

ATM and Frame Relay to MPLS Control Plane Interworking: Client-Server

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Editor:

Chris Metz
chmetz@cisco.com

For more information contact:

The MFA Forum
Suite 307
39355 California Street
Fremont, CA 94538 USA

Phone: +1 (510) 608-3997
FAX: +1 (510) 608-5917
E-Mail: info@mplsforum.org
WWW: <http://www.mplsforum.org/>

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1 Introduction

Many service providers derive significant revenues by offering and delivering VC-based services across dedicated Frame Relay (FR) and ATM networks. In a desire to reduce capital and operational expenditures, many of these same providers have embarked upon a strategy of convergence, where many per-service networks (including FR and ATM) and their attendant technologies and services are migrated to a single IP/MPLS packet-switched network (PSN). It is envisaged that existing network services such as FR and ATM and emerging new services, including IP VPN, will operate over this multi-service converged PSN.

Native FR and ATM networks employ dynamic signaling and routing protocols to expedite connection setup and recovery. PNNI is an example of one such protocol used to dynamically set up switched ATM connections across a native ATM network [4].

Pseudo-wire (PW) technology enables tunneling of ATM and FR connections through a PSN [2]. When transitioning to a PSN, service providers will expect ATM (and Frame Relay) signaling and routing protocols (e.g. PNNI) to interoperate with pseudo-wire signaling and IP routing protocols for the purpose of establishing switched connections across the PSN. This portends a need to define methods by which the control plane functions of a client (i.e. FR, ATM) network can be interworked with corresponding server (i.e. IP/MPLS) network control plane functions. The net result is an ability to dynamically establish switched connections between client network end-points that cross an IP/MPLS network.

1.1 Purpose

The purpose of this specification is to define the control plane and protocol interworking procedures for ATM and Frame Relay connections across an IP/MPLS PSN using pseudo wires.

1.2 Scope and Requirements

The scope and requirements for the functions described in this document are as follows:

- The architecture is general in nature. It supports a wide range of ATM and Frame Relay control plane protocols, including intra-network and inter-network (NNI) protocols such as PNNI, AINI, IISP, X.76, etc., and UNI protocols such as ATM Forum UNI 3.1 and 4.0, Q.2931, and X.36. Where appropriate and applicable, aspects of these native protocols pertaining to routing, signaling, OAM, etc, should not be reduced to subsets of their functionality.
- This approach needs to be *scalable* in a number of dimensions, to allow it to be used effectively in service provider networks, to support signaling rates commonly found in today's ATM networks, and to allow network growth and expansion. These dimensions include:
 - Performance: This approach must not reduce the signaling capabilities required in current networks.
 - Network resources: This approach must make effective use of network resources.
 - Future growth: As networks grow, the network resource usage to support this architecture must be similar to that required for the growth of current PNNI networks.

- This architecture should be standards-based, meaning that existing specifications and implementations should be used to the greatest extent possible. In particular:
 - Minimal changes to current ATM and Frame Relay networks should be required to support the architecture.
 - Existing IETF mechanisms should be used whenever possible.
 - Any standards-based IP or MPLS PSN tunnel capable of carrying MPLS pseudo wires is not precluded
 - Specific to MPLS, existing mechanisms and features commonly in use (especially for network resilience and efficiency), such as traffic engineering, fast reroute, standby LSPs, equal cost multipath, penultimate hop popping, diff-serv support, the ability to multiplex multiple pseudo wires and traffic types through the same PSN tunnels, etc., cannot be precluded from use.
 - The use of MPLS network resilience mechanisms is encouraged to allow ATM and FR VCs to survive switch or link outages within the MPLS network, if at all possible. ATM and FR-layer VC clearing should be avoided if at all possible.
- Support multiple ATM service categories efficiently
- Only point-to-point pseudo wires are supported. In the approach identified in this specification (since the mapping between client connections and pseudo wires is one-to-one), this may restrict the ability to support point-to-multipoint client connections. There are methods to work around this limitation, e.g. use of the "restricted branching" flag in PNNI routing [4].

The following items ARE NOT within the current scope of this document:

- Service interworking between ATM and Frame Relay control planes [12].
- Control Plane interworking between ATM (or Frame Relay) AND IP/MPLS control planes for setting up and managing switched connections between ATM (or Frame Relay) and IP/MPLS end-points and networks.
- User plane interworking between ATM (or Frame Relay) and IP/MPLS [14].
- L2TPv3 pseudo wires [13]

1.3 Overview

Figure 1 depicts the high-level architecture of the solution described in this document. Client networks operating a native client (routing and signaling) control plane attach to Label Edge Routers (LER) that are part of an IP/MPLS PSN. The LERs operate an IP/MPLS control plane (e.g. IGP/BGP, LDP, PWE3, RSVP-TE, etc.) to set up and manage label-switched paths (LSP) across the server network. In addition the LERs operate one (or more) instances of a client control plane.

Client network control plane messages used to dynamically route, set up, manage and tear down inter-client network point-to-points connections (e.g. PNNI) are processed by client network devices and the client control plane instances running on the LERs. Receipt of client control plane messages by an LER will dynamically trigger the corresponding IP/MPLS server network control plane functions necessary to carry encapsulated client network payloads contained in pseudo wires across the IP/MPLS PSN from one client network device to another.

The high-level principles behind this design are:

- Use of separated client and pseudo-wire control planes with a distinct (and implementation-specific) pseudo-wire service interface between them.
- Use of pseudo-wire control mechanisms defined in [1] as the initial pseudo-wire control plane in all scenarios except those with a null pseudo-wire control plane. Future specification of other pseudo-wire control plane mechanisms is not precluded.
- PSN and underlying pseudo wire protocol suite are providing a control plane interworking function to the attached client networks.

Techniques enabling switched connection setup across an MPLS networks have previously been defined[6] [10]. In these approaches, the client networks are ATM and the client control plane is ATM UNI, AINI, or PNNI. They define extensions for ATM signaling to distribute pseudo-wire labels between the MPLS edge nodes. The client and pseudo-wire control functions are collapsed into a single ATM signaling protocol.

The solution defined in this document opts for a different approach by decoupling the client and pseudo-wire control planes so as to lessen the dependencies of one on the other. This will allow for future additions to the pseudo-wire control plane to be used in ATM and Frame Relay to MPLS control plane interworking scenarios. This also enables different client control planes (e.g. Frame Relay) to employ the same pseudo-wire control plane. Conversely different pseudo-wire control planes may be used to support inter-client network connection setups.

Another approach uses virtual trunks through which ATM switches can transparently establish and maintain Virtual Circuit Connections (VCCs) and Virtual Path Connections (VPCs)[11]. Each virtual trunk is transported across an MPLS network as a single pseudo wire.

This specification describes a control plane interworking approach in which both control planes run on the same physical interworking element at the edge of the MPLS network. This approach:

- interworks each client virtual connection with a single pseudo wire that emulates the connection across the PSN,
- requires no change to deployed client network switches, and
- allows the LER to optimize utilization of resources in the MPLS network since it is aware of the traffic and QoS requirements of each client connection.

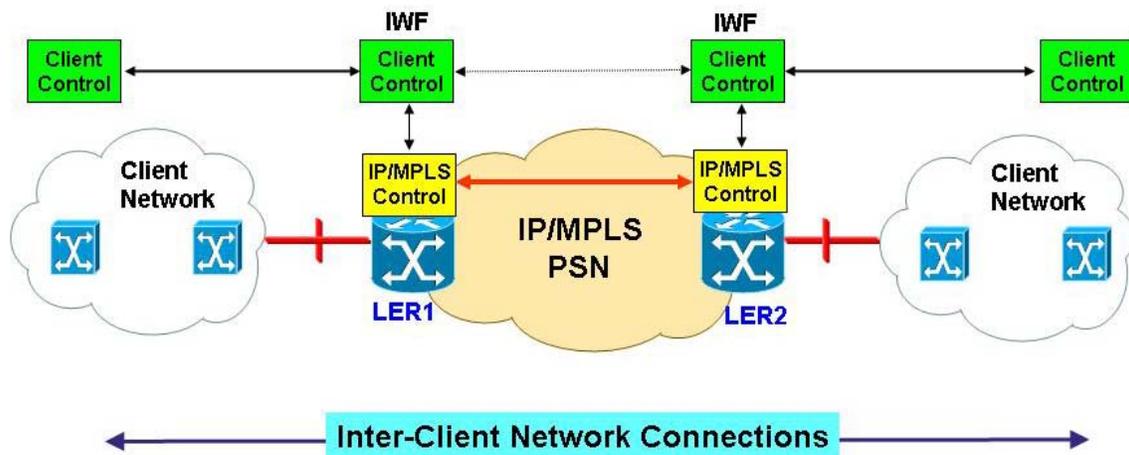


Figure 1 High-Level Architecture

2 Definitions and Terminology

2.1 Definitions

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

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.

2.2 Acronyms

Acronym	Definition
AI	Attachment Identifier
ATM	Asynchronous Transfer Mode
BFD	Bidirectional Forwarding Detection
CE	Customer Edge
FR	Frame Relay
IANA	Internet Assigned Numbers Authority
IE	Information Element
IETF	Internet Engineering Task Force
IWF	Interworking Function
LDP	Label Distribution Protocol
LER	Label Edge Router
MP-BGP	Multi-Protocol BGP
MPLS	Multi-protocol Label Switching
PE	Provider Edge
PGL	Peer Group Leader
PNNI	Private Network-Network Interface
PSN	Packet-Switched Network
PW	Pseudo wire
PWE3	Pseudo wire Emulation Edge-to-Edge
RSVP-TE	Resource Reservation Protocol – Traffic Engineering
RVPI	Relative VPI
SAI	Source Attachment Identifier
TAI	Target Attachment Identifier
VC	Virtual Connection
VCC	Virtual Channel Connection
VCI	Virtual Connection Identifier
VP	Virtual Path
VPC	Virtual Path Connection
VPI	Virtual Path Identifier
VT	Virtual Trunk

2.3 References

2.3.1 Normative

- [1] RFC4447, *Pseudowire Setup and Maintenance using LDP*. Martini, L., et al., April, 2006.
- [2] RFC3985, *Pseudo Wire Emulation Edge-to-Edge (PWE3) Architecture.*, IETF, S. Bryant, Ed., P. Pate, Ed. March 2005. (Status: INFORMATIONAL)
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- [5] RFC3036, *LDP Specificatio*”, IETF, January 2001
- [6] ATM Forum, af-aic-0206.00 , “*ATM-MPLS Control Plane Network Interworking*””, May 2005
- [7] RFC2277, “*IETF Policy on Character Sets and Languages*”, Internet Engineering Task Force, January 1998.
- [8] IANA-assigned Pseudo Wires Name Spaces, available at: <http://www.iana.org/assignments/pwe3-parameters>

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- [9] ATM Forum. af-cs-0197.000.pdf . *ATM-MPLS Interworking Signalling Specification Version 1.0*. August, 2003
- [10] ITU-T, Q.2920. *Broadband integrated services digital network (B-ISDN) Digital Subscriber Signalling System No. 2 (DSS 2): Call/connection control for the support of ATM-MPLS network interworking*. September, 2003.
- [11] MFA Forum, “*The Use of Virtual Trunks for ATM/MPLS Control Plane Interworking*”, MFA Forum 9.0.0, February 2006
- [12] Frame Relay Forum, FRF.18, “*Network-to-Network FR/ATM SVC Service Interworking Implementation Agreement*”, Frame Relay Forum Technical Committee April 2000
- [13] RFC3931, “*Layer Two Tunneling Protocol - Version 3 (L2TPv3)*”, Internet Engineering Task Force, March 2005
- [14] Martini, L., et al., *Encapsulation Methods for Transport of ATM Cells/Frames Over IP and MPLS Networks*. IETF, draft-ietf-pwe3-atm-encap-11.txt, May, 2006.

3 Reference Model

This section describes the reference model and components.

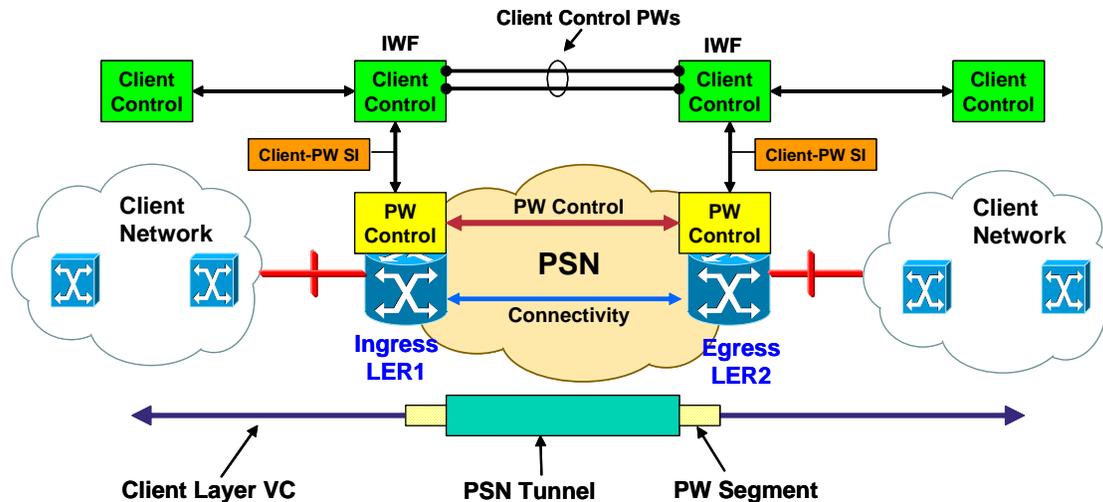


Figure 2 Reference diagram for client/pseudowire control plane interworking.

3.1 Components

Figure 2 illustrates the reference model and its components.

A *Packet-Switched Network (PSN)* provides *IP or MPLS* infrastructure to support *pseudo wires*. A *Label Edge Router (LER)* provides an *interworking function (IWF)* that connects the PSN and a segment of the client network. In the user plane, the LER interworks each client virtual connection with a single pseudo wire that emulates the connection across the PSN. The IWF also supports interworking between a *client control plane* and a set of functions which support setup, teardown, and maintenance of pseudo wires, which is called the *pseudo-wire control plane*. This is done by means of a *pseudo-wire service interface* within the IWF. Pseudo wires may also be used to carry client control plane traffic between LERs. With respect to a given client setup request, an LER is considered an *ingress LER* if it is the first LER along the signaling path to process a client control plane SETUP message. An LER is considered an *egress LER* if it is the last LER along the signaling path to process a client control plane SETUP message.

Between the ingress and egress LERs, *PSN tunnels* are established, and pseudo wires are carried encapsulated in these PSN tunnels. PSN tunnels can be any technology, as described in [2].

The mapping between client connections and pseudo wires is as follows: One client control plane pseudo wire is established for each client control plane connection. Each client virtual connection is mapped to a single pseudo wire which meets the service requirements of the client virtual connection, and which is established on-demand. These pseudo wires are carried in PSN tunnels which satisfy connection service requirements.

3.2 Client/Pseudo-Wire Control Plane Interactions

Separation of client and pseudo-wire control planes, with a distinct service interface between them, is a basic principle.

The pseudo-wire control plane manages pseudo wire set up and tear down, multiplexing, and service differentiation. Other functionality is left to the client control plane thus allowing support for client control planes that have significant differences from pseudo-wire control planes in state machine, timers, and semantics.

The pseudo-wire service interface supports the following:

- Request establishment of a pseudo wire
- Request tear down of a pseudo wire
- Pseudo wire status notification to client control plane (e.g. teardown notification, establishment completed notification)
- Managing a pseudo wire and its related resources. For example, traffic and QoS parameters of each client connection may be passed across the pseudo-wire service interface. This information would allow the LER to dynamically track the resources required by the PSN Tunnels that transport the pseudo wires across the MPLS network, and can also be used when selecting resources for local support of pseudo wires and attachment circuits.

These requests will have parameters. For example, the client user plane encapsulation and connection identifiers used to bind the pseudo wire to be established to the attachment circuits created by the client control plane.

The pseudo wire service interface is an internal interface, it is not formally specified in this specification.

4 The Pseudo-Wire Control Plane

This specification uses the pseudo-wire control mechanisms defined in [1] as the initial pseudo-wire control plane in all scenarios except those with a null pseudo-wire control plane. Future specification of other pseudo-wire control plane mechanisms is not precluded.

In providing services to the client control plane, the offered pseudo-wire control plane capabilities can be:

- Null, with all pseudo-wire management done by configuration. When the client control plane makes a request, it can only be satisfied by preconfigured pseudo wires.
- Connection management. The pseudo-wire control plane may know where the connection points are that the client control plane might want, but pseudo wires are not set up until they are needed.

When the pseudo-wire control plane is used, at a minimum it is responsible for setup and teardown of pseudo wires between LERs. This requires exchange of pseudo wire-related information between the LERs (such as the pseudo-wire labels, the encapsulation used to transport client data in the pseudo wire, and some identification of the attachment circuits to which the pseudo wire is bound at the LERs).

5 The Client Control Plane

A pseudo-wire service interface can provide services for a diversity of client control planes, varying both in protocol family and in functionality. Just as the pseudo-wire control plane can vary, the client control plane functions at the service interface can be any of:

- Null, with all client protocol management done by configuration.
- Connection management only. Connections are set up dynamically but the client control plane expects a particular topology from the PSN.
- Connection and connectivity management. The client control plane explores its connectivity, determines paths to use, and sets up connections dynamically. An example is ATM PNNI.

When a client control plane is used at the LERs, it is responsible for establishment, maintenance, and release of attachment circuits on the LERs' interfaces facing the client networks, as well as propagation of end-to-end client control plane information across the PSN. The information exchanged by the client control plane includes both end-to-end information such as the called party address, traffic descriptors, and endpoint application information, and (at the interfaces connecting the client networks to the LERs) local information such as the ATM VPI/VCI or the Frame Relay DLCI. The local information is not needed for the user plane connection segment across the PSN (pseudo wire-related information is handled by the pseudo-wire control plane), but this information may still be exchanged between the LERs to be used by the control and management planes.

There are several options for routing client control plane connection establishment messages across the PSN:

- Static routes may be configured at the client network and at the LERs, based on prefixes of client control plane addresses.
- Dynamic routing may be included in the client control plane, both between the client network and the LERs, and between LERs across the PSN. For example, if the client layer is ATM, PNNI may be used, with each LER represented as one lowest level node in the PNNI topology. Peer Group Leader (PGL) and border node functionality may be used at LERs. The PSN places no restrictions on the use of PNNI hierarchy.
- Prefixes of client control plane addresses can be exchanged across the PSN network using a PSN routing protocol such as MP-BGP. When this information is exchanged between LERs, each LER uses this information to decide dynamically how a setup request should be directed, based upon topology and resource availability at the time, and to respond well to failures.

The use of MP-BGP for exchanging ATM reachability across the PSN is for further study.

- Combinations of the above may be used.

5.1 Logical Links

From the client control plane's point of view, the connectivity between a pair of LERs appears as a logical link over which client connections can be established. The logical link may have a set of resources associated with it, for example, for advertisement in a client routing protocol such as PNNI. Note that these resources need not be exclusive to this client control plane instance. They can be shared by all or a subset of applications at the LER.

A set of client control channels (e.g. ATM signaling, PNNI routing, and ILMI) is associated with each logical link.

Typically there will be only one instance of a logical link between a pair of LERs for each client control plane (though presence of multiple logical links is not precluded). If a client routing protocol is used, only one instance of that client routing protocol needs to run between the LERs.

The fact that the connectivity between the LERs appears to the client control plane as a logical link does not imply that there is any restriction on the usage of PSN tunnels. Any PSN tunnel between the LERs is a candidate for transport of the pseudo wires that carry client user connections and client control channels between the LERs, subject to policy, QoS, or other constraints as for any other pseudo wire between the LERs.

5.2 Establishment of Control Pseudo Wires

The support of dynamic client (ATM or Frame Relay) connections across an intermediate IP or MPLS network requires the transport of client signaling messages and depending upon the configuration client routing and link management messages between the LERs.

Some client layer protocols (i.e. ATM) employ reserved native client encapsulation headers (i.e. ATM uses VPI/VCI values) to identify connections associated with various protocols or functions. These values may have a per-interface context, which means that a native client node can receive the same client encapsulation header from other native client nodes with the understanding that <client encapsulation header, interface> provides a combination that uniquely identifies the sender. MPLS pseudo wires, on the other hand, use a per-platform label range.

Before client control messages can be carried across a PSN tunnel, the LER at each end of the PSN tunnel must be made aware of the labels that will carry the control channel traffic for that instance of the client control plane between the LERs. These client control channels must be identified so that the data on the corresponding control pseudo wire is delivered to the correct instance of the client control plane and not forwarded out an egress interface.

There are three distinct control pseudo wires that can be established between peering LERs:

- Signaling control PW. This is mandatory if the client control plane is non-null.
- Routing control PW. This is optional.
- Link Management PW. This is optional.

5.2.1 Control Pseudo-Wire Signaling

The native client control channel to pseudo-wire label bindings are distributed as defined in [1]. The LERs establish an LDP session using the Extended Discovery mechanism described in [5]. An LDP Label Mapping message is used to establish the relationship between the client control channels and labels. An LDP Label Mapping message contains a FEC TLV, a Label TLV, and zero or more optional parameter TLVs.

To remain consistent with the signaling procedures for the establishment of data-bearing pseudo wires outlined in section 6, it is mandatory that LDP signaling of control pseudo wires employ the Generalized ID FEC element (type 129).

MPLS packets on a given control PW (or any PW) are forwarded within an LER by a forwarder; the forwarder is the component inside an LER that selects the control pseudo wire through which packets will be sent. The concept of an attachment identifier (AI) is used to identify the forwarder to which a pseudo wire is attached. The AI is unique within the context of the LER in which the forwarder resides, so the combination of <LER, AI> is globally unique in the network.

Forwarders within an LER can be associated with a group, where pseudo wires may only be set up among members of the group. Forwarders associated with the group are identified by an Attachment Group Identifier (AGI) and an Attachment Individual Identifier (AII). This pair represents the AI.

The AGI, source AII (SAII), and target AII (TAII) are encoded as TLVs and described in [1]; this specification does not define any restrictions on the contents of the AGI.

The format for an AII is illustrated in Figure 3. This format is used for both the SAI and the TAI.

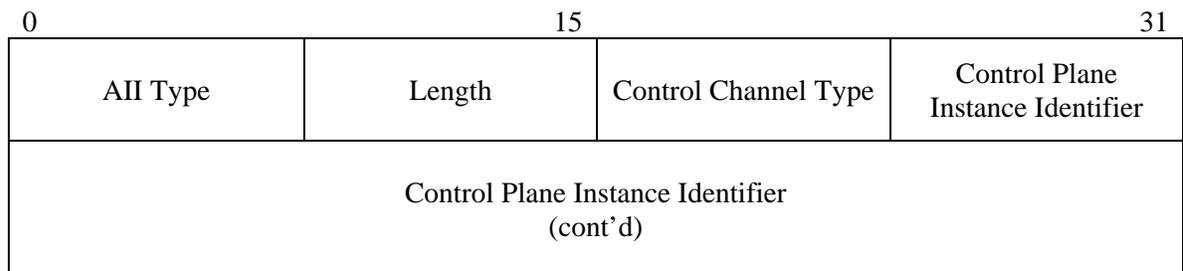


Figure 3: SAI and TAI Format for Control PW Setup

AII (type) field

This one-byte field contains the AII type codepoint used for establishing control PWs as defined in Table 1. The length of the corresponding value associated with this AII type is also provided as defined in [8].

AII Type Codepoint	Length	Meaning

0x03	Variable (1-33 bytes)	ATM/FR Control Channel
------	-----------------------	------------------------

Table 1 AII Type Codepoint for Control PW Setup

Control Channel Type

This one-byte field indicates the control channel type as specified in Table 2 below. The ATM-specific values are common with those defined in [6].

<u>Control Channel Type</u>	<u>Meaning</u>
<u>0</u>	<u>PNNI Routing Control Channel</u>
<u>1</u>	<u>ATM Signalling</u>
<u>2</u>	<u>ILMI</u>
<u>3</u>	<u>Frame Relay Signaling</u>

Table 2: Control Channel Type Field Values

Control Plane Instance Identifier

The Control plane instance identifier is used to distinguish among multiple client control plane instances running between the same two LERs, in the same group (in which case pseudo wires established in response to those client control plane instances would use the same AGI value in the pseudo-wire control plane). This could be due to the possibility of multiple different control planes being used between the two LERs, e.g. ATM and Frame Relay, or due to multiple instances of the same client control plane being used between the two LERs [6].

Connections for the same logical link shall use the same value of the CPII in the AII. Connections for different logical links between the same two LERs that use the same value for the AGI shall use different values in the AII.

The Control plane instance identifier takes the form of a variable length human-readable character string conforming to [7] and not to exceed 32 octets in length. The default value for the CPII is the null string specified by setting the length field to 1.

6 ATM and FR to LDP Signaling Interworking

This section contains the procedures for interworking ATM and FR signaling with PWE3 (LDP) signaling, and will employ the following terminology:

- PW Source LER – first LER to initiate a PW control plane message directed towards the PW Target LER
- PW Target LER – Receiver of initial PW control plane message sent from the PW source LER.

The ingress and egress LERs respectively are defined in section 3.1 .

6.1 ATM and FR to LDP Signaling Interworking Procedures

When the client control plane's SETUP message arrives at the ingress LER, the setup request is passed to the client control plane's call control in the usual fashion. Pseudo-wire signalling shall not be initiated. If pseudo-wire connection admission control is supported, the LER shall determine whether the PSN has adequate resources to support the connection across the PSN to the egress LER. If the PSN does not have adequate resources, the call shall be cleared (possibly using crankback) using normal client control plane procedures.

When the client control plane's SETUP message arrives at the egress LER, the setup request is passed to the client control plane's call control in the usual fashion. If pseudo-wire connection admission control is supported, the LER shall determine whether the PSN has adequate resources to support the connection across the PSN to the ingress LER. If the PSN does not have adequate resources, the call shall be cleared (possibly using crankback) using normal client control plane procedures.

If the PSN has adequate resources or if pseudo-wire connection admission control is not supported, the client control plane's call control shall trigger the pseudo-wire control plane to initiate pseudo wire establishment using the Generalized PW ID FEC Element (FEC Type 129), as defined in [1]. Details of construction of the TAI are discussed in Section 6.2.

If the egress LER's pseudo-wire control plane is unable to send the Label Mapping message for any reason such as no label resources available, the call shall be cleared (possibly using crankback) using normal client control plane procedures. If the client control plane is ATM PNNI or AINI (including support for Signalling Congestion Control), and the reason why the pseudo-wire control plane is unable to send the Label Mapping message is congestion in the pseudo-wire control plane (i.e. lack of internal resources such as queuing resources, memory and CPU realtime), then, the call shall be cleared using crankback with cause and crankback cause (#42 "Switching Equipment Congestion") fields set. In the absence of errors, the egress LER shall start the PseudoWireFailureTimer with initial value the same as T310 (as defined for ATM and Frame Relay Signalling) for this client control plane instance. The egress LER has two options for the propagation of the SETUP message in the client control plane:

1. Hold the SETUP message until the pseudo-wire control plane indicates that pseudo-wire establishment has been completed, or
2. Immediately forward the SETUP message towards the called party.

Option 1 must be employed if the client control plane requires that the data plane be established as the SETUP message is progressed. This is the case when the setup request indicates "susceptible to clipping"

in the Broadband bearer capability information element. Figure 4 illustrates option 2, and also clarifies that the egress LER is performing the role of PW source LER.

When the Label Mapping message is received at an LER, the normal procedures for the Generalized PW ID FEC Element defined in [1] shall be followed. If the TAI does not indicate a known pseudo wire for which an LSP has already been set up in the opposite direction, then it is assumed that this is the ingress LER (i.e. PW target LER). The TAI is used to associate the control information for the client connection and pseudo wire. If the TAI contains a call reference value that is not known to the indicated client control plane instance, then the procedures for a TAI that cannot be mapped to a forwarder shall be followed (defined in [1]), causing the Label Mapping message to be rejected.

If the TAI contains a call reference value that is known to the indicated client control plane instance, then that call reference shall be used to determine the appropriate forwarder as the pseudo-wire end-point. If a forwarder has been determined but the corresponding client control connection is not in a compatible pending state on the logical link (for example, if this router is not an ingress LER for this client connection), then the Label Mapping message shall be rejected and the client connection shall be cleared in both directions using normal client control plane procedures.

If a forwarder has been determined and there are any errors in the Label Mapping message that cause it to be rejected, then the client connection shall be cleared in both directions using normal client control plane procedures. If the ingress LER's pseudo-wire control plane is unable to send the Label Mapping message for the second LSP of the pseudo wire for any reason such as no label resources available, then the first LSP of the pseudo wire shall be released and the client connection shall be cleared using normal client control plane procedures. If the client control plane is ATM PNNI or AINI (including support for Signalling Congestion Control), and if the reason why the ingress LER's pseudo-wire control plane is unable to send the Label Mapping message for the second LSP is congestion in the pseudo-wire control plane (i.e. lack of internal resources such as queuing resources, memory and CPU realtime), then, the call shall be cleared using crankback with cause and crankback cause (#42 "Switching Equipment Congestion" [3]) fields set.

When the Label Mapping message is received at an LER and the TAI indicates a known pseudo wire for which an LSP has already been set up in the opposite direction, then it is assumed that this is the egress LER (i.e. PW source LER). If there are any errors in the Label Mapping message that cause it to be rejected, then in addition to replying with a Label Release message as per normal pseudo-wire control plane procedures, the label for the other direction of the pseudo wire shall be withdrawn using normal pseudo-wire control plane procedures and the client connection shall be cleared in both directions using normal client control plane procedures. Otherwise, in addition to the normal procedures defined in [1], an indication shall be passed to the client control plane that the PW control plane has completed pseudo-wire establishment and the PseudoWireFailureTimer shall be stopped. If option 1 was employed above, the egress LER shall propagate the client control plane's SETUP message towards the called party.

When the client control plane's CONNECT message arrives at the egress LER from the direction of the called party, the connect request is passed to the client control plane's call control in the usual fashion. If no indication has been received indicating that the pseudo wire control plane has completed pseudo-wire establishment (this is never the case if option 1 was employed above), then the client control plane's call control shall hold the connect request. Once the indication is received from the pseudo-wire control plane, the client control plane shall resume processing of the connect request, causing the egress LER to progress the CONNECT message to the ingress LER according to normal client control plane procedures. The egress LER shall enable traffic flow over the user plane for the client connection and the corresponding pseudo wire before progressing the CONNECT message. If no indication that the pseudo-wire control plane has completed pseudo-wire establishment is received before the

PseudoWireFailureTimer expires, then the pseudo wire shall be cleared using normal pseudo-wire control plane procedures, and the client connection shall be cleared in both directions using normal client control plane procedures.

When the client control plane's CONNECT message arrives at the ingress LER, normal client control plane procedures are followed. The ingress LER shall enable traffic flow over the user plane for the client connection and the corresponding pseudo wire before progressing the CONNECT message towards the called party. If there is no active pseudo wire for this client connection, then the call shall be cleared in both directions using normal client control plane procedures and the remaining state in the pseudo-wire control plane, if any, shall also be cleared.

If a Label Withdraw or Label Release message is received for any pending or active connection, then the pseudo wire shall be cleared using normal pseudo-wire control plane procedures, and the client connection shall be cleared in both directions using normal client control plane procedures.

If a client control plane call clearing message is received for any pending or active connection, or upon initiating call clearing due to client control plane error handling procedures, then in addition to normal client control plane procedures, the pseudo wire shall be cleared using normal pseudo-wire control plane procedures.

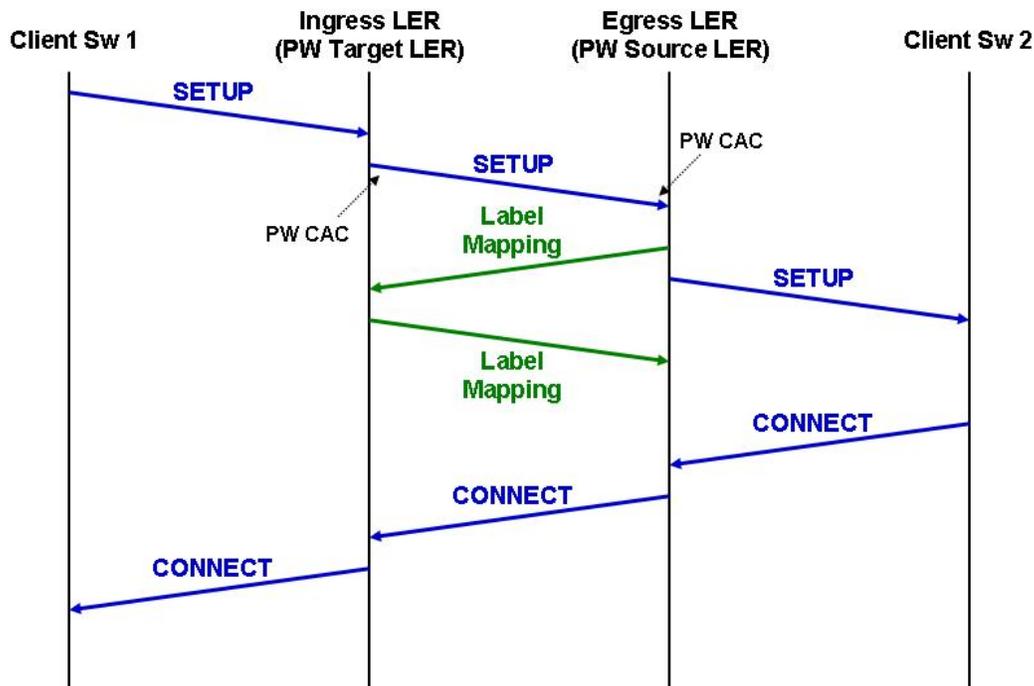


Figure 4 PW Establishment Triggered by Client Connection SETUP at Egress LSR

6.2 The SAI and the TAI in LDP Signaling

The TAI is used as the key that allows the *PW Target LER* to correlate an incoming Label Mapping message with an ATM or Frame Relay connection created in response to client control plane messages.

For switched connections established using the client and pseudo-wire control planes, the TAI and SAI are encoded as illustrated in Figure 5:

0	15	31
AII Type	Length	LDP Call Reference Flag (1 bit) and Call Reference Value
Call Reference Value (cont'd)	Control Plane Instance Identifier	

Figure 5 SAI and TAI Encoding for Client Connection PW Setup

AII (type) field

This one-byte field contains the AII type codepoint for data-plane PWs as specified in Table 3. The length of the corresponding value associated with this AII type codepoint is also provided as defined in [8].

AII Type Codepoint	Length	Meaning
0x04	Variable (3-35 bytes)	ATM/FR Signaling Call Reference

Table 3 AII Type Codepoint for Data Plane PW Setup

LDP call reference flag

Bit	
8	
0	The LER that originated the call reference has a smaller IP address than the opposite LER, based on the IP addresses used to establish this LDP session between the LERs.
1	The LER that originated the call reference has a larger IP address than the opposite LER, based on the IP addresses used to establish this LDP session

| between the LERs.

Call reference value

The call reference value used in the client (i.e., ATM or Frame Relay) control plane between the LERs.

Control plane instance identifier

See section 5.2.1

END OF DOCUMENT