Performance Monitoring Across Multiservice Networks Technical Specification

MFA Forum 17

MFA Forum Technical Committee
April, 2007

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1 Introduction

1.1 Overview

Many end-users are demanding Service Level Agreements (SLAs) on Frame Relay and ATM services, and service providers are providing them. However, in most cases service providers are not able to measure whether they are meeting their SLAs or not. There are some vendor-specific, single network features that allow service providers to measure Round Trip Delay (RTD) and Frame/Data Delivery Rates (FDR/DDR), but interoperable standards are lacking.

I.356 [3] and I.610 [4] suggest the possibility of using ATM Performance Monitoring OA&M cells to measure RTD and DDR for ATM virtual connections, but leave all implementation details as areas for further study. FRF.13 [1] and FRF.19.1 [2] apply only to FR.

FRF.13 and FRF.19.1 established a common set of definitions and a framework for measuring SLA parameters, including round-trip delay and data delivery rate. FRF.19.1 includes the concept of "Administrative Domains", and allows for multiple "monitoring points", so that the SLA parameters can be measured for each network involved in a multi-network connection, and for different segments within each network. However, FRF.19.1 only allows for Frame Relay monitoring points. Since most network-to-network connections are currently ATM, and are starting to evolve to MPLS, it is desirable to allow for Performance Management OA&M interworking among FR, ATM, and MPLS, for various service and network interworking scenarios.

This specification provides for Performance Management OA&M interworking between FR and ATM. It is based largely upon the terminology and methods specified in FRF.13 and FRF.19.1 for Frame Relay and I.610 for ATM.

1.2 Scope and Requirements

1.2.1 Scope

This document specifies procedures for interworking FR OA&M procedures from FRF.19.1 with ATM OA&M procedures from I.610 to allow ATM points to function as monitoring points as defined in FRF.19. The addition of ATM monitoring points should allow round-trip delay (RTD) measurements across a connection or connection segment that includes ATM and/or FR, Data delivery rate (DDR) measurements are for further study.

The capabilities detailed here apply to bi-directional connection-orientated services only.

The following types of connection are applicable:

- End-to-end or edge-to-edge single or multiple-network FR, ATM, or FR/ATM service interworked connection (FRF.8).
- FR, ATM, or FR/ATM segments of a single or multiple-network FR/ATM service or network interworked connection (FRF.4 or FRF.8).
- Connections types to be supported include PVCs, SPVCs, and optionally, SVCs.

The following items are for further study, and considered out of scope for this version:

1. The inclusion of MPLS monitoring points (MPs) for MPLS VCs (as defined in MPLS – FR Alliance 2.0.1), or cases where FR, ATM, or FR/ATM connections are mapped to pseudo wires at an MPLS IWF.
2. Measurement of data delivery rates to ATM MPs and Originating Monitoring Points OMPs.
3. Extension of FRF.19.1 latching and non-latching loopback functionality to ATM MPs and OMPs.

1.2.2 Requirements

The following is a summary of the requirements :

1) Enhanced Performance Management Interworking (PMIW) implementations should be backwards-compatible with original FRF.19.1 and I.610 implementations to the extent that they should not negatively impact existing FRF.19.1 or I.610 implementations, and should be able to co-exist with such implementations. Interoperability between these procedures and FRF.19.1 is not required.
2) Network operators must be able to define MPs and OMPs on appropriate UNI and NNI interfaces, as follows:
   a) FR or ATM OMPs should generally be provisioned at the service-provider end of either or both UNIs, although provisioning them at other network points is not precluded.
      i) OMPs may be provisioned at the customer-end of either or both UNIs, in addition to, or instead of, the service-provider ends.
      ii) OMPs may also be provisioned on NNIs to carriers not participating in performance monitoring.
   b) FR or ATM MPs should generally be defined on NNI ports or UNI ports that are not OMPs, although provisioning them at other network points is not precluded.
   c) I.610 defines Connection Points (CPs) and Termination Connection Points (TCPs) that are analogous to MPs and OMPs. Any ATM CP could map to an MP. An ATM TCP could map to a terminating MP, or to an ATM OMP.
3) Network operators must be able to enable or disable individual OAM functions on an individual-connection basis (details may be implementation-specific).
   a) When OAM is enabled on a connection, the OMP(s) must be able to discover all MPs/OMPs on the connection path. Implementations may allow the operator to select a subset of these points on which to enable OAM functions.
   b) Note: when dynamic routing protocols are used, the set of MPs on a connection path could change as the result of a reroute action. Some means of discovering such changes must be provided.
4) A protocol should be defined to do this discovery when Performance Management is initially enabled on a given connection. This protocol must continue to run periodically, at a given time interval or in responses to specific network actions such as reroutes, to satisfy the previous requirement.
5) Once an OMP has discovered one or more downstream MPs/OMPs through Hello message exchanges, it may initiate "Service Verification" message exchanges with some or all of these MPs/OMPs, per the procedures in FRF.19, Section 4.4.
6) OAM messages must follow the same VC path as user data.
7) It should be possible to calculate RTD in all cases. DDR and FDR are for further study.

a) For FR/ATM interworking connections, the presence of pad bytes in the last cell of a frame introduces an inherent inaccuracy into the DDR calculation. This inaccuracy would typically be small and could be adjusted for by implementation-specific means.

8) To the degree possible, required changes should be confined to the FR/ATM IWF rather than requiring changes to basic ATM hardware or software functions.
9) In the FR to ATM direction the IWF must recognize the FR OA&M Multi-protocol Encapsulation format, and may optionally support the Non-IU encapsulation (reference FRF.19, Section 3.1).
10) The number of information elements included in a single request should be limited by an MTU of 48 bytes, to fit into a single cell, whenever the Capability Information Field value indicates the presence of an ATM MP.

2 Definitions and Terminology

2.1 Definitions

Must, Shall or Mandatory — the item is an absolute requirement of this specification.

Should — the item is desirable.

May or Optional — the item is not compulsory, and may be followed or ignored according to the needs of the implementer.

Notes — outside of Tables and Figures are informative.

2.2 Acronyms

ATM	Asynchronous Transfer Mode
CP	Connection Point (per I.610)
DDR	Data Delivery Ratio
FDR	Frame Delivery Ratio
FR	Frame Relay
FROMP	Frame Relay OA&M Monitoring Point
FTD	Frame Transfer Delay
IA	Implementation Agreement
IF	Information Field
ITU	International Telecommunication Union
MP	Monitoring Point
MPLS	Multi Protocol Label Switching
NLPID	Network Layer Protocol Identification
NNI	Network to Network Interface
OA&M	Operations, Administration, and Maintenance
OMP	Originating Monitoring Point
PVC	Permanent Virtual Circuit
PM	Performance Management
PMP	Proxy Monitoring Point
RTD	Round Trip Delay
SLA	Service Level Agreement
SVC	Switched Virtual Circuit
TCP	Termination Connection Point (per I.610)
UNI	User-to-Network Interface
VC	Virtual Circuit

2.3 References

2.3.1 Normative

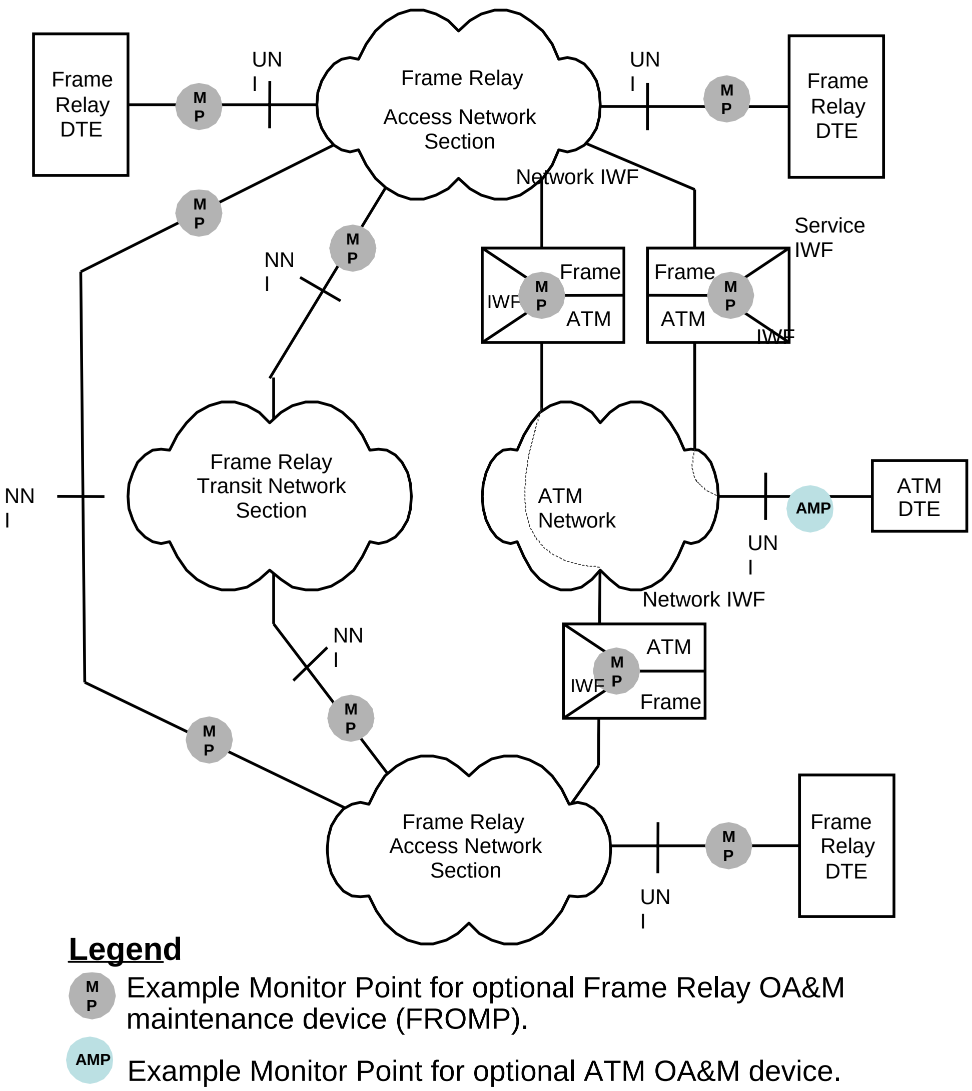
1. FRF.13 – “Service Level Definitions Implementation Agreement”, Kenneth Rehbehn (editor), Frame Relay Forum Technical Committee, August 1998.
2. FRF.19.1 – “Frame Relay Operations, Administration, and Maintenance Implementation Agreement”, Timothy Mangan and Ed Sierecki (editors), MFA Forum Technical Committee, April 2007.
3. ITU-T Recommendation I.356 – “B-ISDN ATM Layer Cell Transfer Performance”, March 2000.
4. ITU-T Recommendation I.610 – “B-ISDN Operations and Maintenance Principles and Functions”, February 1999.
5. ITU-T Recommendation I.610 Amendment 2, December 2006.

3 Reference Model

3.1 FRF.19.1 Reference Mode

The following diagram shows the original reference model for FR OA&M (taken from FRF.19):

Figure 1: FR OA&M Reference Model



Note: Monitoring points may be external probes, or embedded in DTE or DCE equipment.

Note: AMP shown for reference to ATM OA&M function. Coexistence with this function is not precluded by this specification. Interoperability with this function is beyond the scope of this specification, and is shown for reference only.

Figure 1 illustrates a reference Frame Relay network that is interworking with an ATM network. A number of example monitoring points are indicated. Note that an ATM Monitoring Point (AMP) is shown on the ATM UNI, but it is stated that ATM interworking is beyond the scope of the original FRF.19.

This model is not completely representative of how most carriers currently design their networks. Most carriers no longer operate pure Frame Relay networks, but rather have integrated FR/ATM networks with the IWF located very close to the FR UNI. This is an important distinction since Figure 1 shows the IWF on the links between the FR Access Sections, and the ATM Network with a FR MP shown on the FR side of the IWF. In reality the links between network segments are likely to be ATM or MPLS, and it is very important to service providers to have monitoring points on these links, which would need to be ATM or MPLS.

3.2 Revised Reference Model

Figure 2 shows a revised reference model, including ATM monitoring points on ATM NNI and UNI ports. Note that the ATM NNI could either be static or dynamic, running an inter-network routing or signaling protocol such as AINI or HPNNI. Figure 2 also introduces the concept of full functionality "Origination Monitoring Points" (OMPs) and limited functionality "Monitoring Points" (MPs). "Proxy Monitoring Points" (PMPs) are also introduced at FR/ATM IWFs. It is the function of the PMP to make all necessary conversions between FRF.19.1 functions on the FR side of the IWF and ATM I.610 OAM functions on the ATM side of the IWF. Similar functionality for ATM/MPLS and FR/MPLS IWFs is for further study.

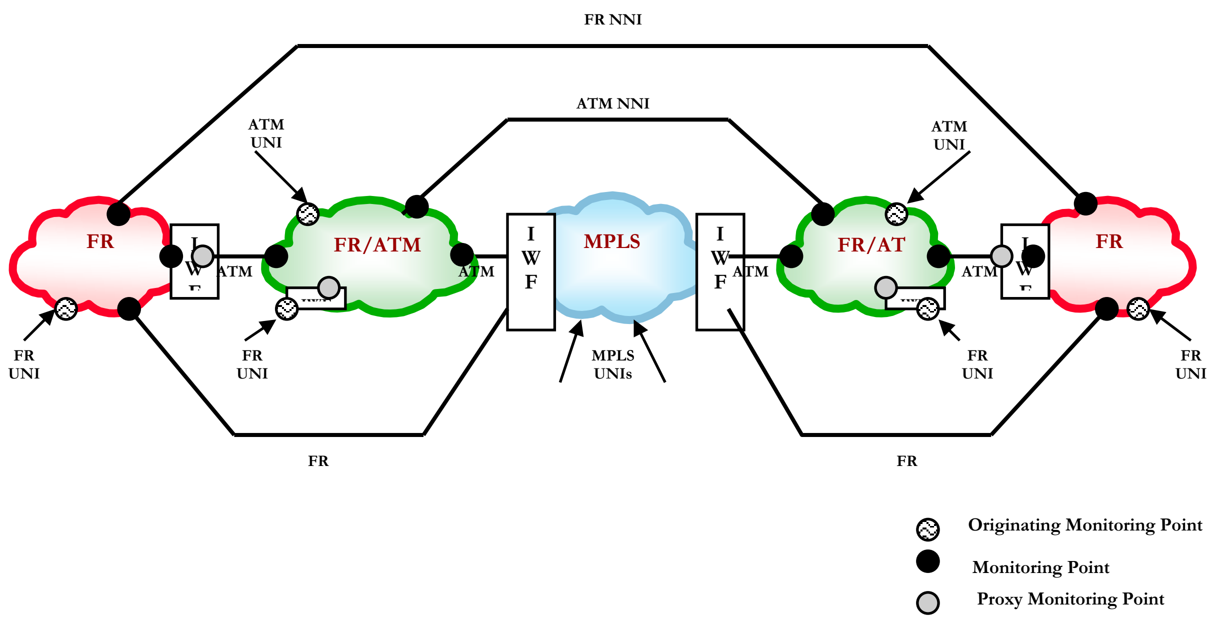


Figure 2: Revised Reference Model

The reference network includes an MPLS core. While the initial version of this specification does not define interworking with MPLS Performance Monitoring, PM frames or cells between ATM or Frame

Relay MPs/OMPs should flow transparently through the MPLS core. Future versions of this specification may allow for MPLS MPs and OMPs to extend Performance Monitoring interworking to MPLS.

Only OMPs would initiate functions including:

- Discovery and keep-alive through the Hello protocol.
- Service verification (SLA parameter measurements).

All MPs, including OMPs, must be able to respond to these requests.

Only OMPs will maintain state information and use timers to determine when to send messages, and how long to wait for responses to those messages. MPs will only send messages in response to messages received from an OMP.

An OMP must be defined on at least one end-point of a measurement domain for any connection requiring performance monitoring.

OMPs or MPs may be defined at any point in the network. These would normally be defined at UNI or NNI network ingress or egress points, but could optionally be defined at mid-points as well.

- The OMP(s) for any connection should be fixed by configuration. The MPs and PMPs that any connection goes through could change as a result of actions taken by dynamic routing protocols such as AINI or HPNNI.
- On the egress side of edge-to-edge connections [1], MPs or OMPs should be upstream from the egress queue function; optionally they may also be defined downstream of the egress queue.
- The Frame Relay OMP function defined here is equivalent to the FROMP function defined in FRF.19.
- I.610 defines “Connection Points” (CPs) and “Termination Connection Points” (TCPs) as reference points along an ATM connection at which OAM functions can occur. ATM MPs need only be defined as CPs or TCPs in the ATM network. PMPs will perform all functional translations to allow a CP or TCP to act as an MP under the definition given here. ATM OMPs will require additional configuration and functionality beyond what is defined in I.610.

PMPs are defined to allow implementation of PM functionality at FR/ATM IWFs in such a way as to utilize existing ATM OAM capabilities to provide the MP functionality for ATM ports.

- A PMP may be defined at any FR/ATM IWF.
- At a FR/ATM IWF that is not defined as a PMP, any FR PM frame would pass through the IWF as standard user plane data. Since the PM frames are not converted to OAM cells, no PM functions could be conducted with MPs within the ATM network. However these functions could be conducted with other FR MPs located beyond this ATM network.
- An IWF defined as a PMP must recognize PM frames destined for MPs in the adjacent ATM network. The PMP would have to convert any such frame into an appropriate ATM OAM cell and convert these cells back to PM frames in the reverse direction. PM frames not destined for an ATM MP in the adjacent ATM network would pass through the PMP as normal user data.
- While FRF.19.1 supports the concept of multiple domains, I.610 does not. A PMP would therefore proxy only for the adjacent ATM domain. The scope of this ATM domain is not subject to standardization. It could be limited to a single ATM network or it could span multiple networks depending upon the configuration of the networks and their interconnecting links, as well as the way I.610 has been implemented in those networks.

The PMP will always be collocated with the IWF. In some cases, such as a FR UNI attached directly to a FR/ATM network, as in Figure 2, the PMP and IWF could also be on the same line card as the FR UNI/OMP on the edge of a FR/ATM network. In these cases the collocated OMP and PMP could communicate via internal means and directly generate ATM OAM cells without necessarily producing PM frames.

3.3 General Approach

The basic procedures and frame formats from FRF.19.1 shall be followed for all Frame Relay network sections, except for modifications or extensions specifically noted in this document. The PMP function will convert the FRF.19-like PMIW frames into I.610 ATM OAM cells. Standard I.610 OAM loopback cells shall be used for Hello/discovery and RTD measurement purposes within ATM network segments.

4 OAM PM Message Formats

4.1 Frame Relay Message Formats

4.1.1 Encapsulation Formats

As in FRF.19.1, Frame Relay OA&M messages are carried in standard Frame Relay frames. Two encapsulation formats for the data portion of these Frame Relay frames are defined to allow for interoperability with other traffic.

- Implementations must support the Multiprotocol Encapsulation format to be compliant with this specification.
- Implementations may optionally support the Non-UI encapsulations.

The Multiprotocol encapsulation format is compatible with Frame Relay equipment and applications. This format uses a NLPID (0xB2) to distinguish OA&M traffic from U-plane traffic conforming to FRF.3.2, FRF.11, and FRF 8.1 traffic. The non-UI encapsulation format is designed for use with Frame Relay traffic that is not distinguishable from the OA&M multiprotocol encapsulation format. The prime example of this is I.555 section 5 (X.25 encapsulated) traffic.

4.1.2 OA&M Message Format

Figure 3 shows the OA&M message format from FRF.19, Figure 6:

Bits

8	7	6	5	4	3	2	1	Octet
Message Type								N+1 (Note 1)
Domain Identification								N+2
Source Location Identifier								N+7
Destination Location Identifier								N+11
Information Field 1								N+15
Information Field x								N+m (Note 2)

Note 1: Offset N is 4, 6, or 10, depending upon encapsulation and address size used.

Note 2: Information fields are populated as needed.

Figure 3: FRF.19.1 OA&M Message Format

Note that there are source and destination location IDs, but only a single domain ID, the first octet of which specifies the address plan being used. This implies that the domain must apply to both the source and destination MP addresses. In multi-provider, multi-service networks, it is unlikely that the same address plan, let alone the same domain ID, would apply to all MPs that are expected to inter-work to provide PM measurements. FRF.19.1 allows MPs to be in multiple domains by having multiple addresses with different domain IDs with different address types. However, allowing configurations where single network points carry multiple addresses with different formats and network prefixes may be problematic. Also, the FRF.19.1 format allows for a total of 8 address octets split evenly between the Domain ID and Location ID fields, and provides explicit guidelines as to how various address formats should be encoded into these fields.

Section 5 of this specification describes a different method for address handling and domain verification. This method includes:

- A variable number of address digits is allowed to accommodate ATM, and in the future, MPLS addressing plans.
- The way any set of addresses is split between Domain ID and Location ID is arbitrary. The resulting variable number of Domain ID digits allows domain matching to be performed on whatever number of high order address digits as makes sense within a particular carrier's or group of carriers' addressing plan(s). This includes a special case, referred to as domain plan-only matching, where the number of Domain ID digits is 0 and a match would occur for any point with a matching Domain Plan.
- Domain matching is not based upon the actual Domain ID of the originating OMP, but rather on one of a number of "search domains" separately configured for each OMP. The OMP will send out discovery messages based upon its configured search domains, which may or may not include its own configured Domain ID.

To accommodate these considerations, the following new format for the FR OAM message is required:

Bits								
8	7	6	5	4	3	2	1	Octet
Message Type								N+1
Source Domain ID Plan								N+2
Destination Domain ID Plan								N+3
Information Field 1								N+4
Information Field x (see Note 2)								N+m

Note 1: Offset N is 4, 6, or 10 depending upon encapsulation and address size used.

Note 2: Information fields are populated as necessary.

Figure 4: Revised OA&M Message Format

The differences in the modified format include:

- The modified format contains separate source and destination ID Plans or address types as separate, required, one-octet fields.
- Since both domain and location ID fields are now variable in length, all of the identification fields are included as information fields rather than being shown as fixed elements in the message format.

To allow for co-existence with FRF.19.1 implementations, separate message types will be used for this specification (PMIW) than are used by FRF.19.1. Equipment that supports both FRF.19.1 and PMIW should use the message type field in any PM frame to determine if that frame originated from an FRF.19.1 FROMP or a PMIW OMP, and process it accordingly. Equipment supporting only PMIW should allow PM frames with FRF.19.1 message types to pass through without attempting any PM-related processing. The following table shows FRF.19.1 message types as well as those required for PMIW:

Message Type Value	Usage
0x1	FRF.19.1 Hello
0x2	FRF.19.1 Service Verification
0x3	FRF.19.1 Non-Latching Loopback
0x4	FRF.19.1 Latching Loopback
0x5	FRF.19.1 Diagnostic Indication
0x81	PMIW Hello (see Section 5.3)
0x82	PMIW Service Verification (see Section 5.4)

Table 1: OA&M Message Type Values

4.1.2.1 Configuration Requirements

Any MP or OMP must be configured with its own domain plan, domain and location identifications, and identification lengths. PMPs do not require specific location identifications but they must be configured with the domain plan and identification as well as the domain and identification lengths for both the adjacent FR and ATM networks. ATM-side configurations may include two domain plan types, a segment, and an end-to-end type. A single domain identification would correspond to both types.

In addition, every FR OMP must be configured with information about one or more search domain plans and/or domain plans plus domain IDs for which it attempts to discover MPs or OMPs with which it can initiate service verification sessions. The list of destination domains may or may not include the OMP's own domain.

Each FR MP and OMP, as well as the FR side of any PMP, should also be configured with information about originating domain plans and/or domain plans plus domain IDs from which it may accept PM messages. This would provide a security mechanism to prevent one carrier's network from conducting PM measurements with a connecting carrier's network without prior agreement to do so.

Each search or originating domain or domain plan configuration should include the number of domain and location identification octets to be used for that domain or domain plan. When only domain plan matching is being done, the number of domain octets must be 0, with the entire address space accommodated in the location identification IF. When domain matching is being done, a non-zero number of domain octets and the domain identification must be specified, as well as the number of location identification octets.

Since I.610 does not recognize domains, an ATM OMP would only be configured with information about its own address. An ATM OMP would only send out a single discovery message. This discovery message would flow as far as permitted under normal I.610 processing. Should this discovery message encounter a PMP, the PMP would convert it to a PM Hello frame using the domain and address length information configured for the FR side of the PMP.

For every applicable domain plan in a given network application, either domain or domain plan matching must be specified, these two domain matching techniques cannot be mixed.

4.1.2.2 Domain Plan Values

Table 2 provides a list of Domain Plan ID code points. This list includes all of the code points from FRF.19.1 Table 2, as well as new code points for ATM Domain Plans.

Domain ID Plan Value	Usage
0x00	Reserved for future use
0x01	User Defined Identifier
0x02	OUI Identifier
0x03	FR IPv4 Network Identifier
0x04	IPv6 Network Identifier
0x31	FR X.121 Identifier
0x33	FR E.164 Identifier
0x47	ATM Endpoint AESA
0x48	ATM Segment AESA
0x4E	ATM Endpoint Private Domain Identifier
0x4F	ATM Segment Private Domain Identifier
0xFF	FR Private Domain Identifier

Table 2: Expanded Domain Plan Values Table

In addition to the added code points, the new table includes the following changes:

- All entries include the supported technology (ATM or Frame Relay). This provides a convenient method to allow MPs and PMPs to determine relevant OAM frames based upon technology.
- For ATM code points, separate values are provided for “Segment” and “End-point”. This provides a means of informing PMPs when to use segment versus end-to-end loopback cells when doing the conversion from FR to ATM.

4.1.2.3 Information Field Type Values

Section 3 of FRF.19.1 defines the Frame Relay OAM message formats. Some of the Information Field Type Values defined in FRF.19.1, Table 3,, will also be used by this specification. Additional IF types required include source and destination domain and location ID values, as well as a new “Correlation Tag” IF required for compatibility with I.610. Table 3 includes all IF types from FRF.19.1, as well as the additional ones required by this specification.

Information Field Type Value	**Usage**	**Reference Section**
0x01	Capabilities	Section 4.1.3.1
0x02	Frame Transfer Delay	FRF.19.1 Section 3.3.1.2
0x03	Frame Transfer Delay Results	FRF.19.1 Section 3.3.1.3
0x04	Frame Delivery Ratio Sync *	FRF.19.1 Section 3.3.1.4
0x05	Frame Delivery Ratio Results *	FRF.19.1 Section 3.3.1.5
0x06	Data Delivery Ratio Sync *	FRF.19.1 Section 3.3.1.6
0x07	Data Delivery Ratio Results *	FRF.19.1 Section 3.3.1.7
0x08	Non-Latching Loopback *	FRF.19.1 Section 3.3.1.8
0x09	Latching Loopback *	FRF.19.1 Section 3.3.1.9
0x0A	Diagnostic Indication *	FRF.19.1 Section 3.3.1.10
0x0B	Full Source Address *	FRF.19.1 Section 3.3.1.11
0x0C	Source Domain Identification	Section 4.1.3.2
0x0D	Source Location Identification	Section 4.1.3.3
0x0E	Destination Domain Identification	Section 4.1.3.4
0x0F	Destination Location Identification	Section 4.1.3.5
0x10	Correlation Tag	Section 4.1.3.6
0xFE	Opaque *	FRF.19.1 Section 3.3.1.12
0xFF	Pad *	FRF.19.1 Section 3.3.1.13

* These IF types are defined in FRF.19, but are not used in this version of PMIW

Table 3: Information Field Type Values

4.1.2.4 Information Field Length

The Length field of an Information Field includes the Type, Length and Data Fields. The value of this field must be in the range of 2 through 255, inclusive.

4.1.3 OA&M Information Fields

An OA&M message includes multiple information fields. These fields shall be as defined in FRF.19.1 with the following additions and exceptions:

4.1.3.1 Capabilities Information Field

The Capabilities Information Field (FRF.19.1 Section 3.3.1.1) must be expanded to indicate OMP versus MP and Frame Relay, versus ATM. This new specification of the Capabilities IF must be supported. Figure 5 and Table 4 show the original FRF.19.1 definition for this IE.

Bits

8	7	6	5	4	3	2	1	Octet
0	0	0	0	0	0	0	1	1
Type								
x	x	x	x	x	x	x	x	2
Length								
Capability #1 (Notes 1, 2)								3
Capability #N								3+N

Note 1: Capability field values are multi-octet, with the high-order bit used to indicate extension of this capability (high order bit=1 indicates that another octet follows for this capability); they are defined in Table 4

Note 2: The Capabilities IF must include the Hello Message capability. All other capabilities are optional..

Figure 5: FRF.19.1 Capabilities Information Field Layout

Capability Sub-field Value (Bits 1-4)	Length	Usage
0x01	5-octet	Hello Message
0x02	1-octet	Supports Frame Transfer Delay
0x03	5-octet	Supports Frame Delivery Ratio
0x04	5-octet	Supports Data Delivery Ratio
0x05	1-octet	Supports Latching Loopback
0x06	1-octet	Supports Non-latching Loopback

Table 4: Capability Information Sub-field Type Values

As defined in FRF.19, bits 4-7 are always 0. For this specification, the values shown in Table 4 are defined for bit positions 1-4 only of the capability field. Bit 5 is defined as 0 for OMPs and 1 for MPs. Bits 6-7 **a**re defined for the protocol type, as shown in Table 5.

Protocol Sub-field Value (Bits 6-7)	Usage
00	Frame Relay
01	ATM
10	ATM AAL5*
11	Reserved for MPLS

Table 5: Protocol Sub-field Type Values

* An ATM connection using AAL5 must use either code point 01 or 10. Code point 10 should be used if performance monitoring requires frame awareness.

The single-octet capabilities are formatted using an 8-bit value of the capability, MP/OMP, and protocol sub-fields as, described above, and shown in Figure 6. Multiple octet capability IEs use this value as the first octet, with additional information as shown in Section 3.3.1.1 of FRF.19.

8	7	6	5	4	3	2	1
Ext	Protocol Sub-Field		MP/ OMP	Capabilities Sub-Field			

Figure 6: Modified Capabilities Information Field Layout

4.1.3.2 Source Domain Identification Information Field

Every OAM PM frame must contain a source domain identification IF**.** The Source Domain Identification information field is used to provide the domain part of the address. The domain represents the high order portion of the address. When domain matching is being done on the domain plan ID only, the domain identification shall be null, with all address octets included in the location identification field. In these cases it is required to include this IF with just the type octet and a length of 2. For ATM domain plans, the maximum length of the source identification is 16 octets.

This IF must immediately follow the destination location IF in the OA&M message. The format of this information field is shown in Figure 7:

Bits								
8	7	6	5	4	3	2	1	Octet
0	0	0	0	1	0	1	0	1
Type								
x	x	x	x	x	x	x	x	2
Length (see Note 1)								
Source Domain ID								3 - N

Note 1: Length includes Type and Length.

Figure 7: Source Domain Information Field

4.1.3.3 Source Location Identification Field

Every OAM PM frame must contain a source location identification IF. This IF must immediately follow the source domain identification IF The location represents the low order portion of the address. The minimum length of the location identification is 0 octets. The maximum length for ATM domain plan types is 16 octets. The combined length of the domain and location IDs must be at least 1 and, for ATM domain plan types, a maximum of 16 octets. The format of this information field is shown in Figure 8.

Bits

8	7	6	5	4	3	2	1	Octet
0	0	0	0	1	0	1	1	1
Type								
x	x	x	x	x	x	x	x	2
Length (see Note 1)								
Source Location ID								3 - N

Note 1: Length includes Type and Length.

Figure 8: Source Location Information Field

4.1.3.4 Destination Domain Identification Information Field

Every OAM PM frame must contain a destination domain identification IF. The destination domain identification information field is used to provide the domain part of the address, and must always be the first IF in any OA&M message. The domain represents the high order portion of the address that will be matched against the configured values at receiving MPs, OMPs, and PMPs. When domain matching is being done on the domain plan ID only, the domain identification shall be null with all address octets included in the location identification field. In these cases it is required to include this IF with just the type octet and a length of 2. For ATM domain plans, the maximum length of the source identification is 16 octets. The format of this information field is shown in Figure 9.

Bits

8	7	6	5	4	3	2	1	Octet
0	0	0	0	1	1	1	0	1
Type								
x	x	x	x	x	x	x	x	2
Length (see Note 1)								
Destination Domain ID								3 - N

Note 1: Length includes Type and Length.

Figure 9: Destination Domain Information Field

4.1.3.5 Destination Location Identification Field

Every OAM PM frame must contain a destination location identification IF. This can be an actual location identification or the special all 0's or all 1's address described in Section 5.1. It must immediately follow the destination domain identification IF. The location represents the low-order portion of the address. The minimum length of the location identification is 0 octets. When the all 0's or all 1's values are used, the location identification should normally be a single octet. The maximum length for ATM domain plan types is 16 octets. The combined length of the domain and location IDs must be at least 1, and, for ATM domain plan types, a maximum of 16 octets. The format of this information field is shown in Figure 10.

Bits

8	7	6	5	4	3	2	1	Octet
0	0	0	0	1	1	1	1	1
Type								
x	x	x	x	x	x	x	x	2
Length (see Note 1)								
Destination Location ID								3 - N

Note 1: Length includes Type and Length.

Figure 10: Destination Location Information Field

4.1.3.6 Correlation Tag Information Field

I.610 defines a "Correlation Tag" field in the OA&M LB cell format to allow nodes to correlate loopback commands and responses. The use of this field is optional, and its precise usage is application-specific. However, when an I.610-originating LB cell with a non-zero correlation tag is received at a PMP, the PMP must transfer the correlation tag from the cell into a correlation tag IF in the resulting PM frame. When a FR MP or OMP loops back any PM frame containing a correlation tag IF, it must copy that IF into the returned PM frame. When a PM frame arrives at a PMP with a matching domain, the correlation tag IF from the frame must be transferred to the resulting I.610 LB cell. If there is no correlation tag IF in the PM frame, the correlation tag field in the resulting I.610 LB cell shall be set to all zeros. The format of this information field is shown in Figure 11.

Bits

8	7	6	5	4	3	2	1	Octet
0	0	0	1	0	0	0	0	1
Type								
0	0	0	0	1	1	0	0	2
Length (see Note 1)								
Correlation Tag								3 - 6

Note 1: Length includes Type and Length.

Figure 11: Correlation Tag Information Field

4.2 ATM OA&M Message Formats

When a FR OMP sends a PM request to an ATM MP or OMP, the PMP at the FR to ATM IWF must convert the FR PM frames to ATM OAM cells. The format of these cells shall be as specified in Section 10 of I.610 [4, 5], except as specifically noted here.

It must be possible to perform any PM function in a single ATM cell. FRF.19.1 allows a single PM frame to perform multiple PM functions, such as RTD and DDR. However, due to cell size limitations, as well as the requirement to use different types of ATM OAM cell for different PM functions, a single FRF.19.1 PM frame could require multiple ATM OAM cells. To eliminate this possibility, FR OMPs must recognize when a PM request is addressed to an ATM MP or OMP and limit the functions in any PM frame to what could be accommodated in a single ATM OAM cell. One possible way to meet this requirement would be to always limit PM frames this way.

Note that if a FR OMP is sending a PM request to a FR MP, and there is an ATM network in the middle, no special handling is required. In this case, the PM frames should pass transparently through the ATM network using standard segmentation/reassembly procedures.

ATM OMPs will send all PM requests out as standard I.610 OA&M cells, with only those modifications shown below. The OMP will need to recognize when these cells are returned, and perform the required PM processing. All downstream ATM switches should handle these OA&M cells as specified by I.610. When one of these cells encounters an ATM to FR IWF with a PMP configured, the PMP will convert the OA&M cell into a corresponding PM frame.

4.2.1 Discovery/Hello

While ATM OAM standards do not include discovery/hello procedures, OAM segment and end-to-end loopback cells (Seg_LB and e-t-e_LB) with all 1's or all 0's Loopback Identification (LLID) fields can be used to discover ATM segment end-points or connection end-points, or all ATM CPs along a path. ATM OMPs shall send out these LB cells with the Hello flag, as shown in Figure 12, set for discovery. The PMP function will be responsible for converting between PM Hello frames and appropriate OAM LB cells, as described in Section 5.3.2, for either PM frames originating from a FR OMP, or LB cells originating from an ATM OMP.

4.2.2 Round Trip Delay Measurements

These same OAM LB cells, but with the SV flag set, shall be used to conduct Round Trip Delay (RTD) measurements in an ATM measurement domain. In a FR-ATM connection or segment, the PMP will be responsible for converting Service Verification – RTD frames into appropriate ATM LB_OAM cells. The format of the LB cell is specified in Section 10.2.3 of I.610.

- The Originating Timestamp field shall be used to carry a timestamp inserted by an originating ATM OMP or copied from a Service Verification RTD frame. The timestamp field shall represent milliseconds. The value is of local significance only
- When a LB cell returns to an ATM OMP or a PMP, the OMP or PMP must be able to determine whether this cell is in response to a Hello message, a Service Verification message, or some other function not related to PM. The 1-bit Hello flag is used to signify Hello messages and responses. The 1-bit SV flag is used to signify Service Verification messages and responses.

The format for the LB cell is shown below in Figure 12:

Note 1 – The originating timestamp is only used when the Service Verification (SV) flag is 1; otherwise this field is unused and set to all '6A' hex characters.

Note 2 - The LB flag retains its original usage from I.610. It is initially set to "1" and then set to "0" if an ATM layer loopback function returns the cell in the direction it from which it came (to distinguish from a possible layer 1 loopback). In this application it may also be used to distinguish between originating and responding PM messages.

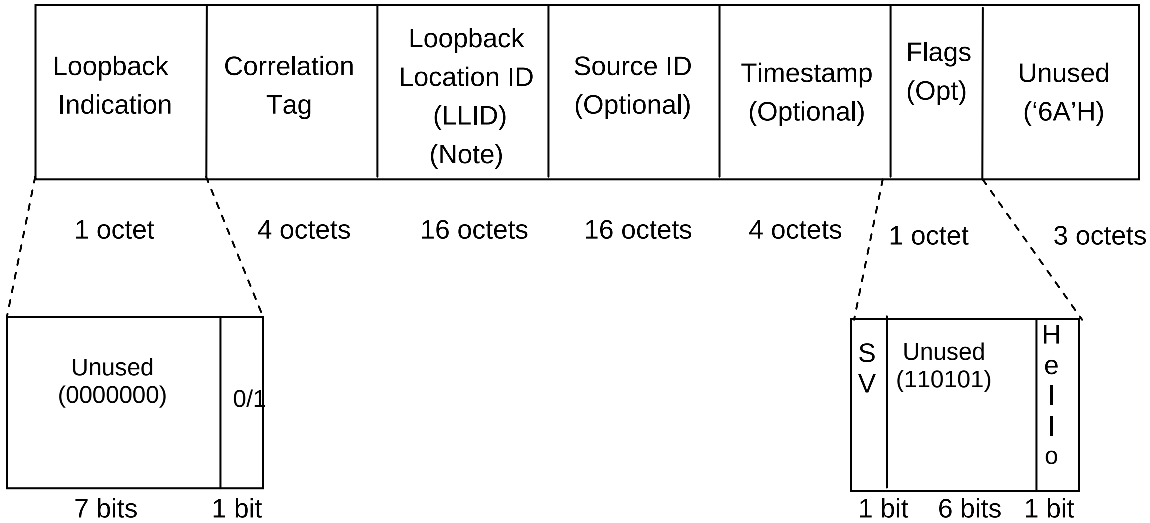


Figure 12: Modified OAM Loopback Cell Format

4.2.3 Address Mapping

I.610 allows 16 octets for addresses, but does not specify a format for these addresses, and does not support the domain concept. This specification allows addresses to be of any length, with a domain and a location identification field. The address formats specified for ATM domain plans can include a maximum of 16 octets, but shorter address formats may also be used. It is a requirement of the PMP to translate address formats when converting PM frames to or from I.610 OAM cells.

This PMP mapping function must also take into account whether PM frames and ATM OAM cells are enquiry or response messages. There are two reasons for this:

1. OMPs need to be able to determine if Hello and Service Verification cells or frames they receive were initiated by a far end OMP or are responses to enquiries they sent out. The means for recognizing this are different for PM frames and OAM cells, and the PMP must be able to translate between these different mechanisms.
2. The address mapping itself is different depending upon whether the enquiry was initiated from a FR or ATM OMP. An ATM OMP sends out a LB cell as an enquiry. Per the LB cell handling rules in I.610, the source address field should remain unchanged during the entire round trip path of the LB cell. The address of the location that looped the cell back goes in the LLID field. FRF.19.1 treats Hello and Service Verification exchanges as separate enquiry and response messages. As such, the source address from the enquiry frame becomes the destination address in the response, and the address of the location generating the response becomes the source address in the response message.

4.2.3.1 Address mapping in the FR to ATM direction

1. A Hello frame originating from a FR OMP can be recognized by an all 0's or all 1's destination location identification IF value. A Service Verification frame originating from a FR OMP can be recognized by an RTD IF with a length of 6 octets. The destination address could be all 0's, all 1's, or an explicit address. In these cases the address mapping must be done as follows:
    a. The Loopback Indication bit in the I.610 LB cell shall be set to "1"
    b. If the PM frame contains an all 0's destination location identification IF of any length, the entire 16 octet LLID field in the I.610 LB cell shall be set to all 0's.
    c. If the PM frame contains an all 1's destination location identification IF of any length, the entire 16 octet LLID field in the I.610 LB cell shall be set to all 1's.
    d. If the PM frame contains a destination location identification IF that is not all 0's or all 1's, the value of this IF shall be moved to the low order N octets of the I.610 LB cell LLID field where N = the length of this IF – 2. The value of the destination domain identification IF shall then be moved into octets N+1 – N+M of the I.610 LB cell LLID field where M = the length of this IF – 2. Any remaining high order octets of the I.610 LB cell LLID field shall be zero-filled.
    e. The source location identification IF shall be moved to the low order N octets of the I.610 LB cell source ID field where N = the length of this IF – 2. The value of the source domain identification IF shall then be moved into octets N+1 – N+M of the I.610 LB cell source ID field where M = the length of this IF – 2. Any remaining high order octets of the I.610 LB cell source ID field shall be zero-filled.
2. A Hello response from the FR direction can be recognized by having an explicit destination address. A Service Verification response from the FR side will always have an explicit destination address and an RTD IF with a length of 14 octets. In these cases the source and destination addresses must be reversed in the I.610 LB cell, so that the ATM OMP will see the expected source and destination addresses. The address mapping must therefore be done as follows:
    a. The Loopback Indication bit in the I.610 LB cell shall be set to "0".
    b. The value of the source location identification IF shall be moved to the low-order N octets of the I.610 LB cell LLID field, where N = the length of this IF – 2. The value of the source domain identification IF shall then be moved into octets N+1 – N+M of the I.610 LB cell LLID field, where M = the length of this IF – 2. Any remaining high order octets of the I.610 LB cell LLID field shall be zero-filled.
    c. The destination location identification IF shall be moved to the low-order N octets of the I.610 LB cell source ID field, where N = the length of this IF – 2. The value of the destination domain identification IF shall then be moved into octets N+1 – N+M of the I.610 LB cell source ID field, where M = the length of this IF – 2. Any remaining high-order octets of the I.610 LB cell source ID field shall be zero filled.

4.2.3.2 Address mapping in the ATM to FR direction

1. The source domain plan ID field shall be set to the configured domain plan ID for the ATM side of the PMP.

2. The destination domain plan ID field shall be set to the configured domain plan ID for the FR side of the PMP.
3. A returning I.610 LB cell can be identified by a LB flag value of 0. Any such cell should contain the address of the CP that looped it back in the LLID field, and the original source address in its "Source ID" field. In forming the return PM frame, the PMP must map the source id into the destination address fields, and the LLID into the source address fields as follows:
   a. The low-order N octets of the LLID field (where N is the configured value for the length of the location identification for the ATM side of the PMP) shall be used as the value for a source location identification IF. The type shall be set to 0x0D, and the length to N+2.
   b. Octets N+1 – N+M of the LLID field (where M is the configured value for the length of the domain identification for the ATM side of the PMP) shall be used as the value for a source domain identification IF. The type shall be set to 0x0C, and the length to M + 2.
   c. The value for the destination location identification IF shall be set to the low-order N octets of the source ID field from the I.610 return LB cell, where N is the configured length of the location identification for the FR side of the PMP. The length of this IF shall be set to N + 2 and the type to 0x0F.
   d. The value for the destination domain identification IF shall be set to octets N+1 – N+M of the source ID field from the I.610 return LB cell, where M is the configured value for the length of the domain identification for the FR side of the PMP. The length of this IF shall be set to M + 2, and the type to 0x0E.
4. An I.610 LB cell that originated from an ATM OMP can be identified by a LB flag value of 1. For these cells the PMP must form a PM frame, mapping the source id field into the source address fields and the LLID field into the destination address fields, as follows:
   a. The low-order N octets of the source id field (where N is the configured value for the length of the location identification for the ATM side of the PMP) shall be used as the value for the source location identification IF. The type shall be set to 0x0D, and the length to N + 2.
   b. Octets N+1 – N+M of the source id field (where M is the configured value for the length of the domain identification for the ATM side of the PMP) shall be used as the value for the source domain identification IF. The type shall be set to 0x0C, and the length to M + 2.
   c. If the LLID field in the LB cell is set to all 0's or all 1's, the configured domain length and value for the FR side of the PMP shall be used to populate the destination domain identification IF. The destination location identification IF field shall be populated with a single octet of all 1's value along with a type of 0x0F and a length of 3.
   d. If the LLID field is not all 0's or all 1's, the low-order N octets of this field (where N is the configured length of the location identification for the FR side of the PMP) shall be used as the value for the destination location identification IF. The length of this IF shall be set to N + 2, and the type to 0x0F.
   e. If the LLID field is not all 0's or all 1's, octets N+1 – N+M of this field (where M is the configured value for the length of the domain identification for the FR side of the PMP) shall be used as the value for the destination domain identification IF. The length of this IF shall be set to M + 2 and the type to 0x0E.

4.2.4 Data Delivery Rate Measurements

Section 10.3 of I.610 provides specific cell formats to allow measurement of Data Delivery Rates (DDR) using Performance Management "Forward Performance Management" (FPM) and "Backwards Reporting" (BR) OAM cells. For DDR measurement requests from a FR OMP to an ATM MP, the FR to ATM PMP should convert the originating PM packet into an ATM FPM cell and then convert the returned BR cell into a FR PM frame. The exact mapping of data fields between PM packets and FPM/BR cells is for further study.

5 OAM Procedures

5.1 MP/OMP Addressing

In any Hello/discovery message, an all 1's or all 0's Destination Location Identification IF must be used. For Hello messages specifying FR Destination Domain Plans, the global destination indicator of all 1's as specified in FRF.19.1 must be used as the Destination Location Identification value. This all 1's global destination indicator may also be used for FR Service Verification messages to indicate the first MP or OMP encountered with the matching Domain. In all cases, an explicit or null destination domain identification value must be specified.

I.610 specifies a destination LLID field of all 1's for a segment or connection end-point, and all 0's for any configured CP on a segment or connection. Support for the all 1's value is required. This would allow the identification of one segment and one connection end-point from a given OMP. Support for the all 0's value is optional, to allow identification of all configured CPs, allowing any of these to be reached through explicit addressing.

A FR OMP could specify all 1's or all 0's for a Hello message, and all 1's or an explicit location identification for a Service Verification message in the Destination Location ID field for messages to ATM Domain Plan IDs. PMPs would be required to recognize these values and transfer them to the ATM OAM LB cells. An ATM OMP could specify an all 0's or all 1's LLID field in either a Hello or Service Verification request. A PMP would be required to translate either of these values to a single all 1s octet for the destination location identification in the resulting PM frame. The destination domain type and location would be taken from the configuration information for the FR side of the PMP.

5.2 Domain Verification

This section provides two methods of domain verification. The first method is required and the second method, which is a generalization of the first, is optional**.** The term "domain match" used anywhere in this specification may refer to either of these procedures.

5.2.1 Domain Verification Method 1 (Required)

This required domain-handling procedure is based upon the Destination Domain Plan ID value only. For each FR OMP the set of Domain Plan IDs that the OMP should attempt to discover must be configured as part of the OMP definition. The use of this procedure shall be indicated by a null Destination Domain ID value. The PM message handling rules using this alternative are:

- Any PM frames with a Destination Plan ID = "User Defined ID" must be passed through all service provider network elements to the customer's egress UNI. This will allow for end-user CPE-based solutions independent of what the service providers are doing.
- Only PM frames with a Destination Plan ID = User Defined ID may be accepted on a UNI interface or an NNI not configured for PMIW.
- No PM frame with a Plan ID other than User Defined ID should be forwarded over a UNI or an NNI configured as a termination point.

- A PMP must convert any PM frame with a Destination Domain Plan ID that matches one of its own ATM-side configured values into an appropriate Seg or end-to-end LB OAM cell. A PMP may have two configured ATM-side Domain Plan ID values, one corresponding to segment and the other to end-to-end. PM frames with any other Destination Domain Plan ID must be passed through the FR-ATM IWF as user-plane data.
- A FR MP must consider any PM frame with a matching Destination Domain Plan ID as a domain match and take appropriate action. A PM frame with any other Destination Domain Plan ID must be forwarded or dropped according to the above rules.

5.2.2 Domain Verification Method 2 (Optional)

This domain handling procedure would match on the Destination Domain ID as well as on the Domain Plan ID, based upon a set of allowed Domain Plan IDs/Domain IDs configured for a FR OMP. Each configured domain would have to specify Domain Plan ID/Domain Length /Domain ID. The basic procedure would be the same as the required procedure detailed above, with the following additions:

- In all cases where a Domain Plan ID match occurs, an additional check must be made between the Destination Domain field and the MP’s configured domain (in the case of ATM, this check would be performed at the PMP, which would have to be configured with the Domain Plan ID/Domain ID of the adjacent ATM network).
- Both the Domain Plan IDs and the Domain IDs would have to match so as to have a domain match.
- Matching Domain Plan IDs with different Domain IDs would be considered a domain mismatch and would lead to the same actions described above for Domain Plan ID mismatches.

5.2.3 Domain Verification from ATM OMPs

Since I.610 does not include the concept of domains, an ATM OMP would not be configured with target domains, and would send out a maximum of two Hello messages, one end-to-end and one segment. These Hello LB cells would travel through the adjacent ATM network as far as would be allowed by normal I.610 procedures. If such a cell reached a PMP, the PMP would convert it to a PM frame using the domain information that was configured for the FR side of the PMP.

5.2.4 Source Domain Verification

This specification is meant to allow performance monitoring for connections that cross carrier boundaries, assuming that the carriers agree to this joint monitoring. A carrier that has not agreed to such monitoring with a connecting carrier is not required to respond to Performance Monitoring messages from that carrier. Different mechanisms are required in different situations to allow one network to not respond to enquires from other networks when agreements are not place:

- When a FR MP or OMP receives a PM message that appears to be addressed to it, based upon a matching explicit address or on a matching domain with an all 1’s location ID, it should check the source domain plan type and identification (or just the domain plan type if the identification field is null) against its configured list of authorized source domains.
    - If the source domain is in the authorized list, the MP or OMP must proceed to respond to the received message.
    - If the source domain is not in the authorized list, the MP or OMP must not respond to it. The received message may be forwarded or discarded. If the received PM message contained a null destination domain plan identification and an all 1’s destination location identification, it should be forwarded since it could be destined for a downstream network. If the received PM message contained an explicit matching domain or location identification, it should be discarded.

- When the FR side of a PMP receives a PM frame that appears to be addressed to its adjacent ATM domain, based upon a destination domain match, it should check the source domain plan type and identification (or just the domain plan type if the identification field is null) against its configured list of authorized source domains.
  - If the source domain is in the authorized list, the PMP must proceed to process the received message.
  - If the source domain is not in the authorized list, the PMP must not process it. The received message may be allowed to flow through the corresponding IWF as user-plane data, or it may be discarded. If the received PM message contained a null destination domain plan identification, it should be allowed to flow through as it could be destined for a downstream network. If the received PM message contained an explicit matching domain or location identification, it should be discarded.
- When the link between the two carriers is ATM, a PM request could come across the link as an ATM LB OAM cell originated by an ATM OMP or a PMP in the sending network. In this case the flow of this cell would be determined by standard I.610 procedures.
  - I.610 does not recognize the domain concept, but many existing ATM applications allow ATM NNIs to be configured to either accept or reject all OAM cells coming across the NNI . These existing capabilities may be used to control unwanted PM requests in this ATM interconnection case.
  - I.610 does distinguish between segment OAM and end-to-end OAM. A VPC/VCC segment is typically under the control of one Administration or organization; however, it can be extended beyond the control of one Administration/organization by mutual agreement. By limiting segments to its own Administration area, a carrier could utilize the existing capabilities of I.610 to achieve protection from unauthorized PM requests that utilize segment LB cells.

5.3 Discovery Procedures

The discovery procedure is based upon the Hello message (message type 0x81). This section describes this procedure for either of the alternate domain verification procedures described above, as well as the processing required of PMPs and ATM OMPs in the discovery/hello procedure.

5.3.1 OMP Discovery Procedures

Only OMPs autonomously send out Hello messages. An MP shall send a return Hello message only in response to receiving a Hello. A FR OMP must send out separate Hello messages for each Search Domain (based on just Domain Plan ID or Domain Plan ID/Domain ID) configured for the OMP on each connection that has PM enabled and is served by the OMP.

An ATM OMP would send out a maximum of two Hello messages, one end-to-end and one segment, for each enabled connection. These Hello messages would be end-to-end or segment OA&M LB cells with all 0's or all 1's LLIDs.

All OMPs must send each required Hello at regular intervals based upon configured TIMER_HELLO_TX timers. The recommended range for this timer is 15 – 3600 seconds, with a default of 900 seconds. Implementers are encouraged to develop methods to spread out the required Hello messages over time.

Hello processing shall be started for each PVC configured for PM when the PVC goes from an inactive to an active state per Q.933 signaling status messaging. Hello processing should also be started when performance management is initially enabled from the management system for an active PVC. Transmission of the Hello message may be suspended when the data link connection is not operational for reasons including:

- A failure of the link integrity verification mechanism,
- The clearing of the "active" bit,
- The setting of the "delete" bit,
- The absence of the data link connection information element.

Transmission of the Hello message should resume upon connection restoration, as described above.

The format of the Hello PM frame is specified in Section 4.1, with addressing options as specified in Section 5.1.

- Source and destination domain plan IDs must be specified.
- The destination domain identification IF must be included, but may have a null value.
- The destination locations identification IF must be included as all “1”s or all “0”s, as specified in Section 5.1.
- The originating OMP’s configured source domain and location identification must be included in the appropriate IFs.
- All appropriate capability information fields must be specified. As a minimum, Hello and Service Verification – RTD capabilities must be included.

A FR MP receiving a valid Hello message with a matching destination domain and a valid source domain must send a return Hello in the same format. The various information fields in the return Hello message must be set as follows:

- The source and destination domain plan identification fields from the received message must be swapped in the return message.
- The FR MP must copy the source domain and location identification IFs into the corresponding destination identification fields in the return message.
- The FR MP must insert its own configured domain and location identification length and values into the respective source identification IFs in the return Hello message.
- The FR MP must include all appropriate capability information fields in the return Hello message.
- The FR MP must also pass on the originally-received Hello message in the forward direction unless it is also an OMP, or it sits at the edge of the network (on a UNI port or an NNI port configured to terminate OA&M).

A given connection may have an OMP at one or both ends. When there are OMPs at both ends, each OMP must also function as an MP to the far end OMP. The OMP therefore requires a way to distinguish a Hello message sent in response to one of its Hello messages from a Hello originating from the far end OMP. For FR OMPs, a returned Hello messages will contain the receiving OMP’s full address as the destination. A Hello message originating from the far end OMP will contain a matching destination domain plan identification, a matching or null destination domain identification, and an all 1’s destination location identification. For ATM OMPs, a return Hello message will have a LB flag of 0 while a Hello that originated from the far end OMP will have a LB flag of 1.

When an OMP receives a response from a newly-discovered MP, it may initiate a service verification measurement session to that MP based upon the capabilities advertised by the MP. To allow for RTD measurements, the Hello response from the MP must specify at least two capabilities, Hello capability and Frame Transfer Delay capability.

The OMP must continue to send the Hello messages every TIMER_HELLO_TX time. Any time a previously-discovered MP does not respond in a reasonable timeframe (TIMER_HELLO_RX, with a recommended range of 1 – 60 seconds and a default of 5 seconds) the OMP must suspend any service verification sessions with that MP.

For networks using dynamic routing protocols such as PNNI or AINI, PVCs could be rerouted. While the PVC end-points (and therefore OMPs) should remain fixed, any intermediate point could change. OMPs must have the ability to recognize and allow for these reroutes. Any time an OMP receives a returned Hello message from a new source address, it should initiate Service Verification exchanges with the newly-discovered MP. The source addresses of the newly-discovered MP should be reported to the management system, along with the PM data. It would then be up to the downstream processing systems to recognize and allow for the changes in MPs.

5.3.2 PMP Role in Discovery Procedures

5.3.2.1 Frame Relay to ATM Direction

A PMP at a FR/ATM IWF must convert any PM Hello frame with a destination domain that matches one of the PMP's configured ATM side domains to an appropriate end-to-end or Seg_LB OAM cell. The PMP shall allow any other Hello message to pass through as standard user plane data.

The PMP must determine if a matching Hello message originated from the FR side or was a response to a Hello that had originated from the ATM side.

- A Hello message that originated from the FR side will have an all 0's or all 1's destination location identification. In this case the LLID field in the resulting OA&M LB cell should be set to all 0's or all 1's based upon the value that was in the PM frame; the LB flag in the OAM cell should be set to 1. The source address IFs in the PM frame must be mapped into the source address field in the resulting LB cell, as described in Section 4.2.3.
- A PM frame that is a Hello response will include the explicit address of the originating ATM OMP in the destination address IFs. This address must be mapped into the source address field of the resulting OA&M LB cell, and the source address from the PM frame must be mapped into the LLID field of the LB cell, as described above in Section 4.2.3. The LB flag in the LB cell must be set to 0.

All of the other fields of the ATM OAM LB cell that the PMP will form are the same for both the originating and response case, and are as follows:

- The common OAM cell fields must be set as shown in I.610, Section 10.1 with OAM type = Fault Management, Function type = LB.
- For the FR/ATM interworking case, only F5 or VC level OAM cells shall be used.
- The PTI value must be set to 4 for a segment OAM F5 flow cell or to 5 for an end-to-end F5 flow cell based upon the Domain Plan ID value.
- The LB cell-specific fields shall be set as shown in I.610, Section 10.2.3:
- A 1-bit flag must be set to "1" to indicate that this is a Hello message.
- If the PM frame included a Correlation Tag IF, the value of that IF must be copied into the Correlation Tag field of the OAM cell; otherwise this field should be set to 0.

Once formed, the OAM LB cell must be inserted into the cell stream leaving the PMP. From this point on, all ATM switches shall treat this cell as a standard I.610 OAM LB cell. No special processing is required as a result of this cell being generated from the PM frame. Each ATM switch must forward and/or return the LB cell according to the following rules, per I.610:

- The network operator must be able to configure various points in their ATM network as CPs, as defined in I.610.
- An F5 Seg_LB cell with an all 1's LLID field shall be looped back by the first configured segment end-point CP that it encounters. The address of this CP shall replace the all 1's value in the LLID field of the returned cell.

- An F5 Seg_LB cell with an all 0's LLID field shall be looped back by every configured CP that it encounters. A copy of the cell would also be forwarded on down the VC path to the connection segment's termination point. The address of each CP looping back a copy of the cell shall replace the all 0's value in the LLID field of the returned cell.
- While an end-to-end F5 LB cell must terminate at the connection end-point (TCP), there are various points that could be considered as the end-point within multi-service, multi-carrier networks:
    - An ATM UNI would always be considered as a connection end-point.
    - An ATM to FR IWF would be considered as a connection end-point for the ATM portion of the connection. If this IWF is configured as a PMP, the OAM cell should be passed to the PMP, where it should be handled as described above.
    - An NNI interconnecting two separate ATM networks should be configurable as either being a connection end-point or not, based upon a bi-lateral agreement between the operators of the two networks.
- Under the above definitions, a connection could have more than one terminating endpoint. An e-t-e LB cell with an all 1's LLID field should generally be looped back at the first end-point encountered.

5.3.2.2 ATM to Frame Relay Direction

The ATM side of the PMP IWF must recognize OAM LB cells with the Hello flag = "1" and convert these cells into PM Hello frames. Such cells could represent Hello messages that originated from an ATM OMP (if the LB flag = 1) or responses to PM Hello frames generated by a FR OMP (if the LB flag = 0). Section 4.2.3 describes the different address mappings required for these two cases. The format of the return Hello message is the same as for the forward direction Hello message described above. The various information fields in the return Hello message must be set as follows:

- The source and destination address fields for the return PM frame must be set according to the procedures in Section 4.2.3 of this specification.
- The PMP must insert at least two capability information fields, one indicating the Hello capability, and one indicating the Frame Transfer Delay capability. Information on the ATM side capabilities should be part of the PMP configuration.
- If the Correlation Tag field in the OAM cell is non-zero, the PMP must transfer this value to a Correlation Tag IF to be included in the PM frame.

5.4 Service Verification Procedures

Service verification messages must be sent periodically on all active PVCs with PM enabled, to all discovered MPs or OMPs that have indicated the capability of performing such measurements. The frequency of these measurements should be configurable (TIMER_SLV). This timer value is not subject to standardization; the FRF.19.1 recommended default is 900 seconds, but shorter intervals, such as 60 seconds would be preferable.

In FRF.19, Service Verification messages are used to collect statistics on round-trip delay (RTD), data delivery rate (DDR) and frame delivery rate (FDR). A single FRF.19.1 service verification message may be used to measure all of these statistics by specifying multiple information fields. For PMIW service verification sessions between a FR OMP and a FR MP or OMP, the procedures contained in FRF.19.1 Section 4.4, including the use of multiple information fields, may be applied.

There are, however, limitations on service verification sessions when an ATM MP or OMP is involved:

- FDR could potentially be measured for FR/ATM and ATM connections carrying AAL5 data. This item is for further study.
- DDR could potentially be measured, but there would always be inaccuracies for FR/ATM connections as a result of cell padding. Vendor-specific methods could be used to attempt to compensate for this.
- A single I.610 LB cell would not have sufficient space to accommodate multiple measurements. Even for just RTD measurements, the LB cell format does not have sufficient space to accommodate the three separate timestamp values specified in FRF.19.
- I.610 suggests doing DDR measurements using ATM forward performance monitoring (FPM) and backwards reporting (BR) OAM cells. The interworking of the I.610 DDR measurements with PMIW measurements for FR/ATM connections is an area for further study.

5.4.1 RTD Measurement

The first version of this specification only supports RTD measurements; other possibilities are for further study. FR OMPs will use the PMIW Service Verification message, message type 0x82, with a single type of measurement IF, RTD Information Field Type Value = 0x02, to perform these measurements. The format of this information field is shown in FRF.19, Figure 10. The originating FR OMP will populate this IF with a timestamp representing the time the RTD measurement request was launched.

FRF.19.1 specifies the use of the same information field in the service verification - RTD request and response messages with the length field used to distinguish between the two. Request messages specify a length of 6 octets and contain a single 4-octet initiator timestamp field, while response messages specify a length of 14 octets and contain three 4-octet timestamps: initiator, receiver receive, and receiver transmit. These additional timestamps are meant to permit the originating OMP switch to subtract out the processing time in the terminating MP switch when calculating RTD.

However, this processing time should be small, and there is no strong argument for excluding it from the RTD computation. Excluding these receiver switch timestamps from the calculation allows the timestamp format to be application-specific since the originating switch would only need to consider its own timestamps in calculating RTD. Also, the format of the I.610 ATM OAM LB cell that will be used to correspond to the RTD Measurement PM frames does not have enough room to support three timestamps.

Therefore, the presence of the three timestamp fields is required in the PMIW RTD response messages to distinguish them from RTD origination messages, but the values for the receiver timestamps may be set to either all 0's or to specific values by FR MPs or OMPs responding to an RTD request. In the case where an ATM MP or OMP is responding to an RTD request from a FR OMP, the ATM MP or OMP cannot populate these additional timestamps, so the PMP will be required to insert 0's into these fields when processing RTD responses in the ATM to FR direction. The originating switch may ignore these receiver timestamps in calculating RTD.

The addressing options for service verification messages are similar to those specified for the Hello message, except that the option exists to use explicit destination addresses:

- Source and destination domain plan IDs must be specified.
- The OMP source address IFs are required in the request message.
- The explicit address for the terminating MP or OMP may be specified in the destination domain and location identification IFs of request messages. Alternatively, an all 1's location identification IF value may be specified to designate the first FR MP or OMP with a matching domain or to designate the ATM segment or connection end-point.

When a FR MP or OMP receives a service verification message with a matching destination domain plan identification, and, if specified, destination domain and location identifications, as well as a valid source domain, it must respond with a return service verification message as follows:

- The source and destination domain plan identification fields from the received message must be swapped in the return message.
- The responding MP or OMP must copy the source domain and location identification IFs into the corresponding destination identification fields in the return message.
- The responding MP or OMP must populate the source domain and location identification IFs with its own configured address.
- The 6-octet Frame Transfer Delay Information Field must be converted into a 14-octet response FTD IF.
    - The initiator timestamp must be copied from the received service verification message to the response message.
    - Receiver RX and TX timestamps may be inserted per FRF.19, or these fields may be set to all 0's.

ATM MPs and OMPs will use I.610 OAM LB cells, with the SV flag set and a timestamp inserted, as shown in Section 4.2, for RTD measurements. All ATM switches other than those serving as an originating OMP or PMP will treat these cells as standard I.610 OAM LB cells. The timestamp will be passed unaltered by all of these switches. PMPs will be required to map between these OAM cells and the RTD Measurement PM frames.

An originating ATM OMP would construct the RTD request LB cell as follows:

- The source address field must be set to the configured address of the originating OMP.
- The LLID field may be set to the specific address of an MP or OMP to which the request is directed, or it may be set to all 1's to specify an ATM segment or connection end-point, or to specify the first FR MP or OMP encountered.
- The originating OMP will populate the timestamp field with the time the RTD measurement request was launched.
- The SV and LB flags must both be set to 1.
- The Correlation Tag field may be set to a non-zero value, or left at zero to indicate that it is not being used.

When an OMP receives an RTD response message it should calculate the time that it took for the message to reach its end-point and return by subtracting the value of the initiator timestamp from current time in the originating switch when the response is received. The OMP may adjust for the processing time in the far end switch by subtracting the difference of the two receiver timestamps from the calculated round-trip transit time. The way these RTD readings are stored and presented is application-specific.

The OMP should maintain a timer (TIMER_SLV_RX) for each transmitted service verification request. A lost or damaged service verification request or response message can result in a missed measurement period. Implementations may optionally time-out and retransmit to recover the period.

5.4.2 PMP Service Verification Procedures

5.4.2.1 FR to ATM Direction

A PMP must recognize a service verification message addressed to an ATM MP or OMP with a destination domain plan identification, and optionally domain identification matching a domain configured for the ATM side of the PMP, and a valid source domain. The PMP must convert such messages to corresponding ATM OAM LB cells. Other service verification messages must be passed through the PMP/IWF as user plane data. The domain matching and address handling for these messages is the same as for the Hello messages, except that specific destination addresses may be used.

The PMP must determine if a matching Service Verification message originated from the FR side or was a response to an SV message that had originated from the ATM side.

- A Service Verification message that originated from the FR side will have an RTD IF with a length of 6. In this case the LB flag in the OAM cell should be set to 1.
- A Service Verification response will have an RTD IF with a length of 14. In this case the LB flag in the OAM cell should be set to 0.

All of the other fields of the ATM OAM LB cell that the PMP will form are the same for both the originating and response case, and should be set as follows:

- The common OAM cell fields must be set as shown in I.610, Section 10.1 with OAM type = Fault Management, Function type = LB.
- For the FR/ATM interworking case, only F5 or VC level OAM cells shall be used.
- The PTI value shall be set to 4 for segment OAM F5 flow celsl or to 5 for end-to-end F5 flow cells, based upon the Domain Plan ID value.
- The LB cell-specific fields shall be set as shown in I.610, Section 10.2.3.
- A 1-bit flag must be set to “1” to indicate that this is a Service Verification message.
- The 4-octet Initiator Timestamp must be copied into the timestamp field in the OAM LB cell.
- If the PM frame included a Correlation Tag IF, the value of that IF must be copied into the Correlation Tag field of the OAM cell; otherwise this field must be set to 0.
- The LLID and source id fields shall be derived from the address information field in the PM frame, following the procedures in Section 4.2.3 of this specification.

5.4.2.2 ATM to FR Direction

Within the ATM network segment, these LB cells would be handled as standard I.610 OAM LB cells. The PMP must recognize incoming LB cells with the SV flag = “1” as Service Verification messages, and convert such cells back into Service Verification PM frames.

The PMP must determine if incoming OAM LB cells with the SV flag set to 1 are SV requests that originated from an ATM OMP, or SV responses to requests from a FR OMP.

- A LB cell with the SV and LB flags both set to 1 represents a SV request that originated from an ATM OMP. In forming the corresponding PM frame the PMP must include an RTD IF with a length of 6, octets and copy the timestamp from the LB cell into the single timestamp field in this IF
- A LB cell with the SV flag set to 1 and the LB flag set to 0 represents a SV response from an ATM MP or OMP. In forming the corresponding PM frame the PMP must include an RTD IF with a length of 14 octets. The PMP must copy the timestamp from the LB cell into the Initiator timestamp field in this IF and set the other two timestamp fields to 0.

All other fields of the PM frame that the PMP will form are the same for the originating and response cases, and should be set as follows:

- The Message Type field must be set to 0x82, PMIW Service Verification.
- The source and destination address fields for the return PM frame must be set according to the procedures in Section 4.2.3 of this specification.
- If the Correlation Tag field in the OAM cell is non-zero, the PMP must transfer this value to a Correlation Tag IF to be included in the PM frame.

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