                        LDP Extensions for Pseudowire
                Binding to Label Switched Path (LSP) Tunnels

Abstract

   Many transport services require that user traffic, in the form of
   Pseudowires (PWs), be delivered via either a single co-routed
   bidirectional tunnel or two unidirectional tunnels that share the
   same routes. This document defines an optional extension to the
   Label Distribution Protocol (LDP) that enables the binding between
   PWs and the underlying Traffic Engineering (TE) tunnels. The
   extension applies to both single-segment and multi-segment PWs.

Status of This Memo

   This is an Internet Standards Track document.

   This document is a product of the Internet Engineering Task Force
   (IETF). It represents the consensus of the IETF community. It has
   received public review and has been approved for publication by the
   Internet Engineering Steering Group (IESG). Further information on
   Internet Standards is available in Section 2 of RFC 7841.

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1. Introduction

   Pseudo Wire Emulation Edge-to-Edge (PWE3) [RFC3985] is a mechanism to
   emulate Layer 2 services, such as Ethernet Point-to-Point circuits.
   Such services are emulated between two Attachment Circuits, and the
   Pseudowire-encapsulated Layer 2 service payload is transported via
   Packet Switching Network (PSN) tunnels between Provider Edges (PEs).
   PWE3 typically uses the Label Distribution Protocol (LDP) [RFC5036]
   or Resource Reservation Protocol - Traffic Engineering (RSVP-TE)
   [RFC3209] Label Switched Paths (LSPs) as PSN tunnels. The PEs select
   and bind the Pseudowires to PSN tunnels independently. Today, there
   is no standardized protocol-based provisioning mechanism to associate
   PWs with PSN tunnels; such associations must be managed via
   provisioning or other private methods.

   PW-to-PSN Tunnel Binding has become increasingly common and important
   in many deployment scenarios, as it allows service providers to offer
   service level agreements to their customers for such traffic
   attributes as bandwidth, latency, and availability.

   The requirements for explicit control of PW-to-LSP mapping are
   described in Section 5.3.2 of [RFC6373]. Figure 1 illustrates how
   PWs can be bound to particular LSPs.

```
                    +------+                    +------+
      ---AC1 ---|..............PWs...............|---AC1---
      ---...----|  PE1  |======LSPs======|  PE2  |---...--
      ---ACn ---|       |-------Links------|       |---ACn---
                    +------+                    +------+
```
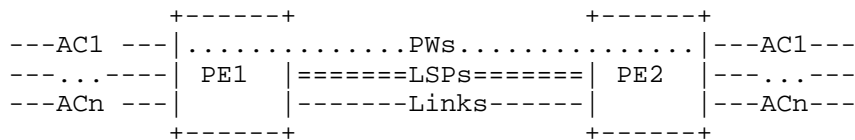
                Figure 1: Explicit PW-to-LSP Binding Scenario

   There are two PEs (PE1 and PE2) connected through multiple parallel
   links that may be on different physical fibers. Each link is managed
   and controlled as a bidirectional LSP. At each PE, there are a large
   number of bidirectional user flows from multiple Ethernet interfaces
   (access circuits in the figure). Each user flow utilizes a pair of
   unidirectional PWs to carry bidirectional traffic. The operators
   need to make sure that the user flows (that is, the PW-pairs) are
   carried on the same fiber or bidirectional LSP.

   There are a number of reasons behind this requirement. First, due to
   delay and latency constraints, traffic going over different fibers
   may require a large amount of expensive buffer memory to compensate
   for the differential delay at the head-end nodes. Further, the
   operators may apply different protection mechanisms on different
   parts of the network (e.g., to deploy 1:1 protection in one part and
   1+1 protection in other parts). As such, operators may prefer to

   have a user's traffic traverse the same fiber. That implies that
   both forwarding and reserve direction PWs that belong to the same
   user flow need to be mapped to the same co-routed bidirectional LSP
   or two LSPs with the same route.

   Figure 2 illustrates a scenario where PW-LSP binding is not applied.

```
                    +----+    +--+ LSP1 +--+    +----+
      +-----+        | PE1|===|P1|======|P2|===| PE2|    +-----+
      |     |----|   |    |   +--+       +--+   |    |----|     |
      | CE1 |    |   |............PW................|    | CE2 |
      |     |----|   |    |   +--+              |    |----|     |
      +-----+    |   |    |======|P3|==========|    |    +-----+
                     +----+      +--+ LSP2     +----+
```
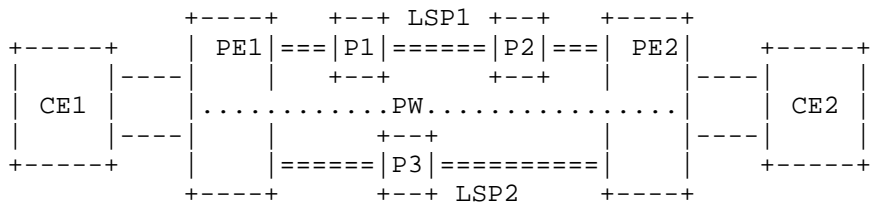
                 Figure 2: Inconsistent SS-PW-to-LSP Binding Scenario

   LSP1 and LSP2 are two bidirectional connections on diverse paths.
   The operator needs to deliver a bidirectional flow between PE1 and
   PE2. Using existing mechanisms, it's possible that PE1 may select
   LSP1 (PE1-P1-P2-PE2) as the PSN tunnel for traffic from PE1 to PE2,
   while selecting LSP2 (PE2-P3-PE1) as the PSN tunnel for traffic from
   PE2 to PE1.

   Consequently, the user traffic is delivered over two disjointed LSPs
   that may have very different service attributes in terms of latency
   and protection. This may not be acceptable as a reliable and
   effective transport service to the customer.

   A similar problem may also exist in multi-segment PWs (MS-PWs), where
   user traffic on a particular PW may hop over different networks in
   forward and reverse directions.

   One way to solve this problem is by introducing manual provisioning
   at each PE to bind the PWs to the underlying PSN tunnels. However,
   this is prone to configuration errors and does not scale.

   This document introduces an automatic solution by extending
   Forwarding Equivalence Class (FEC) 128/129 PW based on [RFC4447].

2. Requirements Language

   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 [RFC2119].

3. LDP Extensions

   This document defines a new optional TLV, the PSN Tunnel Binding TLV,
   to communicate tunnel/LSP selection and binding requests between PEs.
   The TLV carries a PW's binding profile and provides explicit or
   implicit information for the underlying PSN Tunnel Binding operation.

   The binding operation applies in both single-segment (SS) and multi-
   segment (MS) scenarios.

   The extension supports two types of binding requests:

   1. Strict binding: The requesting PE will choose and explicitly
       indicate the LSP information in the requests; the receiving PE
       MUST obey the requests; otherwise, the PW will not be
       established.

   2. Co-routed binding: The requesting PE will suggest an underlying
       LSP to a remote PE. Upon receipt, the remote PE has the option
       to use the suggested LSP or reply to the information for an
       alternative.

   In this document, the term "tunnel" is identical to the "TE Tunnel"
   defined in Section 2.1 of [RFC3209], which is uniquely identified by
   a SESSION object that includes the Tunnel endpoint address, the
   Tunnel ID, and the Extended Tunnel ID. The term "LSP" is identical
   to the "LSP tunnel" defined in Section 2.1 of [RFC3209], which is
   uniquely identified by the SESSION object together with the
   SENDER_TEMPLATE (or FILTER_SPEC) object that consists of the LSP ID
   and the Tunnel endpoint address.

3.1. PSN Tunnel Binding TLV

   The PSN Tunnel Binding TLV is an optional TLV and MUST be carried in
   the LDP Label Mapping message [RFC5036] if PW-to-LSP binding is
   required. The format is as follows:

```
    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 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |U|F| PSN Tunnel Binding(0x0973)|            Length             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |C|S|T|    Unallocated flags    |            Reserved           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                      PSN Tunnel Sub-TLV                       ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
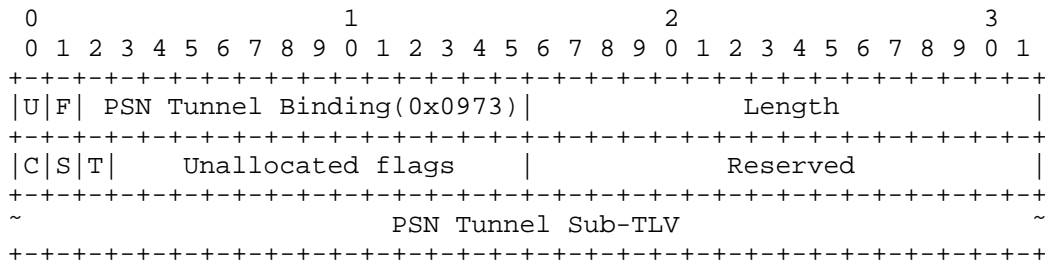
                   Figure 3: PSN Tunnel Binding TLV

The U-bit and F-bit are defined in Section 3.3 [RFC5036]. Since the
PSN Tunnel Binding TLV is an optional TLV, the U-bit MUST be set to 1
so that a receiver MUST silently ignore this TLV if unknown to it,
and continue processing the rest of the message.

A receiver of this TLV is not allowed to forward the TLV further when
it does not know the TLV. So, the F-bit MUST be set to 0.

The PSN Tunnel Binding TLV type is 0x0973.

The Length field is 2 octets long. It defines the length in octets
of the value field (including Flags, Reserved, and sub-TLV fields).

The Flags field is 2 octets in length and three flags are defined in
this document. The rest of the unallocated flags MUST be set to zero
when sending and MUST be ignored when received.

   C (Co-routed path) bit: This bit informs the remote T-PE/S-PEs
   about the properties of the underlying LSPs. When set, the remote
   T-PE/S-PEs SHOULD select the co-routed LSP (as the forwarding
   tunnel) as the reverse PSN tunnel. If there is no such tunnel
   available, it may trigger the remote T-PE/S-PEs to establish a new
   LSP.

   S (Strict) bit: This bit instructs the PEs with respect to the
   handling of the underlying LSPs. When set, the remote PE MUST use
   the tunnel/LSP specified in the PSN Tunnel Sub-TLV as the PSN
   tunnel on the reverse direction of the PW, or the PW will fail to
   be established.

      Either the C-bit or the S-bit MUST be set. The C-bit and S-bit
      are mutually exclusive from each other, and they cannot be set
      in the same message. If a status code set to "both C-bit and
      S-bit are set" or "both C-bit and S-bit are clear" is received,
      a Label Release message with the status code set to "The C-bit
      or S-bit unknown" (0x0000003C) MUST be the reply, and the PW
      will not be established.

   T (Tunnel Representation) bit: This bit indicates the format of
   the LSP tunnels. When the bit is set, the tunnel uses the tunnel
   information to identify itself, and the LSP Number fields in the
   PSN Tunnel sub-TLV (Section 3.1.1) MUST be set to zero.
   Otherwise, both the tunnel and LSP information of the PSN tunnel
   are required. The default is set. The motivation for the T-bit
   is to support the MPLS protection operation where the LSP Number
   fields may be ignored.

The Reserved field is 2 octets in length and is left for future use.

3.1.1. PSN Tunnel Sub-TLV

   PSN Tunnel Sub-TLVs are designed for inclusion in the PSN Tunnel
   Binding TLV to specify the tunnel/LSPs to which a PW is required to
   bind.

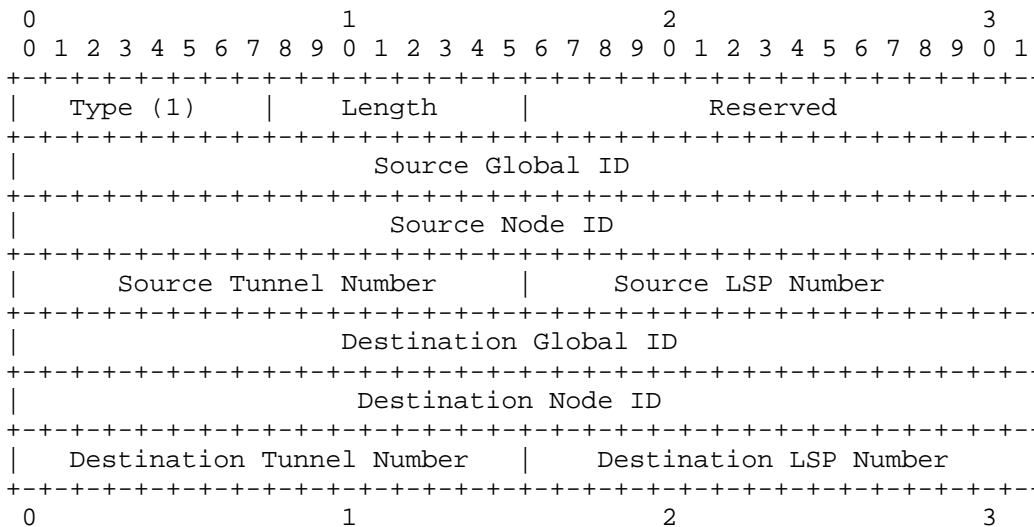   Two sub-TLVs are defined: The IPv4 and IPv6 Tunnel sub-TLVs.

```
    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 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Type (1)    |    Length     |            Reserved           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       Source Global ID                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        Source Node ID                         |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Source Tunnel Number     |      Source LSP Number        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Destination Global ID                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                      Destination Node ID                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Destination Tunnel Number   |    Destination LSP Number     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    0                   1                   2                   3
```

                Figure 4: IPv4 PSN Tunnel Sub-TLV Format

```
    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 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Type (2)    |    Length     |            Reserved           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                       Source Global ID                        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                        Source Node ID                         ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Source Tunnel Number     |      Source LSP Number        |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                     Destination Global ID                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                      Destination Node ID                      ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |   Destination Tunnel Number   |    Destination LSP Number     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
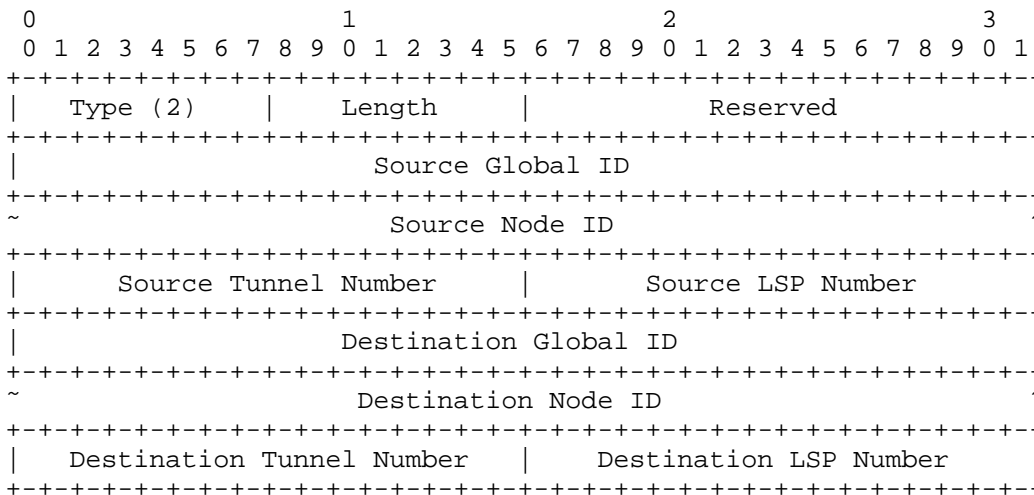
                Figure 5: IPv6 PSN Tunnel Sub-TLV Format

The definition of the Source and Destination Global/Node IDs and
Tunnel/LSP Numbers are derived from [RFC6370]. This describes the
underlying LSPs. Note that the LSPs in this notation are globally
unique. The ITU-T style identifiers [RFC6923] are not used in this
document.

As defined in Sections 4.6.1.1 and 4.6.1.2 of [RFC3209], the "Tunnel
endpoint address" is mapped to the Destination Node ID, and the
"Extended Tunnel ID" is mapped to the Source Node ID. Both IDs can
be either IPv4 or IPv6 addresses. The Node IDs are routable
addresses of the ingress LSR and egress LSR of the Tunnel/LSP.

A PSN Tunnel sub-TLV could be used to identify either a tunnel or a
specific LSP. The T-bit in the Flags field defines the distinction
as such that, when the T-bit is set, the Source/Destination LSP
Number fields MUST be zero and ignored during processing. Otherwise,
both Source/Destination LSP Number fields MUST have the actual LSP
IDs of specific LSPs.

Each PSN Tunnel Binding TLV MUST only have one such sub-TLV. When
sending, only one sub-TLV MUST be carried. When received, if there
are more than one sub-TLVs carried, only the first sub-TLV MUST be
used, the rest of the sub-TLVs MUST be ignored.

4. Theory of Operation

   During PW setup, the PEs may choose to select the desired forwarding
   tunnels/LSPs and inform the remote T-PE/S-PEs about the desired
   reverse tunnels/LSPs.

   Specifically, to set up a PW (or PW Segment), a PE may select a
   candidate tunnel/LSP to act as the PSN tunnel. If no candidate is
   available or none satisfy the constraints, the PE will trigger and
   establish a new tunnel/LSP. The selected tunnel/LSP information is
   carried in the PSN Tunnel Binding TLV and sent with the Label Mapping
   message to the target PE.

   Upon the reception of the Label Mapping message, the receiving PE
   will process the PSN Tunnel Binding TLV, determine whether it can
   accept the suggested tunnel/LSP or to find the reverse tunnel/LSP
   that meets the request, and respond with a Label Mapping message,
   which contains the corresponding PSN Tunnel Binding TLV.

   It is possible that two PEs request PSN Binding to the same PW or PW
   segment over different tunnels/LSPs at the same time. This may cause
   collisions of tunnel/LSPs selection as both PEs assume the active
   role.

As defined in (Section 7.2.1, [RFC6073]), each PE may be categorized
into active and passive roles:

1. Active PE: The PE that initiates the selection of the tunnel/LSPs
    and informs the remote PE;

2. Passive PE: The PE that obeys the active PE's suggestion.

In the rest of this document, we will elaborate upon the operation
for SS-PW and MS-PW:

1. SS-PW: In this scenario, both PEs for a particular PW may assume
    the active roles.

2. MS-PW: One PE is active, while the other is passive. The PWs are
    set up using FEC 129.

5. PSN Binding Operation for SS-PW

As illustrated in Figure 6, both PEs (e.g., PE1 and PE2) of a PW may
independently initiate the setup. To perform PSN Binding, the Label
Mapping messages MUST carry a PSN Tunnel Binding TLV, and the PSN
Tunnel sub-TLV MUST contain the desired tunnel/LSPs of the sender.

```
                    +----+           LSP1         +----+
       +-----+      | PE1|===================| PE2|     +-----+
       |     |----  |    |                   |    |----  |     |
       | CE1 |      |    |............PW..............|  | CE2 |
       |     |----  |    |                   |    |----  |     |
       +-----+      |    |===================|    |     +-----+
                    +----+           LSP2         +----+
```
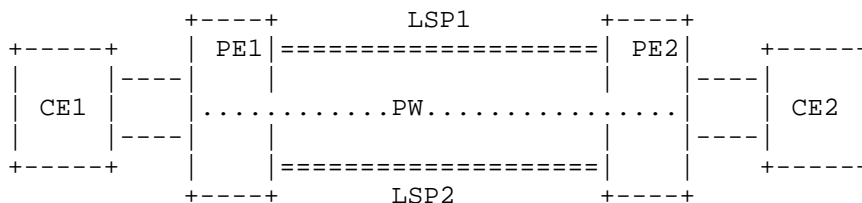
            Figure 6: PSN Binding Operation in SS-PW Environment

As outlined previously, there are two types of binding requests:
co-routed and strict.

In strict binding, a PE (e.g., PE1) will mandate that the other PE
(e.g., PE2) use a specified tunnel/LSP (e.g., LSP1) as the PSN tunnel
on the reverse direction. In the PSN Tunnel Binding TLV, the S-bit
MUST be set, the C-bit MUST be cleared, and the Source and
Destination IDs/Numbers MUST be filled.

Upon receipt, if the S-bit is set, as well as following the
processing procedure defined in Section 5.3.3 of [RFC4447], the
receiving PE (i.e., PE2) needs to determine whether to accept the
indicated tunnel/LSP in PSN Tunnel Sub-TLV.

The receiving PE (PE2) may also be an active PE, and it may have
initiated the PSN Binding requests to the other PE (PE1); if the
received PSN tunnel/LSP is the same as was sent in the Label Mapping
message by PE2, then the signaling has converged on a mutually agreed
upon Tunnel/LSP. The binding operation is completed.

Otherwise, the receiving PE (PE2) MUST compare its own Node ID
against the received Source Node ID as unsigned integers. If the
received Source Node ID is larger, the PE (PE2) will reply with a
Label Mapping message to complete the PW setup and confirm the
binding request. The PSN Tunnel Binding TLV in the message MUST
contain the same Source and Destination IDs/Numbers as in the
received binding request, in the appropriate order (where the source
is PE2 and PE1 becomes the destination). On the other hand, if the
receiving PE (PE2) has a Node ID that is larger than the Source Node
ID carried in the PSN Tunnel Binding TLV, it MUST reply with a Label
Release message with the status code set to "Reject - unable to use
the suggested tunnel/LSPs", and the received PSN Tunnel Binding TLV,
and the PW will not be established.

To support co-routed binding, the receiving PE can select the
appropriate PSN tunnel/LSP for the reverse direction of the PW, so
long as the forwarding and reverse PSNs share the same route (links
and nodes).

Initially, a PE (PE1) sends a Label Mapping message to the remote PE
(PE2) with the PSN Tunnel Binding TLV, with C-bit set, S-bit cleared,
and the appropriate Source and Destination IDs/Numbers. In case of
unidirectional LSPs, the PSN Tunnel Binding TLV may only contain the
Source IDs/Numbers; the Destination IDs/Numbers are set to zero and
left for PE2 to complete when responding to the Label Mapping
message.

Upon receipt, since PE2 is also an active PE, and may have initiated
the PSN Binding requests to the other PE (PE1), if the received PSN
tunnel/LSP has the same route as the one that has been sent in the
Label Mapping message to PE1, then the signaling has converged. The
binding operation is completed.

Otherwise, PE2 needs to compare its own Node ID against the received
Source Node ID as unsigned integers. If the received Source Node ID
is larger, PE2 needs to find/establish a tunnel/LSP that meets the
co-routed constraint, and reply with a Label Mapping message that has
a PSN Binding TLV that contains the Source and Destination IDs/
Numbers of the tunnel/LSP. On the other hand, if the receiving PE
(PE2) has a Node ID that is larger than the Source Node ID carried in
the PSN Tunnel Binding TLV, it MUST reply with a Label Release
message that has a status code set to "Reject - unable to use the

suggested tunnel/LSPs" (0x0000003B) and the received PSN Tunnel
Binding TLV.

In addition, if the received PSN tunnel/LSP endpoints do not match
the PW endpoints, PE2 MUST reply with a Label Release message with
the status code set to "Reject - unable to use the suggested
tunnel/LSPs" (0x0000003B) and the received PSN Tunnel Binding TLV
MUST also be carried.

In both strict and co-routed bindings, if the T-bit is set, the LSP
Number field MUST be set to zero. Otherwise, the field MUST contain
the actual LSP number for the related PSN LSP.

After a PW is established, the operators may choose to move the PWs
from the current tunnel/LSPs to other tunnel/LSPs. Also, the
underlying PSN tunnel may break due to a network failure. When
either of these scenarios occur, a new Label Mapping message MUST be
sent to notify the remote PE of the changes. Note that when the
T-bit is set, the working LSP broken will not provide this update if
there are protection LSPs in place.

The message may carry a new PSN Tunnel Binding TLV, which contains
the new Source and Destination Numbers/IDs. The handling of the new
message should be identical to what has been described in this
section.

However, if the new Label Mapping message does not contain the PSN
Tunnel Binding TLV, it declares the removal of any co-routed/strict
constraints. The current independent PW-to-PSN Binding will be used.

Further, as an implementation option, the PEs may choose not to
remove the traffic from an operational PW until the completion of the
underlying PSN tunnel/LSP changes.

6. PSN Binding Operation for MS-PW

MS-PW uses FEC 129 for PW setup. We refer to Figure 7 for this
operation.

```
                +-----+ LSP1 +-----+ LSP2 +-----+ LSP3 +-----+
      +---+     |T-PE1|======|S-PE1|======|S-PE2|======|T-PE2|     +---+
      |   |---| |     |      |     |      |     |      |     |---|   |
      |CE1|     |.....................PW.....................|     |CE2|
      |   |---| |     |      |     |      |     |      |     |---|   |
      +---+     |     |======|     |======|     |======|     |     +---+
                +-----+ LSP4 +-----+ LSP5 +-----+ LSP6 +-----+
```
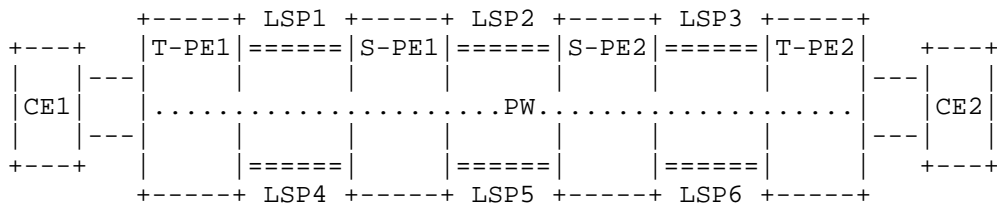
                Figure 7: PSN Binding Operation in MS-PW Environment

When an active PE (that is, T-PE1) starts to signal an MS-PW, a PSN
Tunnel Binding TLV MUST be carried in the Label Mapping message and
sent to the adjacent S-PE (that is, S-PE1). The PSN Tunnel Binding
TLV includes the PSN Tunnel sub-TLV that carries the desired
tunnel/LSP of T-PE1.

For strict binding, the initiating PE MUST set the S-bit, clear the
C-bit, and indicate the binding tunnel/LSP to the next-hop S-PE.

When S-PE1 receives the Label Mapping message, it needs to determine
if the signaling is for the forward or reverse direction, as defined
in Section 4.2.3 of [RFC7267].

If the Label Mapping message is for the forward direction, and S-PE1
accepts the requested tunnel/LSPs from T-PE1, S-PE1 MUST save the
tunnel/LSP information for reverse-direction processing later on. If
the PSN Binding request is not acceptable, S-PE1 MUST reply with a
Label Release Message to the upstream PE (T-PE1) with the status code
set to "Reject - unable to use the suggested tunnel/LSPs"
(0x0000003B).

Otherwise, S-PE1 relays the Label Mapping message to the next S-PE
(that is, S-PE2), with the PSN Tunnel sub-TLV carrying the
information of the new PSN tunnel/LSPs selected by S-PE1. S-PE2 and
subsequent S-PEs will repeat the same operation until the Label
Mapping message reaches to the remote T-PE (that is, T-PE2).

If T-PE2 agrees with the requested tunnel/LSPs, it will reply with a
Label Mapping message to initiate the binding process in the reverse
direction. The Label Mapping message contains the received PSN
Tunnel Binding TLV for confirmation purposes.

When its upstream S-PE (S-PE2) receives the Label Mapping message,
the S-PE relays the Label Mapping message to its upstream adjacent
S-PE (S-PE1), with the previously saved PSN tunnel/LSP information in
the PSN Tunnel sub-TLV. The same procedure will be applied on
subsequent S-PEs, until the message reaches T-PE1 to complete the PSN
Binding setup.

During the binding process, if any PE does not agree to the requested
tunnel/LSPs, it can send a Label Release Message to its upstream
adjacent PE with the status code set to "Reject - unable to use the
suggested tunnel/LSPs" (0x0000003B). In addition, if the received
PSN tunnel/LSP endpoints do not match the PW Segment endpoints, the
receiving PE MUST reply with a Label Release message with the status
code set to "Reject - unable to use the suggested tunnel/LSPs"
(0x0000003B) and the received PSN Tunnel Binding TLV MUST also be
carried.

For co-routed binding, the initiating PE (T-PE1) MUST set the C-bit, reset the S-bit, and indicate the suggested tunnel/LSP in the PSN Tunnel sub-TLV to the next-hop S-PE (S-PE1).

During the MS-PW setup, the PEs have the option of ignoring the suggested tunnel/LSP, and to select another tunnel/LSP for the segment PW between itself and its upstream PE in reverse direction only if the tunnel/LSP is co-routed with the forward one. Otherwise, the procedure is the same as the strict binding.

The tunnel/LSPs may change after a MS-PW has been established. When a tunnel/LSP has changed, the PE that detects the change SHOULD select an alternative tunnel/LSP for temporary use while negotiating with other PEs following the procedure described in this section.

7. PSN Tunnel Select Considerations

   As stated in Section 1, the PSN tunnel that is used for binding can be either a co-routed bidirectional LSP or two LSPs with the same route. The co-routed bidirectional LSP has the characteristics that both directions not only cross the same nodes and links, but have the same life span. But for the two LSPs case, even if they have the same route at the beginning, it cannot be guaranteed that they will always have the same route all the time. For example, when Fast ReRoute (FRR) [RFC4090] is deployed for the LSPs, link or node failure may make the two LSPs use different routes. So, if the network supports co-routed bidirectional LSPs, it is RECOMMENDED that a co-routed bidirectional LSP should be used; otherwise, two LSPs with the same route may be used.

8. Security Considerations

   The ability to control which LSP is used to carry traffic from a PW can be a potential security risk both for denial of service and traffic interception. It is RECOMMENDED that PEs not accept the use of LSPs identified in the PSN Tunnel Binding TLV unless the LSP endpoints match the PW or PW segment endpoints. Furthermore, it is RECOMMENDED that PEs implement the LDP security mechanisms described in [RFC5036] and [RFC5920].

9. IANA Considerations

9.1. LDP TLV Types

   This document defines a new TLV (Section 3.1) for inclusion in the LDP Label Mapping message. IANA has assigned TLV type value 0x0973 from the "LDP TLV Type Name Space" registry.

9.1.1. PSN Tunnel Sub-TLVs

   This document defines two sub-TLVs (Section 3.1.1) for the PSN Tunnel
   Binding TLV. IANA has created a new PWE3 subregistry titled "PSN
   Tunnel Sub-TLV Name Space" for PSN Tunnel sub-TLVs and has assigned
   Sub-TLV type values to the following sub-TLVs:

   IPv4 PSN Tunnel sub-TLV - 1

   IPv6 PSN Tunnel sub-TLV - 2

   In addition, the values 0 and 255 in this new registry should be
   reserved, and values 1-254 will be allocated by IETF Review
   [RFC5226].

9.2. LDP Status Codes

   This document defines two new LDP status codes, IANA has assigned
   status codes to these new defined codes from the "LDP Status Code
   Name Space" registry.

   "Reject - unable to use the suggested tunnel/LSPs" - 0x0000003B

   "The C-bit or S-bit unknown" - 0x0000003C

   The E bit is set to 1 for both new codes.

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