Pseudowire Setup and Maintenance using LDP

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Abstract

Layer 2 services (such as Frame Relay, ATM, ethernet) can be "emulated" over an IP and/or MPLS backbone by encapsulating the layer 2 PDUs and then transmitting them over "pseudowires". It is also possible to use pseudowires to provide low-rate TDM and SONET circuit emulation over an IP and/or MPLS network. This document specifies a protocol for establishing and maintaining the pseudowires, using
extensions to LDP. Procedures for encapsulating layer 2 PDUs are specified in a set of companion documents.
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1. Specification of Requirements

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

2. Introduction

In [FRAME], [ATM], and [ETH] it is explained how to encapsulate a layer 2 Protocol Data Unit (PDU) for transmission over an IP and/or MPLS network. Those documents specify that a "pseudowire header", consisting of a demultiplexor field, will be prepended to the encapsulated PDU. The pseudowire demultiplexor field is put on before transmitting a packet on a pseudowire. When the packet arrives at the remote endpoint of the pseudowire, the demultiplexor is what enables the receiver to identify the particular pseudowire on which the packet has arrived. To actually transmit the packet from one pseudowire endpoint to another, the packet may need to travel through a "PSN tunnel"; this will require an additional header to be prepended to the packet.

Accompanying documents [CEP, SAToP] describe methods for transporting time division multiplexed (TDM) digital signals (TDM circuit emulation) over a packet-oriented MPLS network. The transmission system for circuit-oriented TDM signals is the Synchronous Optical Network (SONET)/Synchronous Digital Hierarchy (SDH) [ITUG]. To support TDM traffic, which includes voice, data, and private leased line service, the pseudowires must emulate the circuit characteristics of SONET/SDH payloads. The TDM signals and payloads are encapsulated for transmission over pseudowires. To this encapsulation is prepended a pseudowire demultiplexor and a PSN tunnel header.

[SAToP] describe methods for transporting low-rate time division
multiplexed (TDM) digital signals (TDM circuit emulation) over PSNs, while [CEP] similarly describes transport of high-rate TDM (SONET/SDH). To support TDM traffic the pseudowires must emulate the circuit characteristics of the original T1, E1, T3, E3, SONET or SDH signals. [SAToP] does this by encapsulating an arbitrary but constant amount of the TDM data in each packet, while the other methods encapsulate TDM structures.

In this document, we specify the use of the MPLS Label Distribution Protocol, LDP [RFC3036], as a protocol for setting up and maintaining the pseudowires. In particular, we define new TLVs for LDP, which enable LDP to identify pseudowires and to signal attributes of pseudowires. We specify how a pseudowire endpoint uses these TLVs in LDP to bind a demultiplexor field value to a pseudowire, and how it informs the remote endpoint of the binding. We also specify procedures for reporting pseudowire status changes, passing additional information about the pseudowire as needed, and for releasing the bindings.

In the protocol specified herein, the pseudowire demultiplexor field is an MPLS label. Thus the packets which are transmitted from one end of the pseudowire to the other are MPLS packets must be transmitted through a PSN tunnel, however if the pseudowire endpoints are immediately adjacent, the PSN tunnel may not be necessary. Any sort of PSN tunnel can be used, as long as it is possible to transmit MPLS packets through it. The PSN tunnel can itself be an LSP, or any other sort of tunnel which can carry MPLS packets. Procedures for setting up and maintaining the PSN tunnels are outside the scope of this document.

This document deals only with the setup and maintenance of point to point pseudowires. Neither point to multipoint nor multipoint to point pseudowires are discussed.

QoS related issues are not discussed in this document.

The following two figures describe the reference models which are derived from [ARCH] to support the Ethernet PW emulated services.
For the purpose of this document, PE1 will be defined as the ingress router, and PE2 as the egress router. A layer 2 PDU will be received at PE1, encapsulated at PE1, transported, decapsulated at PE2, and transmitted out of PE2.
3. The Pseudowire Label

Suppose it is desired to transport layer 2 PDUs from ingress LSR PE1 to egress LSR PE2, across an intervening PSN. We assume that there is a PSN tunnel from PE1 to PE2. That is, we assume that PE1 can cause a packet to be delivered to PE2 by encapsulating the packet in a "PSN tunnel header" and sending the result to one of its adjacencies. If the PSN tunnel is an MPLS Label Switched Path (LSP), then putting on a PSN tunnel encapsulation is a matter of pushing on an additional MPLS label.

We presuppose that a large number of pseudowires can be carried through a single PSN tunnel. Thus it is never necessary to maintain state in the network core for individual pseudowires. We do not presuppose that the PSN tunnels are point to point; although the pseudowires are point to point, the PSN tunnels may be multipoint to point. We do not presuppose that PE2 will even be able to determine the PSN tunnel through which a received packet was transmitted. (E.g., if the PSN tunnel is an LSP, and penultimate hop popping is used, when the packet arrives at PE2 it will contain no information identifying the tunnel.)

When PE2 receives a packet over a pseudowire, it must be able to determine that the packet was in fact received over a pseudowire, and it must be able to associate that packet with a particular pseudowire. PE2 is able to do this by examining the MPLS label which serves as the pseudowire demultiplexor field shown in Figure 2. Call this label the "PW label".

So when PE1 sends a layer 2 PDU to PE2, it first pushes a PW label on its label stack, thereby creating an MPLS packet. It then (if PE1 is not adjacent to PE2) encapsulates that MPLS packet in a PSN tunnel header. (If the PSN tunnel is an LSP, this is just a matter of pushing on a second label.) The PW label is not visible again until the MPLS packet reaches PE2. PE2’s disposition of the packet is based on the PW label.

Note that the PW label must always be at the bottom of the packet’s label stack and labels MUST be allocated from the per-platform label space.

This document specifies a protocol for assigning and distributing the PW label. This protocol is LDP, extended as specified in the remainder of this document. An LDP session must be set up between the pseudowire endpoints. LDP MUST be used in its "downstream unsolicited" mode. LDP’s "liberal label retention" mode SHOULD be used.
In addition to the protocol specified herein, static assignment of PW labels MAY be used, and implementations of this protocol SHOULD provide support for static assignment.

This document specifies all the procedures necessary to set up and maintain the pseudowires needed to support "unswitched" point to point services, where each endpoint of the pseudowire is provisioned with the identify of the other endpoint. There are also protocol mechanisms specified herein which can be used to support switched services, and which can be used to support other provisioning models. However, the use of the protocol mechanisms to support those other models and services is not described in this document.

4. Details Specific to Particular Emulated Services

4.1. Frame Relay

When emulating a frame relay service, the Frame Relay PDUs are encapsulated according to the procedures defined in [FRAME]. The PE MUST provide Frame Relay PVC status signaling to the Frame Relay network. If the PE detects a service-affecting condition for a particular DLCI, as defined in [ITUQ] Q.933 Annex A.5 sited in IA FRF1.1, the PE MUST communicate to the remote PE the status of the PW corresponds to the frame relay DLCI. The Egress PE SHOULD generate the corresponding errors and alarms as defined in [ITUQ] on the egress Frame relay PVC. There are two frame relay flags to control word bit mappings described in [FRAME]. The legacy bit ordering scheme will be used for a PW of type "Frame Relay DLCI (Martini Mode)", while the new bit ordering scheme will be used for a PW of type "Frame Relay DLCI".

4.2. ATM

4.2.1. ATM AAL5 SDU VCC Transport

ATM AAL5 CSPS-SDUs are encapsulated according to [ATM] ATM AAL5 CPCS-SDU mode. This mode allows the transport of ATM AAL5 CSPS-SDUs traveling on a particular ATM PVC across the network to another ATM PVC.
4.2.2. ATM Transparent Cell Transport

This mode is similar to the Ethernet port mode. Every cell that is received at the ingress ATM port on the ingress PE, PE1, is encapsulated according to [ATM], ATM cell mode n-to-one, and sent across the PW to the egress PE, PE2. This mode allows an ATM port to be connected to only one other ATM port. [ATM] ATM cell n-to-one mode allows for concatenation (grouping) of multiple cells into a single MPLS frame. Concatenation of ATM cells is OPTIONAL for transmission at the ingress PE, PE1. If the Egress PE PE2 supports cell concatenation the ingress PE, PE1, should only concatenate cells up to the "Maximum Number of concatenated ATM cells" parameter received as part of the FEC element.

4.2.3. ATM n-to-one VCC and VPC Cell Transport

This mode is similar to the ATM AAL5 VCC transport except that cells are transported. Every cell that is received on a pre-defined ATM PVC, or ATM PVP, at the ingress ATM port on the ingress PE, PE1, is encapsulated according to [ATM], ATM n-to-one cell mode, and sent across the LSP to the egress PE PE2. Grouping of ATM cells is OPTIONAL for transmission at the ingress PE, PE1. If the Egress PE PE2 supports cell concatenation the ingress PE, PE1, MUST only concatenate cells up to the "Maximum Number of concatenated ATM cells in a frame" parameter received as part of the FEC element.

4.2.4. OAM Cell Support

OAM cells MAY be transported on the PW LSP. When the PE is operating in AAL5 CPCS-SDU transport mode if it does not support transport of ATM cells, the PE MUST discard incoming MPLS frames on an ATM PW LSP that contain a PW label with the T bit set [ATM]. When operating in AAL5 SDU transport mode an PE that supports transport of OAM cells using the T bit defined in [ATM], or an PE operating in any of the cell transport modes MUST follow the procedures outlined in [ATM] in addition to the applicable procedures specified in [ITUG].

4.2.4.1. SDU/PDU OAM Cell Emulation Mode

A PE operating in ATM SDU, or PDU transport mode, that does not support transport of OAM cells across an LSP MAY provide OAM support on ATM PVCs using the following procedures:
- Loopback cells response

If an F5 end-to-end OAM cell is received from a ATM VC, by either PE that is transporting this ATM VC, with a loopback indication value of 1, and the PE has a label mapping for the ATM VC, then the PE MUST decrement the loopback indication value and loop back the cell on the ATM VC. Otherwise the loopback cell MUST be discarded by the PE.

- AIS Alarm.

If an ingress PE, PE1, receives an AIS F4/F5 OAM cell, it MUST notify the remote PE of the failure. The remote PE , PE2, MUST in turn send F5 OAM AIS cells on the respective PVCs. Note that if the PE supports forwarding of OAM cells, then the received OAM AIS alarm cells MUST be forwarded along the PW as well.

- Interface failure.

If the PE detects a physical interface failure, or the interface is administratively disabled, the PE MUST notify the remote PE for all VCs associated with the failure.

- PSN/PW failure detection.

If the PE detects a failure in the PW, by receiving a label withdraw for a specific PW ID, or the targeted LDP session fails, or a PW status TLV notification is received, then a proper AIS F5 OAM cell MUST be generated for all the affected atm PVCs. The AIS OAM alarm will be generated on the ATM output port of the PE that detected the failure.

4.2.5. ILMI Support

An MPLS edge PE MAY provide an ATM ILMI to the ATM edge switch. If an ingress PE receives an ILMI message indicating that the ATM edge switch has deleted a VC, or if the physical interface goes down, it MUST send a PW status notification message for all PWs associated with the failure. When a PW label mapping is withdrawn, or PW status notification message is received the egress PE SHOULD notify its client of this failure by deleting the VC using ILMI.
4.2.6. ATM AAL5 PDU VCC Transport

ATM AAL5 CSPS-PDUs are encapsulated according to [ATM] ATM AAL5 CPCS-PDU mode. This mode allows the transport of ATM AAL5 CSPS-PDUs traveling on a particular ATM PVC across the network to another ATM PVC. This mode supports fragmentation of the ATM AAL5 CPCS-PDU in order to maintain the position of the OAM cells with respect to the user cells. Fragmentation may also be performed to maintain the size of the packet carrying the AAL5 PDU within the MTU of the link.

4.2.7. ATM one-to-one VCC and VPC Cell Transport

This mode is similar to the ATM AAL5 n-to-one cell transport except an encapsulation method that maps one ATM VCC or one ATM VPC to one Pseudo-Wire is used. Every cell that is received on a pre-defined ATM PVC, or ATM PVP, at the ingress ATM port on the ingress PE, PE1, is encapsulated according to [ATM], ATM one-to-one cell mode, and sent across the LSP to the egress PE PE2. Grouping of ATM cells is OPTIONAL for transmission at the ingress PE, PE1. If the Egress PE PE2 supports cell concatenation the ingress PE, PE1, MUST only concatenate cells up to the "Maximum Number of concatenated ATM cells in a frame" parameter received as part of the FEC element.

4.3. Ethernet Tagged Mode

The Ethernet frame will be encapsulated according to the procedures in [ETH] tagged mode. It should be noted that if the VLAN identifier is modified by the egress PE, according to the procedures outlined above, the Ethernet spanning tree protocol might fail to work properly. If the PE detects a failure on the Ethernet physical port, or the port is administratively disabled, it MUST send PW status notification message for all PWs associated with the port. This mode uses service-delimiting tags to map input ethernet frames to respective PWs.

4.4. Ethernet

The Ethernet frame will be encapsulated according to the procedures in [ETH] "ethernet raw mode". If the PE detects a failure on the Ethernet input port, or the port is administratively disabled, the PE MUST send a corresponding PW status notification message.
4.5. HDLC and PPP

HDLC and PPP frames are encapsulated according to the procedures in [PPPHDLC]. If the MPLS edge PE detects that the physical link has failed, or the port is administratively disabled, it MUST send a PW status notification message that corresponds to the HDLC or PPP PW.

4.6. IP Layer2 Transport

This mode carries IP packets over a Pseudo-Wire. The encapsulation used is according to [RFC3032]. The PW control word MAY be inserted between the MPLS stack and the IP payload. IP interworking is implementation specific, part of the NSP function [ARCH], and is outside the scope of this document.

5. LDP

The PW label bindings are distributed using the LDP downstream unsolicited mode described in [LDP]. The PEs will establish an LDP session using the Extended Discovery mechanism described in [1, section 2.4.2 and 2.5].

An LDP Label Mapping message contains a FEC TLV, a Label TLV, and zero or more optional parameter TLVs.

The FEC TLV is used to indicate the meaning of the label. In the current context, the FEC TLV would be used to identify the particular pseudowire that a particular label is bound to. In this specification, we define two new FEC TLVs to be used for identifying pseudowires. When setting up a particular pseudowire, only one of these FEC TLVs is used. The one to be used will depend on the particular service being emulated and on the particular provisioning model being supported.

LDP allows each FEC TLV to consist of a set of FEC elements. For setting up and maintaining pseudowires, however, each FEC TLV MUST contain exactly one FEC element.

LDP has several kinds of label TLVs. For setting up and maintaining pseudowires, the Generic Label TLV MUST be used.
5.1. The PWid FEC Element

The PWid FEC element may be used whenever both pseudowire endpoints have been provisioned with the same 32-bit identifier for the pseudowire.

For this purpose a new type of FEC element is defined. The FEC element type is 128 [note1], and is defined as follows:

```
| C | PW type | PW info Length |
+-------------------------------+-----------------+-----------------+
| Group ID                      | PW ID           |
+-------------------------------+-----------------+
| Interface parameters          |
| " "                          |
+-------------------------------+
```

- **PW type**

  A 15 bit quantity containing a value which represents the type of PW. Assigned Values are specified in "IANA Allocations for pseudo Wire Edge to Edge Emulation (PWE3)" [IANA].

- **Control word bit (C)**

  The bit (C) is used to flag the presence of a control word as follows:

  \[ C = \begin{cases} 1 & \text{control word present on this PW.} \\ 0 & \text{no control word present on this PW.} \end{cases} \]

  Please see the section "C-Bit Handling Procedures" for further explanation.

- **PW information length**

  Length of the PW ID field and the interface parameters field in octets. If this value is 0, then it references all PWS using the specified group ID and there is no PW ID present, nor any interface parameters.
- **Group ID**

   An arbitrary 32 bit value which represents a group of PWs that is used to create groups in the PW space. The group ID is intended to be used as a port index, or a virtual tunnel index. To simplify configuration a particular PW ID at ingress could be part of the virtual tunnel for transport to the egress router. The Group ID is very useful to send wild card label withdrawals, or PW wild card status notification messages to remote PEs upon physical port failure.

- **PW ID**

   A non-zero 32-bit connection ID that together with the PW type, identifies a particular PW. Note that the PW ID and the PW type must be the same at both endpoints.

- **Interface parameters**

   This variable length field is used to provide interface specific parameters, such as CE-facing interface MTU.

   Note that as the "interface parameters" are part of the FEC, the rules of LDP make it impossible to change the interface parameters once the pseudowire has been set up. Thus the interface parameters field must not be used to pass information, such as status information, which may change during the life of the pseudowire. Optional parameter TLVs should be used for that purpose.

   Using the PWid FEC, each of the two pseudowire endpoints independently initiates the set up of a unidirectional LSP. An outgoing LSP and an incoming LSP are bound together into a single pseudowire if they have the same PW ID and PW type.

### 5.2. The Generalized PW ID FEC Element

The PWid FEC element can be used if a unique 32-bit value has been assigned to the PW, and if each endpoint has been provisioned with that value. The Generalized ID FEC element requires that the PW endpoints be uniquely identified; the PW itself is identified as a pair of endpoints. In addition the endpoint identifiers are structured to support applications where the identity of the remote endpoints needs to be auto-discovered rather than statically configured.

The "Generalized ID FEC Element" is FEC type 129 (provisionally,
The Generalized ID FEC Element not contain anything corresponding to the "group id" of the PWid FEC element. The functionality of the latter is provided by a separate optional LDP TLV, the "PW Grouping TLV", described below. The Interface Parameters field of the PWid FEC element is also absent; its functionality is replaced by the optional Interface Parameters TLV, described below.

5.2.1. Attachment Identifiers

As discussed in [ARCH], a pseudowire can be thought of as connecting two "forwarders". The protocol used to setup a pseudowire must allow the forwarder at one end of a pseudowire to identify the forwarder at the other end. We use the term "attachment identifier", or "AI", to refer to the field which the protocol uses to identify the forwarders. In the PWid FEC, the PWid field serves as the AI. In this section we specify a more general form of AI which is structured and of variable length.

Every Forwarder in a PE must be associated with an Attachment Identifier (AI), either through configuration or through some algorithm. The Attachment Identifier must be unique in the context of the PE router in which the Forwarder resides. The combination <PE router, AI> must be globally unique.

It is frequently convenient to regard a set of Forwarders as being members of a particular "group", where PWs may only be set up among members of a group. In such cases, it is convenient to identify the Forwarders relative to the group, so that an Attachment Identifier would consist of an Attachment Group Identifier (AGI) plus an Attachment Individual Identifier (AII).

An Attachment Group Identifier may be thought of as a VPN-id, or a VLAN identifier, some attribute which is shared by all the Attachment PWs (or pools thereof) which are allowed to be connected.

The details of how to construct the AGI and AII fields identifying the pseudowire endpoints are outside the scope of this specification. Different pseudowire application, and different provisioning models, will require different sorts of AGI and AII fields. The specification of each such application and/or model must include the rules for constructing the AGI and AII fields.

As previously discussed, a (bidirectional) pseudowire consists of a pair of unidirectional LSPs, one in each direction. If a particular pseudowire connects PE1 with PE2, the LSP in the PE1-->PE2 direction...
can be identified as:

<PE1, <AGI, AII1>, PE2, <AGI, AII2>>, 

and the LSP in the PE2--PE1 direction can be identified by:

<PE2, <AGI, AII2>, PE1, <AGI, AII1>>.

Note that the AGI must be the same at both endpoints, but the AII will in general be different at each endpoint. Thus from the perspective of a particular PE, each pseudowire has a local or "Source AII", and a remote or "Target AII". The pseudowire setup protocol can carry all three of these quantities:

- Attachment Group Identifier (AGI).
- Source Attachment Individual Identifier (SAII)
- Target Attachment Individual Identifier (TAII)

If the AGI is non-null, then the Source AI (SAI) consists of the AGI together with the SAII, and the Target AI (TAI) consists of the TAI together with the AGI. If the AGI is null, then the SAII and TAI are the SAI and TAI respectively.

The interpretation of the SAI and TAI is a local matter at the respective endpoint.

The association of two unidirectional LSPs into a single bidirectional pseudowire depends on the SAI and the TAI. Each application and/or provisioning model which uses the Generalized ID FEC element must specify the rules for performing this association.

5.2.2. Encoding the Generalized ID FEC Element

FEC element type 129 [note1] is used. The FEC element is encoded as follows:
This document does not specify the SAII, TAI, AGI type field values; specification of the type field values to use for a particular application is part of the specification of that application. IANA will assign these values based on IETF consensus.

The SAII, TAI, and AGI are all octet strings. The length byte specifies the size of the Value field. The null string can be sent by setting the length byte to 0. If a particular application does not need all three of these sub-elements, it MUST send all the sub-elements, but set the length to 0 for the unused sub-elements.

The PW information length field, contains the length of the SAII, TAI, AGI combined, and the interface parameters field in octets. If this value is 0, then it references all PWS using the specified grouping ID. In this case there are no other FEC element fields (AGI, SAII, etc.) present, nor any interface parameters.

Note that the interpretation of a particular field as AGI, SAII, or TAI depends on the order of its occurrence. The type field identifies the type of the AGI, SAII, or TAI. When comparing two occurrences of an AGI (or SAII or TAI), the two occurrences are considered to be identical if the type, length, and value fields of one are identical, respectively, to those of the other.
5.2.2.1. Interface Parameters TLV

This TLV MUST only be used when sending the Generalized PW FEC. It specifies interface specific parameters. Specific parameters, when applicable, MUST be used to validate that the PEs, and the ingress and egress ports at the edges of the circuit, have the necessary capabilities to interoperate with each other.

A more detailed description of this field can be found in the section "Interface Parameters Field" below.

5.2.2.2. PW Grouping TLV

The PW Grouping ID is an arbitrary 32 bit value which represents an arbitrary group of PWs. It is used to create groups of PWs; for example, a PW Grouping ID can be used as a port index, and assigned to all PWs that lead to that port. Use of the PW Grouping ID enables one to send "wild card" label withdrawals, or "wild card" status notification messages to remote PEs upon physical port failure.

Note Well: The PW Grouping ID is different than, and has no relation to, the Attachment Group Identifier.
The PW Grouping ID TLV is not part of the FEC, and will not be advertised except in the initial PW FEC advertisement. The advertising PE MAY use the wild card withdraw semantics, but the remote PEs MUST implement support for wildcard messages. If the PW Grouping ID is not going to be used for wild card messages, it MAY be omitted. This TLV MAY only be used when sending the Generalized PW ID FEC.

To issue a wildcard command (status or withdraw):

- Set the PW Info Length to 0 in the Generalized ID FEC Element.
- Send only the PW Grouping ID TLV with the FEC (No AGI/SAII/TAII is sent).

5.2.3. Signaling Procedures

In order for PE1 to begin signaling PE2, PE1 must know the address of the remote PE2, and a TAI. This information may have been configured at PE1, or it may have been learned dynamically via some autodiscovery procedure.

To begin the signaling procedure, a PE (PE1) that has knowledge of the other endpoint (PE2) initiates the setup of the LSP in the incoming (PE2-->PE1) direction by sending a Label Mapping message containing the FEC type 129. The FEC element includes the SAII, AGI, and TAI.

What happens when PE2 receives such a Label Mapping message?

PE2 interprets the message as a request to set up a PW whose endpoint (at PE2) is the Forwarder identified by the TAI. From the perspective of the signaling protocol, exactly how PE2 maps AIs to Forwarders is a local matter. In some VPWS provisioning models, the TAI might, e.g., be a string which identifies a particular Attachment Circuit, such as "ATM3VPI4VCI5", or it might, e.g., be a string such as "Fred" which is associated by configuration with a particular Attachment Circuit. In VPLS, the AGI could be a VPN-id, identifying a particular VPLS instance.

If PE2 cannot map the TAI to one of its Forwarders, then PE2 sends a Label Release message to PE1, with a Status Code meaning "invalid TAI", [ note: Status Code 0x00000029 as defined in [IANA] pending IANA allocation ] and the processing of the Mapping message is complete.

The FEC TLV sent in a Label Release is the same as the FEC TLV.
received in the Label Mapping being released (but without the interface parameters). More generally, the FEC TLV is the same in all LDP messages relating to the same LSP. In a Label Release this means that the SAI is the remote peer’s AII and the TAI is the sender’s local AII.

If the Label Mapping Message has a valid TAI, PE2 must decide whether to accept it or not. The procedures for so deciding will depend on the particular type of Forwarder identified by the TAI. Of course, the Label Mapping message may be rejected due to standard LDP error conditions as detailed in [LDP].

If PE2 decides to accept the Label Mapping message, then it has to make sure that an LSP is set up in the opposite (PE1-->PE2) direction. If it has already signaled for the corresponding LSP in that direction, nothing more need be done. Otherwise, it must initiate such signaling by sending a Label Mapping message to PE1. This is very similar to the Label Mapping message PE2 received, but with the SAI and TAI reversed.

Thus a bidirectional PW consists of two LSPs, where the FEC of one is the "reverse" of the FEC of the other.

5.3. Signaling of Pseudo Wire Status

5.3.1. Use of Label Mappings.

The PEs MUST send PW label mapping messages to their peers as soon as the PW is configured and administratively enabled, regardless of the CE-facing interface state. The PW label should not be withdrawn unless the user administratively configures the CE-facing interface down (or the PW configuration is deleted entirely). Using the procedures outlined in this section a simple label withdraw method MAY also be supported as a primitive means of signaling PW status. It is strongly RECOMMENDED that the PW status signaling procedures below be fully implemented. In any case if the Label mapping is not available the PW MUST be considered in the down state.

5.3.2. Signaling PW status.

The PE devices use an LDP TLV to indicate status to their remote peers. This PW Status TLV contains more information than the alternative simple Label Withdraw message.

The format of the PW Status TLV is:
Where the status code is a 4 octet bit field is specified in the PW IANA Allocations document [IANA]. The length specifies the length of the Status Code field in octets (equal to 4).

Each bit in the status code field can be set individually to indicate more than a single failure at once. Each fault can be cleared by sending an appropriate status message with the respective bit cleared. The presence of the lowest bit (PW Not Forwarding) acts only as a generic failure indication when there is a link-down event for which none of the other bits apply.

The Status TLV is transported to the remote PW peer via the LDP notification message. The general format of the Notification Message is:

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0|   Notification (0x0001)     |      Message Length           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Message ID                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Status (TLV)                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      PW Status TLV                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 PWId FEC or Generalized ID FEC                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Status TLV status code is set to 0x00000028 "PW status", to indicate that PW status follows. Since this notification does not refer to any particular message the Message Id, and Message Type fields are set to 0. [note: Status Code 0x00000028 as defined in [IANA] pending IANA allocation]

The PW FEC TLV SHOULD not include the interface parameters as they
are ignored in the context of this message. When a PE’s CE-facing interface encounters an error, use of the PW status message allows the PE to send a single "wild card" status message, using a PW FEC TLV with only the group ID set, to denote this change in status for all affected PW connections. This status message contains either the PW FEC TLV with only the group ID set, or else it contains the Generalized FEC TLV and the PW Grouping ID TLV.

As mentioned above the Group ID field of the PWid FEC element, or the PW Grouping ID TLV used with the Generalized ID FEC element, can be used to send a status notification for all arbitrary sets of PWs. This procedure is OPTIONAL, and if it is implemented the LDP Notification message should be as follows: If the PWid FEC element is used, the PW information length field is set to 0, the PW ID field is not present, and the interface parameters field is not present. If the Generalized FEC element is used, the AGI, SAI, and TAI are not present, the PW information length field is set to 0, the PW Grouping ID TLV is included, and the Interface Parameters TLV is omitted. For the purpose of this document this is called the "wild card PW status notification procedure", and all PEs implementing this design are REQUIRED to accept such a notification message, but are not required to send it.

5.3.3. Pseudowire Status Negotiation Procedures

When a PW is first set up the PEs MUST attempt to negotiate the usage of the PW status TLV. This is accomplished as follows: A PE that supports the PW Status TLV MUST include it the initial label mapping signaling following label mapping TLV, the PW FEC, and the interface parameters field. The PW Status TLV will then be used for the lifetime of the Pseudowire. This is shown in the following diagram:
If PW status TLV is sent following the label mapping TLV in the initial PW FEC Message, but the remote PE corresponding FEC advertisement does not include a PW status TLV, or the remote PE does not support the PW Status TLV and the PW will revert to the label withdraw method to signal PW status. Note that if the PW Status TLV is not supported, by the remote peer, it will automatically be ignored, since the LDP ignore bit is set. The PW Status TLV, therefore, will not be present in the corresponding FEC advertisement from the remote LDP peer resulting in exactly the above behavior.

If the PW Status TLV is not present following the label mapping TLV in the initial PW FEC Message received by a PE, then the PW Status TLV will not be used and both PEs supporting the pseudowire will revert to the label withdraw procedure for signaling status changes.

If the negotiation process results in the usage of the PW status TLV, then the actual PW status is determined by the PW status TLV that was sent within the initial PW label mapping. Subsequent updates of PW status are conveyed through the notification message.
5.4. Interface Parameters Field

This field specifies interface specific parameters. When applicable, it MUST be used to validate that the PEs, and the ingress and egress ports at the edges of the circuit, have the necessary capabilities to interoperate with each other. The field structure is defined as follows:

```
+------------------------------------------------------+
| Parameter ID | Length | Variable Length Value |
+------------------------------------------------------+
| Variable Length Value |
+------------------------------------------------------+
```

The parameter ID Values are specified in "IANA Allocations for pseudo Wire Edge to Edge Emulation (PWE3)" [IANA].

The Length field is defined as the length of the interface parameter including the parameter id and length field itself. Processing of the interface parameters should continue when encountering unknown interface parameters and they MUST be silently ignored.

- Interface MTU

A 2 octet value indicating the MTU in octets. This is the Maximum Transmission Unit, excluding encapsulation overhead, of the egress packet interface that will be transmitting the decapsulated PDU that is received from the MPLS network. This parameter is applicable only to PW types 1, 2, 4, 5, 6, 7, 14, and 15 and is REQUIRED for these PW types. If this parameter does not match in both directions of a specific PW, that PW MUST NOT be enabled.

- Maximum Number of concatenated ATM cells

A 2 octet value specifying the maximum number of concatenated ATM cells that can be processed as a single PDU by the egress PE. An ingress PE transmitting concatenated cells on this PW can concatenate a number of cells up to the value of this parameter, but MUST NOT exceed it. This parameter is applicable only to PW types 3, 9, 0x0a, 0xc, and 0xd and is REQUIRED for these PWC types. This parameter does not need to match in both directions of a specific PW.
- Optional Interface Description string

This arbitrary, OPTIONAL, interface description string is used to send a human-readable administrative string describing the interface to the remote. This parameter is OPTIONAL, and is applicable to all PW types. The interface description parameter string length is variable, and can be from 0 to 80 octets. Human-readable text MUST be provided in the UTF-8 charset using the Default Language [RFC2277].

- Payload Bytes

A 2 octet value indicating the number of TDM payload octets contained in all packets on the CEM stream, from 48 to 1,023 octets. All of the packets in a given CEM stream have the same number of payload bytes. Note that there is a possibility that the packet size may exceed the SPE size in the case of an STS-1 SPE, which could cause two pointers to be needed in the CEM header, since the payload may contain two J1 bytes for consecutive SPEs. For this reason, the number of payload bytes must be less than or equal to 783 for STS-1 SPEs.

- CEP Options.

An optional 16 Bit value of CEM Flags. See [8] for the definition of the bit values.

- Requested VLAN ID.

An Optional 16 bit value indicating the requested VLAN ID. This parameter MUST be used by a PE that is incapable of rewriting the 802.1q ethernet VLAN tag on output. If the ingress PE receives this request, it MUST rewrite the VLAN ID tag at the input to match the requested VLAN ID. If this is not possible, and the VLAN ID does not already match the configured ingress VLAN ID, the PW MUST not be enabled. This parameter is applicable only to PW type 4.

- CEP/TDM bit rate.

This 32-bit integer is mandatory for CEP. For other PWs carrying TDM traffic it is mandatory if the bit-rate cannot be directly inferred from the service type. If present, it expresses the bit rate of the attachment circuit as known to the advertizing PE in "units" of 64 kbit/s. I.e., the value 26 must be used for CEP carrying VT1.5 SPE, 35 - for CEP carrying a VT2 SPE, 107 - for VT6 SPE, 783 - for STS-1 SPE and n*783 - for STS-nc, n = 3, 12, 48, 192. Attempts to establish a PWC between a pair of TDM ports...
with different bit-rates MUST be rejected with the appropriate
status code (see section "Status codes" in [IANA]).

- Frame-Relay DLCI length.

An optional 16 bit value indicating the length of the frame-relay
DLCI field. This OPTIONAL interface parameter can have value of 2
or 4, with the default being equal to 2. If this interface
parameter is not present the default value of 2 is assumed.

6. Control Word

6.1. PW types for which the control word is REQUIRED

The Label Mapping messages which are sent in order to set up these
PWs MUST have c=1. When a Label Mapping message for a PW of one of
these types is received, and c=0, a Label Release MUST be sent, with
an "Illegal C-bit" status code. In this case, the PW will not be
enabled.

6.2. PW types for which the control word is NOT mandatory

If a system is capable of sending and receiving the control word on
PW types for which the control word is not mandatory, then each such
PW endpoint MUST be configurable with a parameter that specifies
whether the use of the control word is PREFERRED or NOT PREFERRED.
For each PW, there MUST be a default value of this parameter. This
specification does NOT state what the default value should be.

If a system is NOT capable of sending and receiving the control word
on PW types for which the control word is not mandatory, then it
behaves exactly as if it were configured for the use of the control
word to be NOT PREFERRED.

If a Label Mapping message for the PW has already been received, but
no Label Mapping message for the PW has yet been sent, then the
procedure is the following:

- i. If the received Label Mapping message has c=0, send a Label
  Mapping message with c=0, and the control word is not used.
- ii. If the received Label Mapping message has c=1, and the PW is
     locally configured such that the use of the control word is
     preferred, then send a Label Mapping message with c=1, and
     the control word is used.
-iii. If the received Label Mapping message has c=1, and the PW is locally configured such that the use of the control word is not preferred or the control word is not supported, then act as if no Label Mapping message for the PW had been received (i.e., proceed to the next paragraph).

If a Label Mapping message for the PW has not already been received (or if the received Label Mapping message had c=1 and either local configuration says that the use of the control word is not preferred or the control word is not supported), then send a Label Mapping message in which the c bit is set to correspond to the locally configured preference for use of the control word. (I.e., set c=1 if locally configured to prefer the control word, set c=0 if locally configured to prefer not to use the control word or if the control word is not supported).

The next action depends on what control message is next received for that PW. The possibilities are:

- i. A Label Mapping message with the same c bit value as specified in the Label Mapping message that was sent. PW setup is now complete, and the control word is used if c=1 but not used if c=0.
- ii. A Label Mapping message with c=1, but the Label Mapping message that was sent has c=0. In this case, ignore the received Label Mapping message, and continue to wait for the next control message for the PW.
- iii. A Label Mapping message with c=0, but the Label Mapping message that was sent has c=1. In this case, send a Label Withdraw message with a "Wrong C-bit" status code, followed by a Label Mapping message that has c=0. PW setup is now complete, and the control word is not used.
- iv. A Label Withdraw message with the "Wrong c-bit" status code. Treat as a normal Label Withdraw, but do not respond. Continue to wait for the next control message for the PW.

If at any time after a Label Mapping message has been received, a corresponding Label Withdraw or Release is received, the action taken is the same as for any Label Withdraw or Release that might be received at any time.

If both endpoints prefer the use of the control word, this procedure will cause it to be used. If either endpoint prefers not to use the control word, or does not support the control word, this procedure will cause it not to be used. If one endpoint prefers to use the control word but the other does not, the one that prefers not to use it is has no extra protocol to execute, it just waits for a Label Mapping message that has c=0.
The diagram in Appendix A illustrates the above procedure.

6.3. LDP label Withdrawal procedures

As mentioned above the Group ID field of the PWid FEC element, or the PW Grouping ID TLV used with the Generalized ID FEC element, can be used to withdraw all PW labels associated with a particular PW group. This procedure is OPTIONAL, and if it is implemented the LDP label withdrawal message should be as follows: If the PWid FEC element is used, the PW information length field is set to 0, the PW ID field is not present, and the interface parameters field is not present. If the Generalized FEC element is used, the AGI, SAII, and TAIi are not present, the PW information length field is set to 0, the PW Grouping ID TLV is included, and the Interface Parameters TLV is omitted. For the purpose of this document this is called the "wild card withdraw procedure", and all PEs implementing this design are REQUIRED to accept such withdrawn message, but are not required to send it. Note that the PW Grouping ID TLV only applies to PW using the Generalized ID FEC element, while the Group ID only applies to PWid FEC element.

The interface parameters field, or TLV, MUST NOT be present in any LDP PW label withdrawal message or release message. A wildcard release message MUST include only the group ID, or Grouping ID TLV. A Label Release message initiated from the imposition router must always include the PW ID.

6.4. Sequencing Considerations

In the case where the router considers the sequence number field in the control word, it is important to note the following when advertising labels

6.4.1. Label Mapping Advertisements

After a label has been withdrawn by the disposition router and/or released by the imposition router, care must be taken to not advertise (re-use) the same released label until the disposition router can be reasonably certain that old packets containing the released label no longer persist in the MPLS network.

This precaution is required to prevent the imposition router from restarting packet forwarding with sequence number of 1 when it receives the same label mapping if there are still older packets persisting in the network with sequence number between 1 and 32768. For example, if there is a packet with sequence number=n where n is
in the interval [1,32768] traveling through the network, it would be possible for the disposition router to receive that packet after it re-advertises the label. Since the label has been released by the imposition router, the disposition router SHOULD be expecting the next packet to arrive with sequence number to be 1. Receipt of a packet with sequence number equal to $n$ will result in $n$ packets potentially being rejected by the disposition router until the imposition router imposes a sequence number of $n+1$ into a packet. Possible methods to avoid this is for the disposition router to always advertise a different PW label, or for the disposition router to wait for a sufficient time before attempting to re-advertised a recently released label. This is only an issue when sequence number processing at the disposition router is enabled.

6.4.2. Label Mapping Release

In situations where the imposition router wants to restart forwarding of packets with sequence number 1, the router shall 1) Send to disposition router a label mapping release, and 2) Send to disposition router a label mapping request. When sequencing is supported, advertisement of a PW label in response to a label mapping request MUST also consider the issues discussed in the section on Label Mapping Advertisements.

7. IANA Considerations

7.1. LDP TLV TYPE

This document uses several new LDP TLV types, IANA already maintains a registry of name "TLV TYPE NAME SPACE" defined by RFC3036. The following values are suggested for assignment:

<table>
<thead>
<tr>
<th>TLV type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x096A</td>
<td>PW Status TLV</td>
</tr>
<tr>
<td>0x096B</td>
<td>PW Interface Parameters TLV</td>
</tr>
<tr>
<td>0x096C</td>
<td>Group ID TLV</td>
</tr>
</tbody>
</table>

7.2. LDP status messages

This document uses several new LDP status codes, IANA already maintains a registry of name "STATUS CODE NAME SPACE" defined by RFC3036. The following values are suggested for assignment:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00000024</td>
<td>&quot;Illegal C-Bit&quot;</td>
</tr>
<tr>
<td>0x00000025</td>
<td>&quot;Wrong C-Bit&quot;</td>
</tr>
</tbody>
</table>
7.3. FEC Type Name Space

This document uses two new FEC element types, 128 and 129. IANA already maintains a registry of values of the "FEC Type Name Space" for the Label Distribution Protocol (LDP RFC3036). In that registry, values in the range 128-191 are assignable on a First Come, First Served basis. IANA should assign values 128 and 129 as specified in this document.

7.4. Pseudowire Type

IANA needs to set up a registry of "Pseudowire Type". These are 15-bit values. PW Type values 1 through 63 are to be assigned by IANA using the "IETF Consensus" policy defined in RFC2434. PW Type values 64 through 127 are to be assigned by IANA, using the "First Come First Served" policy defined in RFC2434. VC Type values 128 through 32767 are vendor-specific, and values in this range are not to be assigned by IANA. A Pseudowire Type description of up to 65 characters is required for any assignment from this registry.

Initial PW type value allocations are specified in "IANA Allocations for pseudo Wire Edge to Edge Emulation (PWE3)" [IANA], and should be incorporated by IANA into the registry.

7.5. Interface Parameters

IANA needs to set up a registry of "Pseudowire Interface Parameter Identifiers". Parameter ID values 1 through 63 are to be assigned by IANA using the "IETF Consensus" policy defined in RFC2434. Parameter ID values 64 through 127 are to be assigned by IANA, using the "First Come First Served" policy defined in RFC2434. Parameter ID values 128 through 255 are vendor-specific, and values in this range are not to be assigned by IANA. Any assignments requested from this registry require a description up to 54 characters. Furthermore a length specified as follows:
7.6. Pseudowire Status Codes

IANA needs to set up a registry of "Pseudowire Status Codes". These are bitstrings of length 32. Status bits 1-15 are to be assigned by IANA using the "IETF Consensus" policy defined in RFC2434. Initial bit allocations are specified in "IANA Allocations for pseudo Wire Edge to Edge Emulation (PWE3)" [IANA], and should be incorporated by IANA into the registry. PW Status Bits 16 through 23 are to be assigned by IANA, using the "First Come First Served" policy defined in RFC2434. PW Status Bits 24 through 31 are vendor-specific, and values in this range are not to be assigned by IANA. Any requests for allocation from this registry must include a 65 character description. Initial Pseudowire Status Codes value allocations are specified in "IANA Allocations for pseudo Wire Edge to Edge Emulation (PWE3)" [IANA], and should be incorporated by IANA into the registry.

8. Security Considerations

This document specifies the LDP extensions that are needed for setting up and maintaining Pseudowires. The purpose of setting up Pseudowires is to enable layer 2 frames to be encapsulated in MPLS [8,9,10,11] and transmitted from one end of a Pseudowire to the other. Therefore we treat the security considerations for both the data plane and the control plane.
8.1. Data-plane Security

With regard to the security of the data plane, the following areas must be considered:

- MPLS PDU inspection.
- MPLS PDU spoofing.
- MPLS PDU alteration.
- MPLS PSN protocol security.
- Access Circuit security.
- Denial of service prevention on the PE routers.

When a MPLS PSN is used to provide pseudowire service, there is a perception that security MUST be at least equal to the currently deployed layer2 native protocol networks that the MPLS/PW network combination is emulating. This means that the MPLS network SHOULD be isolated from outside packet insertion in such a way that it SHOULD not be possible to directly insert an MPLS packet into the network. To prevent unwanted packet insertion, it is also important to prevent unauthorized physical access to the PSN as well as unauthorized administrative access to individual network elements. The PSN transporting the PWs is an MPLS backbone, it should not accept MPLS packets from its external interfaces (i.e. interfaces to CE devices or to other providers’ networks) unless the top label of the packet was legitimately distributed to the system from which the packet is being received. If the packet’s incoming interface leads to a different SP (rather than to a customer), an appropriate trust relationship must also be present, including the trust that the other SP also provides appropriate security measures.

The three main security problem faced when using an MPLS network to transport PWs are spoofing, alteration, and inspection. First there is a possibility that the PW receive endpoint will get a PDU which appears to be from the PE encapsulating the PW into the PSN, but which was not actually transmitted by the PE originating the PW. (I.e., the specified encapsulations do not by themselves enable the decapsulator to authenticate the encapsulator.) A second problem is the possibility that the PW PDU will be altered between the time it enters PSN and the time it leaves the PSN. (I.e., the specified encapsulations do not by themselves assure the decapsulator of the packet’s integrity.) A third problem is the possibility that the PDU’s contents will be seen while the PDU is in transit through the PSN. (I.e., the specification encapsulations do not ensure privacy.) How significant these issues are in practice depends on the security requirements of the applications whose traffic is being sent through the tunnel, and how secure is the PSN itself. E.g. if the PSN is an MPLS backbone, with no external MPLS interfaces, then it might be secured enough to transport PW PDUs.
8.2. Control Protocol Security

General security considerations with regard to the use of LDP are specified in section 5 of RFC 3036. Those considerations apply as well to the case where LDP is used to set up Pseudowires.

A Pseudowire connects two attachment circuits. It is important to make sure that LDP connections are not arbitrarily accepted from anywhere, or else a local attachment circuit might get connected to an arbitrary remote attachment circuit. Therefore an incoming LDP session request MUST NOT be accepted unless its IP source address is known to be the source of an "eligible" LDP peer. The set of eligible peers could be pre-configured (either as a list of IP addresses, or as a list of address/mask combinations), or it could be discovered dynamically via an auto-discovery protocol which is itself trusted. (Obviously if the auto-discovery protocol were not trusted, the set of "eligible peers" it produces could not be trusted.)

Even if an LDP connection request appears to come from an eligible peer, its source address may have been spoofed. So some means of preventing source address spoofing must be in place. For example, if all the eligible peers are in the same network, source address filtering at the border routers of that network could eliminate the possibility of source address spoofing.

For a greater degree of security, the LDP MD5 authentication key option, as described in section 2.9 of RFC 3036, MAY be used. This provides integrity and authentication for the LDP messages, and eliminates the possibility of source address spoofing. Use of the MD5 option does not provide privacy, but privacy of the LDP control messages is not usually considered to be important. As the MD5 option relies on the configuration of pre-shared keys, it does not provide much protection against replay attacks. In addition, its reliance on pre-shared keys may make it very difficult to deploy when the set of eligible neighbors is determined by an auto-configuration protocol.

When the Generalized ID FEC Element is used, it is possible that a particular LDP peer may be one of the eligible LDP peers, but may not be the right one to connect to the particular attachment circuit identified by the particular instance of the Generalized ID FEC element. However, given that the peer is known to be one of the eligible peers (as discussed above), this would be the result of a configuration error, rather than a security problem. Nevertheless, it may be advisable for a PE to associate each of its local attachment circuits with a set of eligible peers, rather than having just a single set of eligible peers associated with the PE as a whole.
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11. Acknowledgments

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12. Normative References


[CEP] "SONET/SDH Circuit Emulation Service Over Packet (CEP)", draft-ietf-pwe3-sonet-09.txt (work in progress)

[SAToP] "Structure-Agnostic TDM over Packet (SAToP)", draft-ietf-pwe3-satop-01.txt (work in progress)


[ATM] "Encapsulation Methods for Transport of ATM Cells/Frame Over IP and MPLS Networks", draft-ietf-pwe3-atm-encap-05.txt (work in progress)

[PPPHDLC] "Encapsulation Methods for Transport of PPP/HDLC Frames Over IP and MPLS Networks", draft-ietf-pwe3-hdlc-ppp-encap-05.txt (work in progress)


[IANA] "IANA Allocations forpseudo Wire Edge to Edge Emulation (PWE3)" Martini,Townsley, draft-ietf-pwe3-iana-allocation-08.txt (work in progress), April 2004
13. Informative References


[ARCH] "PWE3 Architecture" Bryant, et al.,
draft-ietf-pwe3-arch-07.txt (work in progress), March 2004


[Note1] FEC element type 128,129 is pending IANA approval.

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Ap A C-bit Handling Procedures Diagram

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+-----------------------------+
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<th>Y</th>
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</thead>
<tbody>
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<td>Mapping Msg?</td>
<td>----</td>
</tr>
</tbody>
</table>
+-----------------------------+

| C=0 | C=1 |
---------------------

<table>
<thead>
<tr>
<th>Control Word</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capable?</td>
<td>----</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control Word</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred?</td>
<td>----</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control Word</th>
<th>N</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preferred?</td>
<td>----</td>
<td>----</td>
</tr>
</tbody>
</table>

Send C=0  Send C=1  Send C=0  Send C=0  Send C=1

If receive the same as sent, PW setup is complete. If not:

Receive C=1  Receive C=0

Wait for the next message  Send Wrong C-Bit

Send Label  Mapping Message
```