measurement session requires the initiating MP to send a sync indication. Measurements may then be made by the initiating MP sending a second DDR Sync IF message to the receiving MP. This creates a one-way measurement of the parameter. The receiver may send a copy of the results back to the initiator by using the frame delivery results information field. An independent measurement session may also be established in the reverse direction.

This procedure uses the Data Delivery Ratio Sync IF, and the Data Delivery Results IF An example of message flows between an initiating MP and a receiving MP is shown in Figure I.3.

10.1 Data delivery ratio initiation

The data delivery ratio sync IF is used to initialize (or re-initialize) a DDR measurement session.

The initiating MP of this message shall fill in the VC Time (in milliseconds) to ensure that the receiving MP interprets the message to indicate an initialization or a re-initialization. A VC Time of zero is used to indicate initiation or re-initialization.

The initiating MP of this message shall also fill in the current counters for this VC ($DataOffered_{Committed}$ and $DataOffered_{Excess}$) prior to this message being transmitted. OAM messages must be included in these data counts.

When a Data Delivery Ratio Sync IF is received with the VC Time set to zero, or a value less than the previous received value from the initiating MP, the receiving MP shall terminate any previous session and restart a new session. A FROMP receiving this information field (regardless of the VC Time indicated) shall record the receiver frame counts representing the counters for this VC ($DataReceived_{Committed}$ and $DataReceived_{Excess}$) as they were prior to the reception of this frame.

10.2 Data delivery ratio measurement

The Data Delivery Ratio Sync IF is also used to complete a one-way measurement of the ratio of octets delivered to octets offered. The initiator device of this message shall fill in the current counters for this VC ($DataOffered_{Committed}$ and $DataOffered_{Excess}$) prior to this message being transmitted.

A FROMP receiving the data delivery ratio sync IF shall record the receiver octet counts representing the counters for this VC ($DataReceived_{Committed}$ and $DataReceived_{Excess}$) as they were prior to the reception of this frame. The value of the VC Time shall be inspected for indications of a restart as described in clause 10.1.

The receiving MP shall determine if the recorded maximum interval has been exceeded.

- If the interval has been exceeded, the receiving MP shall not use the previous counters to calculate the DDR for the interval terminated by this message. The counters from this poll shall be stored such that the next poll in this measurement session will be valid if it is received within the allowable interval.
- If the interval has not been exceeded, the receiving MP shall use these counters to calculate the DDRs for the interval. DDRs for the receive direction are calculated using the following formulae:

$$\Delta\, DataOffered_{Committed} = DataOffered_{Committed}2 - DataOffered_{Committed}1$$

$$\Delta\, DataOffered_{Excess} = DataOffered_{Excess}2 - DataOffered_{Excess}1$$

$$\Delta\, DataDelivered_{Committed} = DataReceived_{Committed}2 - DataReceived_{Committed}1$$

$$\Delta\, DataDelivered_{Excess} = DataReceived_{Excess}2 - DataReceived_{Excess}1$$

$$\Delta\, DataLost_{Committed} = \Delta DataOffered_{Committed} - \Delta DataDelivered_{Committed}$$

$$\Delta\, DataLost_{Excess} = \Delta DataOffered_{Excess} - \Delta DataDelivered_{Excess}$$

$$DDR_C = \Delta DataDelivered_{Committed} / \Delta DataOffered_{Committed}$$

$$DDR_E = \Delta DataDelivered_{Excess} / \Delta DataOffered_{Excess}$$

Hence

$$DDR = \frac{(\Delta DataDelivered_{Committed} + \Delta DataDelivered_{Excess})}{(\Delta DataOffered_{Committed} + \Delta DataOffered_{Excess})}$$

The receiving MP shall record the counters for use by the next "DDR Sync" message.

10.3 Delivery of data delivery ratio results

Dependent upon provisioning, the receiving MP may forward the calculated one-way DDR results to the initiator device using the data delivery ratio results IF Such forwarding may be done immediately, or held for inclusion in the next measurement interval.

10.4 DDR error handling

A lost or damaged DDR Sync message may result in one or more missed measurement intervals.

- If the maximum interval for counter-wrap (advertised by the peer in the capabilities information field) does not expire prior to the next successful DDR Sync message, this next complete measurement will span the period between the two received messages.
- If the maximum interval for counter-wrap occurs, the next successful DDR Sync message is treated as if it were a restart. In this case, the prior interval(s) are lost and DDR Results shall not be sent.

11 Frame relay service availability estimation procedures

Methods for estimating and monitoring overall service availability and specifying additional criteria to those specified in ITU-T Recs X.144 and X.145 on which to base the transition from the "available" to the "unavailable" state, are for further study.

Annex A

Measurement architectures applicable to the use of test traffic for the estimation of performance

The information in this annex is based on information from ITU-T Rec. X.138 but adapted to the Frame Relay environment. See ITU-T Rec. X.138 for further information on the use of controlled/monitored sources and sinks for measuring specific parameters.

A.1 General considerations and measurement methodologies

A general measurement methodology involves setting up a SVC or PVC between a source and a data sink and generating a known and sufficient quantity of test traffic. The protocol and user information signals transferred across the user/network (DTE/DCE) interfaces are observed in real time and a chronological event history is compiled. This event history can then be analyzed to provide a measurement of the primary performance parameters.

Thus, in general, measurements of frame relay network performance require a source, a sink, and one or more monitors. A source transmits call set-up requests, data frames, or call clearing requests through the portions under test. A sink receives and acknowledges call processing or data from the portions under test. The function of the monitor is to record (or record and timestamp) the relevant reference events. The monitor function(s) should be placed as near as possible to the boundaries of the portions under test. Differences in location between the monitor functions and the appropriate boundaries must be compensated for in the calculation of the performance of the portions.

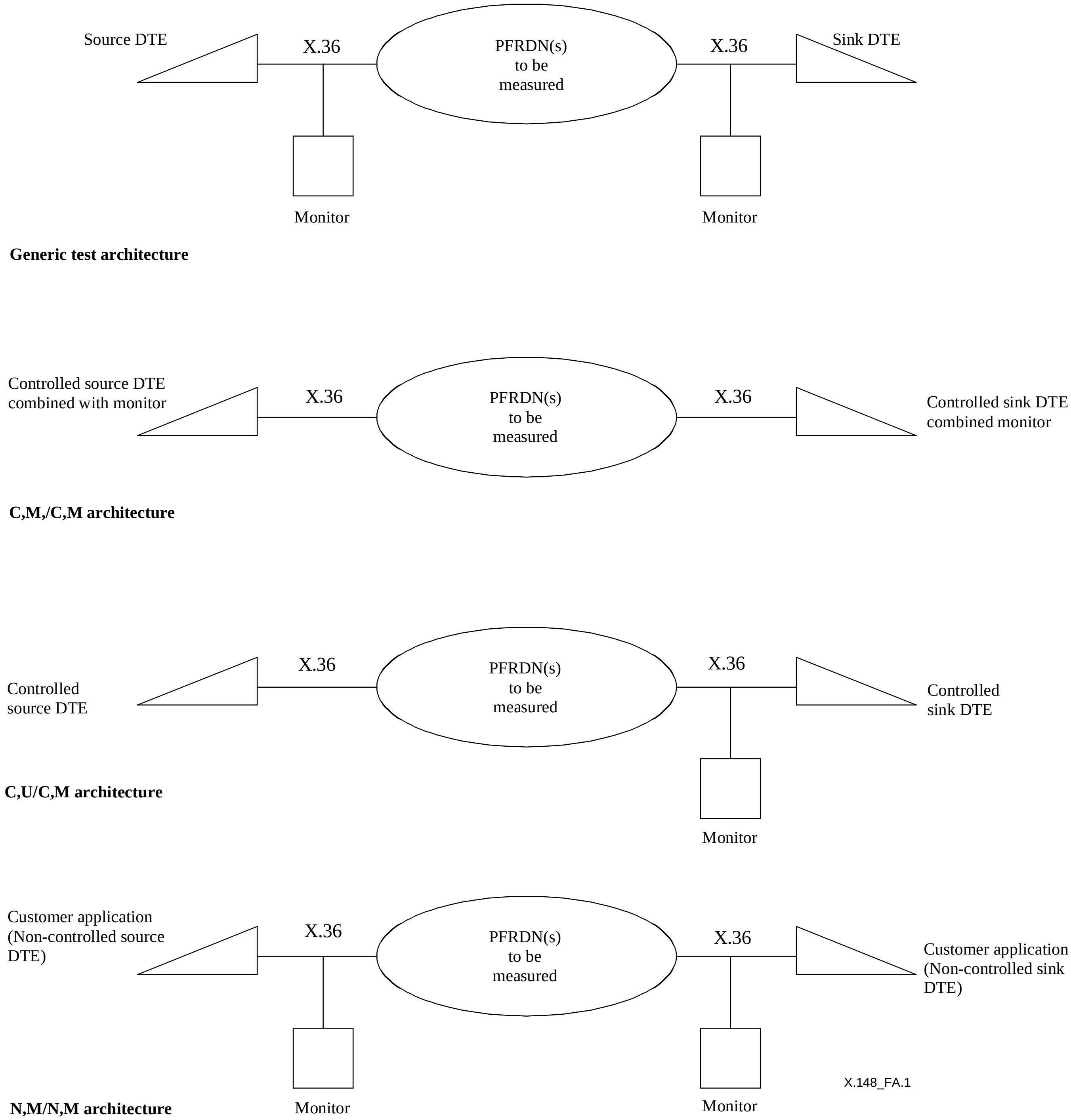
Sources and sinks can be either controlled or non-controlled. Controlled sources and sinks are under the control of the test programme and must respond quickly to events exiting the portions under test. Examples of controlled sources or sinks are stand-alone test equipment, special software within network equipment (for example within frame-relay switches), and special programmes within customer applications. Non-controlled sources or sinks are sources or sinks not under the direct control of a test programme. Non-controlled sources and sinks may not always respond quickly to network events. The most important examples of non-controlled sources and sinks are live customer applications, generating and receiving traffic according to their own needs.

A monitor function can be provided by stand-alone test equipment "T" connected at the appropriate X.36 or X.76 interface. Alternatively, a monitor function can reside in the test device that provides the source or sink function. Network equipment (such as frame-relay switches) and customer equipment (for example, DTEs) can also be programmed to record reference events and serve the monitor function. For example, accounting statistics can be used to estimate some performance parameters such as Frame Loss Ratio.

Various combinations of monitors and controlled and non-controlled sources and sinks can be used to measure frame relay network performance. Figure A.1 illustrates some of these possibilities. The architectures are identified by specifying whether the source and sink are controlled (C) or non-controlled (N), and whether the two portion boundaries are monitored (M) or unmonitored (U). The notation (C,M/N,U) indicates a controlled source, a non-controlled sink, monitored at the source boundary, and no monitoring at the sink boundary. When both the source and the sink are controlled and there are time synchronized monitoring functions at both boundaries (C,M/C,M), all the parameters defined in ITU-T Recs X.144 and X.145 can be measured without further assumptions. Other test architectures are more limited because they cannot be used to measure all of the parameters.

A means of synchronizing monitoring equipment for use in conjunction with a (C,M/C,M) architecture, to measure throughput and delay, is described in clause 6/X.138.

Clause A.2 lists the primary performance parameters (as specified in ITU-T Recs X.144, and X.145) and identifies the test architectures that can be used to measure them. In some cases, the test architectures can be used to measure parameters only if certain additional assumptions are made and such assumptions are described.



PFRDN Public frame relay data network

Figure A.1/X.148 – Examples of test architectures

A.2 Frame relay performance parameters and measurement architectures

Frame relay performance parameters are formally defined in ITU-T Recs X.144 and X.145.

A.2.1 Connection set-up delay

Connection set-up delay can best be measured with monitors at both portion boundaries. If the sink is known to accept set-up requests with constant or insignificant delay, and if the probability of call set-up error events is insignificant, call set-up delay can be measured without a sink-side monitor by subtracting the known sink delay from the one-sided measurement.

A.2.2 User Information frame transfer delay and disconnect delay

Both frame transfer delay and disconnect delay require a sink-side monitor time synchronized with either a source-side monitor or with the source itself.

A.2.3 User information frame delay jitter

Frame delay jitter can be derived from measurements of user information frame transfer delay.

A.2.4 Release delay

Release delay only requires a monitored source (or sink). As it is a local parameter, release delay is not discussed further in this Recommendation.

A.2.5 User information frame loss ratio

Measurement of user information frame loss ratio requires monitored sources and sinks transmitting and receiving user data frames.

A.2.6 Connection set-up error probability

Connection set-up error probability can only be measured if there is monitoring at both portion boundaries.

A.2.7 Connection set-up failure probability

Connection set-up failure probability can best be measured with monitors at both boundaries. The sink device must be fast enough that it does not significantly contribute to the probability of timing out. If the sink can be relied upon to accept every call set-up attempt, connection set-up failure probability can be measured without a monitor at the sink-side.

A.2.8 Residual error ratio and extra frame rate

Residual error ratio requires monitoring at both boundaries or a controlled source transmitting a known sequence of user data. Both these architectures allow the transmitted and received user data to be compared.

A.2.9 Premature disconnect performance

Premature disconnect stimulus probability can be measured by a single monitor at a single boundary. Premature disconnect event probability require monitors at both boundaries. These allow for distinguishing the clearing events that exit the portions under test from the clearing events stimulated at the distant boundary.

A.2.10 Connection clearing failure probability

Connection clearing failure probability can best be measured with monitors at both boundaries. If the transmission of the clear request by a controlled test device is reasonably well synchronized with the sink-side monitor, the monitor can anticipate clearing and observe call clearing failures.

A.3 Loopbacks

Loopbacks provide an alternative measurement architecture allowing a single test device to serve as both a source and a sink. Figure A.2 illustrates the two possibilities for using loopbacks in frame relay network performance measurements.

Routing loopbacks are established within the frame relay network(s) by routing virtual connections through one or more switching functions (or through multiple networks) back to the originating interface. The result is a virtual connection that originates on one DLCI and terminates on a different DLCI on the same test device. A monitor at the portion boundary can then be used to measure all of the primary performance parameters. If the routing loopback is significantly different from an ordinary virtual connection through the portions (for example, in the number of switches or distance traversed), the performance calculations must compensate for those differences.

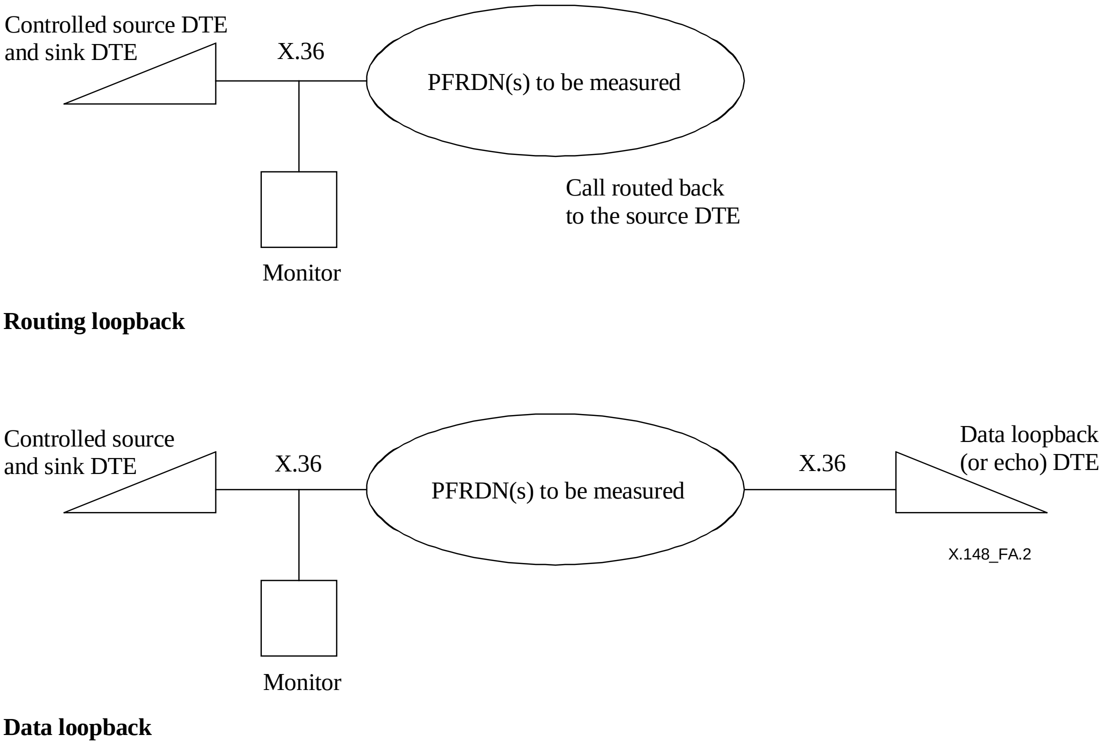


Figure A.2/X.148 – Loopback architectures

Data loopback can be used to measure frame transfer delay, frame loss ratio and residual error ratio. A data loopback can be provided by special software within network equipment, by stand-alone test equipment, or by special test programmes within customer applications. A data loopback device terminates the virtual connection, removes the data from the incoming user data frames and returns that data through the same virtual connection in new outgoing data frames. The data loopback should rapidly receive user data frames and return the user data without significant delay or error. If the portions under test have symmetric delays and residual error ratios, frame transfer delay, loss ratio and residual error ratio are half of what is calculated by comparing outgoing and incoming data packets at a source-side monitor.

Annex B

OAM message formats

This annex provides information on the basic structure of the Frame Relay OAM Message frame as specified by FRF.19, together with information on the structure of the OAM Service Verification Messages and the Information Fields used within this Recommendation. This information is provided for reference purposes only and to aid understanding.

B.1 Basic FR-OAM frame structure

8 7 6 5 4 3 2 1	Octet
Frame Relay Header	1-2
Control (00000011)	3
NLPID (10110010)	4
Message Type	5
Domain Identification	6
Source Location Identifier	11
Destination Location Identifier	15
Information Field Type	19
Length	20
Data	21

Frame Relay Header: Standard FR Header. Can be 2 or 4 bytes in length.

Control (00000011): Constant Value for all FR-OAM frames.

NLPID (10110010): Constant Value for all FR-OAM frames.

Message Type: Identifies the type of OAM frame. When measuring delay or loss the message type used is Service Verification (00000010).

Domain Identification: Used to uniquely identify the administrative domain to which the message belongs.

Source Location Identifier: To uniquely identify the source of an OAM message with the indicated administrative domain.

Destination Location Identifier: To uniquely identify the destination of an OAM message with the indicated administrative domain.

Information Field Type: Indicates the different functions for the OAM frame. Information fields are populated as needed.

Length: Includes the type, length and data fields.

Data: Carries the relevant data for each different frame type.

Figure B.1/X.148 – Basic FR-OAM frame structure

B.2 Frame transfer delay information field

8 7 6 5 4 3 2 1	Octet
Information Field Type (00000010)	19
Length (0000x110) (Note)	20
Initiator T_x Time Stamp	21
Receiver R_x Time Stamp	25
Receiver T_x Time Stamp	29

NOTE – The length of the information field (1110 or 0110) is used to determine if this is a request or a response.

Figure B.2/X.148 – Frame transfer delay information field

B.3 Frame transfer delay results information field

8	7	6	5	4	3	2	1	Octet
Information Field Type (00000011)								19
Length (00000110) (Note Figure B.2)								20
Calculated Result								21

Figure B.3/X.148 – Frame transfer delay results information field

B.4 Frame delivery ratio sync information field

8	7	6	5	4	3	2	1	Octet
Information Field Type (00000100)								19
Length (00001110) (Note Figure B.2)								20
Frames Offered $_{Committed}$								21
Frames Offered $_{Excess}$								25
VC Time								29

Figure B.4/X.148 – Frame delivery ratio sync information field

B.5 Frame delivery ratio results information field

8	7	6	5	4	3	2	1	Octet
Information Field Type (00000100)								19
Length (00001110) (Note Figure B.2)								20
Frames Delivered $_{Committed}$								21
Frames Delivered $_{Excess}$								25
Frames Lost $_{Committed}$								29
Frames Lost $_{Excess}$								33

Figure B.5/X.148 – Frame delivery ratio results information field

Appendix I

OAM message flows

This appendix contains informational examples of message flows that take place between two peer OAM MPs (an Initiating FR-OAM MP and a Receiving FR-OAM MP), undertaking a measurement of the performance parameter for a specific FR VC. If there is a conflict with the text of the main Recommendation, the main Recommendation will supersede these examples. The information is based on FRF.19 Appendix B.

I.1 Use of Hello messages for network discovery

The Hello message is sent periodically; it contains the Capabilities IF The Hello message is used to discover the OAM capability at the various FROMPs. Figure I.1 shows the message flows associated with the Hello message. Note that a subsequent message is allowed to add capabilities, but advertised capabilities are never withdrawn.

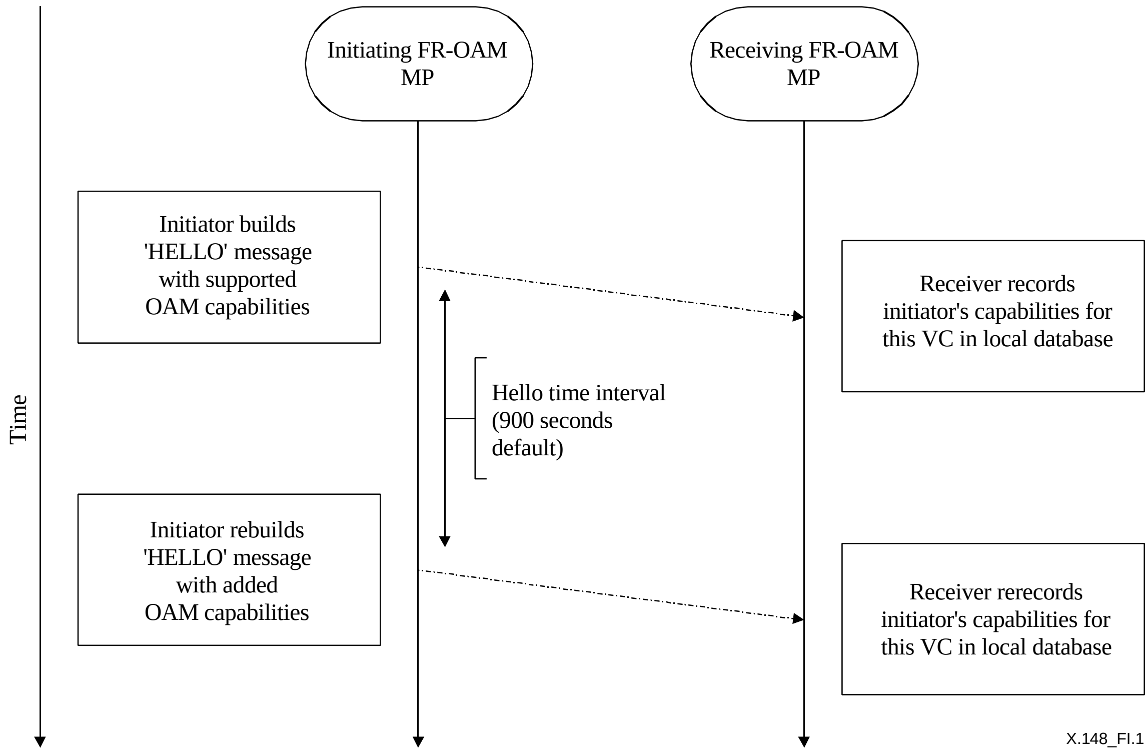
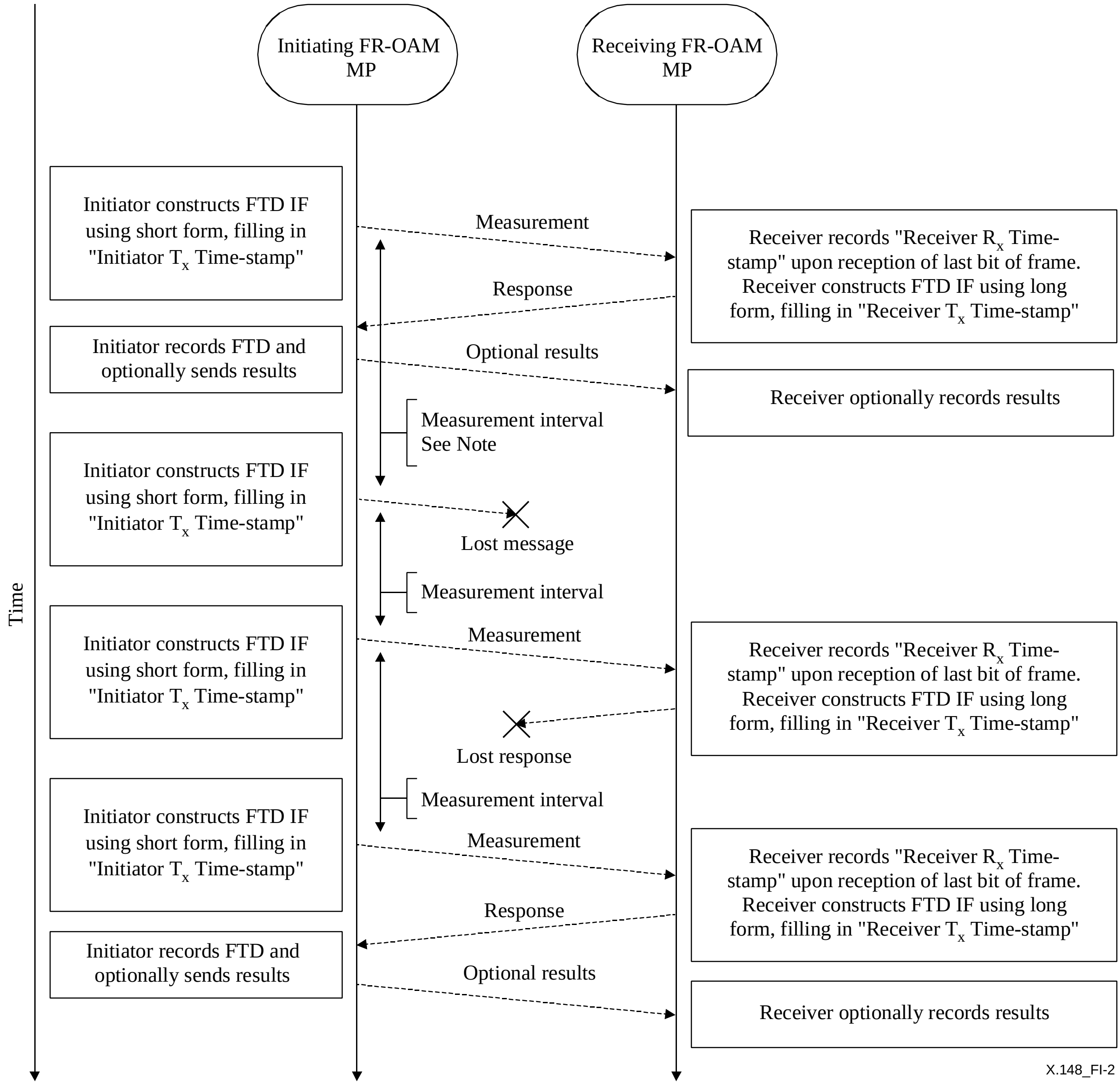


Figure I.1/X.148 – Use of Hello Message for network discovery

I.2 FTD measurement

The FTD measurement can be done periodically. It requires a response as shown in Figure I.2.



NOTE – Measurement interval is set by TIMER -SLV-FTD

Figure I.2/X.148 – OAM message flows for frame transfer delay measurement

I.3 FDR/DDR measurement

The FDR and DDR measurements may be performed periodically. An example of a FDR sequence is shown in Figure I.3. The DDR measurement is done in similar fashion.

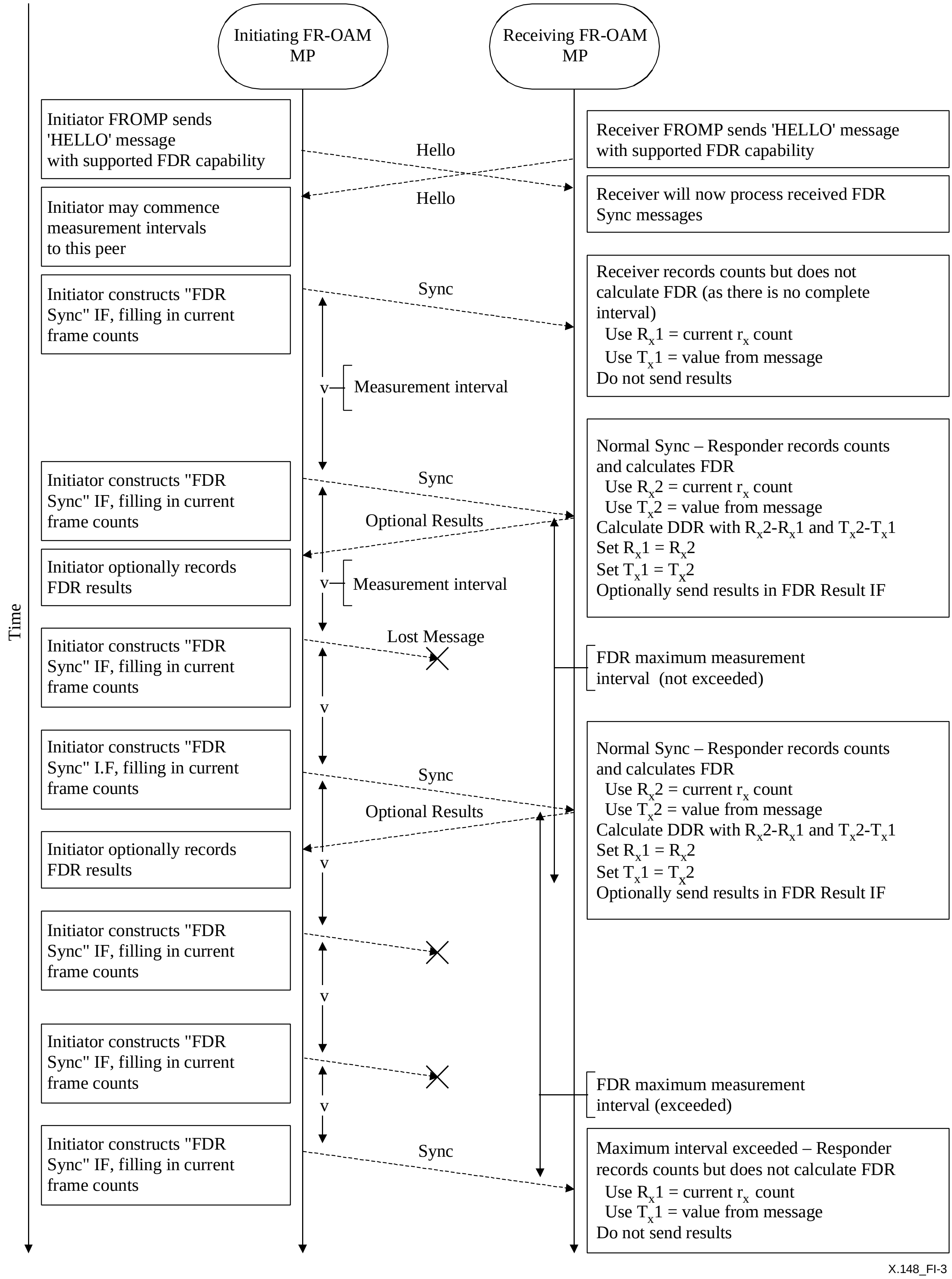


Figure I.3/X.148 – OAM message flows for FDR and DDR measurements

Appendix II

Example of frame delivery ratio (loss) calculations

This appendix presents one method of obtaining the data to calculate delivery (or loss) ratios. The method used for obtaining Frame Delivery Ratio data is likely to be implementation dependent. The method presented is for illustration only. Other methods are possible.

Customer's Frame Relay Service Level Agreements (SLAs) may include a specified objective for Frame Delivery Ratio for either the total traffic stream or the various traffic classes (CIR traffic or EIR traffic).

This appendix describes a procedure to calculate delivery ratios for each of the traffic classes using frame relay OAM messages. The procedure evaluates one-way delivery success between two Measurement Points (MP) in a network. The point where the frames enter the network segment is called the ingress MP. The point where the frames exit the network segment is called the egress MP. Refer to Figure II.1 for a reference diagram of a typical circuit where Location A1 is the ingress MP and Location A2 is the egress MP. The procedure is independently executed for the reverse one-way flow to produce delivery success ratios for both directions. In the example shown in Figure II.1, Location A2 becomes the ingress MP for the reverse one-way flow.

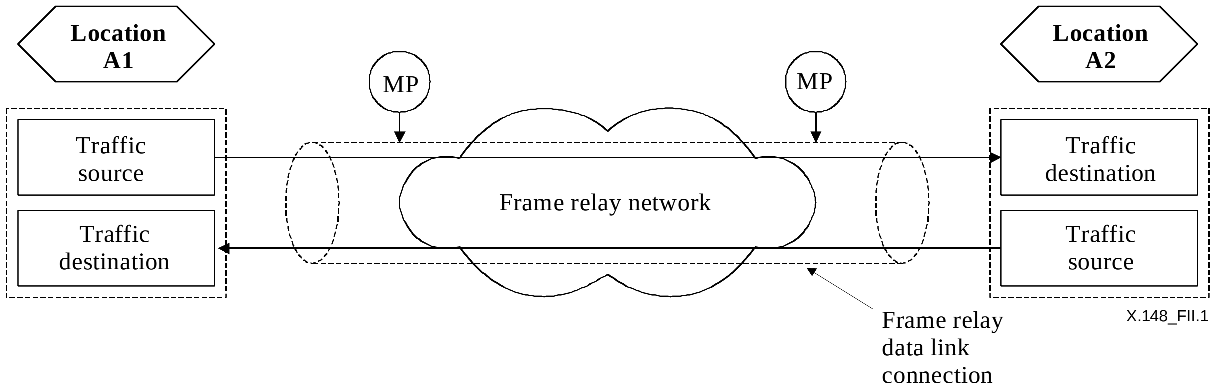


Figure II.1/X.148 – Measurement of end-to-end data delivery ratio

The ingress MP determines the time intervals for making the measurement. The interval starts at T_0 following successful completion of the restart procedure or at the conclusion of the previous measurement interval. Interval duration (Td) is implementation-specific but bounded by counter-wrapping considerations. The egress MP uses received Service Verification messages containing a Frame Delivery Ratio Sync IF to detect the interval boundaries following completion of the restart procedure.

The following description of processing is focused on determination of Frame Delivery Ratio results.

II.1 Ingress processing

The ingress MP determines the traffic class of a frame. The method used to assign frames to particular traffic class is network implementation-specific. This method does not rely upon an indication of the assigned traffic grade of each individual frame to the egress processor. The ingress MP maintains a frame count for each traffic grade. Upon detection of a frame within a given traffic grade, the frame count for that grade is incremented by one. At time Td, a Service Verification message containing a Frame Delivery Ratio Sync Information Field is transmitted from the ingress MP to the egress MP.

The Frame Delivery Ratio Sync IF contains two fields: $FramesOffered_{Committed}$ and $FramesOffered_{Excess}$. The fields contain the frame counts for the corresponding grades. The counts will wrap back to zero periodically, the frequency determined by physical access speed, frame sizes, and frame arrival rates.

II.2 Egress processing

The egress MP counts frames exiting the network during the measurement interval. A single count of total frames exiting the network is maintained, as the frames are NOT identified by Traffic Class.

Upon receipt of a Service Verification message containing a Frame Delivery Ratio Sync IF, (terminating the measurement interval), the egress MP performs the following actions:

1) The running count of total frames exiting the network during the interval is assigned to $\Delta Frames_{Received}$.

2) The $\Delta FramesOffered_{Committed}$ Count for the interval is computed by subtracting the value reported by the ingress MP at the end of the last interval from the value reported by the ingress MP in the just received Service Verification message. The calculation must detect and adjust for counter-wrap.

3) The $\Delta FramesOffered_{Excess}$ Count for the interval is computed by subtracting the value reported by the ingress MP at the end of the last interval from the value reported by the ingress MP in the just received Service Verification message. The calculation must detect and adjust for counter-wrap.

4) The Total Lost Frame Count for the interval just ended is calculated as follows:

$$\Delta FramesLost = (\Delta FramesOffered_{Committed} + \Delta FramesOffered_{Excess}) - \Delta Frames_{Received}$$

5) The counts of committed and excess frames delivered successfully are calculated as follows:

If $\Delta FramesLost >= \Delta FramesOffered_{Excess}$

$$\Delta FramesDelivered_{Excess} = 0$$

$$\Delta FramesDelivered_{Committed} = \Delta Frames_{Received}$$

If $\Delta FramesLost < \Delta FramesOffered_{Excess}$

$$\Delta FramesDelivered_{Excess} = \Delta FramesOffered_{Excess} - \Delta FramesLost$$

$$\Delta FramesDelivered_{Committed} = \Delta FramesOffered_{Committed}$$

6) The Frame Delivery Ratio for the Committed Traffic Class is calculated as follows:

$$FDR_{Committed} = \Delta FramesDelivered_{Committed} / \Delta FramesOffered_{Committed}$$

7) The Frame Delivery Ratio for the Excess Traffic Class is calculated as follows:

$$FDR_{Excess} = \Delta FramesDelivered_{Excess} / \Delta FramesOffered_{Excess}$$

8) The Frame Delivery Ratio for the Total Traffic Grade is calculated as follows:

$$FDR_{total} = \Delta Frames_{Received} / (\Delta FramesOffered_{Committed} + \Delta FramesOffered_{Excess})$$

9) The counts of committed and excess frames lost are calculated as follows:

$$\Delta FramesLost_{Committed} = \Delta FramesOffered_{Committed} - \Delta FramesDelivered_{Committed}$$

$$\Delta FramesLost_{Excess} = \Delta FramesOffered_{Excess} - \Delta FramesDelivered_{Excess}$$

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