Dynamic Placement of Multi Segment Pseudo Wires

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Abstract

There is a requirement for service providers to be able to extend the reach of pseudo wires (PW) across multiple Packet Switched Network domains. A Multi-Segment PW is defined as a set of two or more contiguous PW segments that behave and function as a single point-to-point PW. This document describes extensions to the PW control protocol to dynamically place the segments of the multi segment pseudo wire among a set of Provider Edge (PE) routers.
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3. Introduction

3.1. Scope

[MS-REQ] describes the service provider requirements for extending the reach of pseudo-wires across multiple PSN domains. This is achieved using a Multi-segment Pseudo-Wire (MS-PW). A MS-PW is defined as a set of two or more contiguous PW segments that behave and function as a single point-to-point PW. This architecture is described in [MS-ARCH].

The procedures for establishing PWs that extend across a single PWE3 domain are described in [RFC4447], while procedures for setting up PWs across multiple domains, or control planes are described in [PW-SEG].

The purpose of this draft is to specify extensions to the PWE3 control protocol [RFC4447], and [PW-SEG] procedures, to enable multi-segment PWs to be automatically placed. The proposed procedures follow the guidelines defined in [RFC5036] and enable the reuse of existing TLVs, and procedures defined for SS-PWs in [RFC4447].

3.2. 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.
3.3. Terminology

[MS-ARCH] provides terminology for multi-segment pseudo wires.

This document defines the following additional terms:

- Source Terminating PE (ST-PE). A Terminating PE (T-PE), which assumes the active signaling role and initiates the signaling for multi-segment PW.
- Target Terminating PE (TT-PE). A Terminating PE (T-PE) that assumes the passive signaling role. It waits and responds to the multi-segment PW signaling message in the reverse direction.
- Forward Direction: ST-PE to TT-PE.
- Reverse Direction: TT-PE to ST-PE
- Forwarding Direction: Direction of control plane, signaling flow
- Pseudo wire Routing (PW routing). The dynamic placement of SS-PWs that compose an MS-PW, as well as the automatic selection of S-PEs.

3.4. Architecture Overview

The following figure describes the reference models which are derived from [MS-ARCH] to support PW emulated services across multi-segment PWs.
Figure 1 shows the architecture for a simple multi-segment case. T-PE1 and T-PE2 provide PWE3 to CE1 and CE2. These PEs reside in different PSNs. A PSN tunnel extends from T-PE1 to S-PE1 across PSN1, and a second PSN tunnel extends from S-PE1 to T-PE2 across PSN2. PWs are used to connect the attachment circuits (ACs) attached to T-PE1 to the corresponding AC attached to T-PE2. A PW on the tunnel across PSN1 is connected to a PW in the tunnel across PSN2 at S-PE1 to complete the multi-segment PW (MS-PW) between T-PE1 and T-PE2. S-PE1 is therefore the PW switching point and will be referred to as the switching provider edge (S-PE). PW Segment 1 and PW Segment 3 are segments of the same MS-PW while PW Segment 2 and PW Segment 4 are segments of another MS-PW. PW segments of the same MS-PW (e.g., PW segment 1 and PW segment 3) MUST be of the same PW type, and PSN tunnels (e.g., PSN1 and PSN2) can be the same or different technology. An S-PE switches an MS-PW from one segment to another based on the PW identifiers. (PWid, or AII) How the PW PDUs are switched at the S-PE depends on the PSN tunnel technology: in case of an MPLS PSN to another MPLS PSN PW switching the operation is a standard MPLS label switch operation.

Note that although Figure 1 only shows a single S-PE, a PW may transit more one S-PE along its path. For instance, in the multi-provider case, there can be an S-PE at the border of one provider domain and another S-PE at the border of the other provider domain.
4. Applicability

In this document we describe the case where the PSNs carrying the SS-PW are only MPLS PSNs using the generalized FEC 129. Interactions with an IP PSN using L2TPv3 as described in [PW-SEG] section 7.4 are left for further study.

4.1. Requirements Addressed

Specifically the following requirements are addressed [MS-REQ]:
- Dynamic End-to-end Signaling
- Scalability and Inter-domain Signaling and Routing
- Minimal number of provisioning touches (provisioning only at the T-PEs)
- Same set of T-PEs/S-PEs for both directions of a MS-PWs
- QoS Signaling, Call Admission Control
- Resiliency
- End-to-end negotiation of OAM Capability

4.2. Changes to Existing PW Signaling

The procedures described in this document make use of existing LDP TLVs and related PW signaling procedures described in [RFC4447] and [PW-SEG]. Only an optional Bandwidth TLV is added to address the QoS Signaling requirements (see "MS-PW Next Hop Bandwidth Signaling" section for details).

5. PW layer 2 addressing

Single segment pseudo wires on an MPLS PSN use Attachment circuit identifiers for a PW using FEC 129. In the case of an automatically placed MS-PW, there is a requirement to have individual global addresses assigned to PW attachment circuits, for reachability, and manageability of the PW. Referencing figure 1 above, individual globally unique addresses MUST be allocated to all the ACs, and S-PEs composing an MS-PW.
5.1. Attachment Circuit Addressing

The attachment circuit addressing is derived from [RFC5003] AII type 2 shown here:

```
+-----------------+-----------------+-----------------+
|     0           |     1           |     2           |
|-----------------+-----------------+-----------------|
| 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 |
+-----------------+-----------------+-----------------+
| 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 |
+-----------------+-----------------+-----------------+
| AII Type=02     | Length          | Global ID       |
+-----------------+-----------------+-----------------+
| Global ID (contd.)| Prefix          |                |
+-----------------+-----------------+-----------------+
| Prefix (contd.) | AC ID           |                |
+-----------------+-----------------+-----------------+
| AC ID           |                |                |
+-----------------+-----------------+-----------------+
```

Implementations of the following procedure MUST interpret the AII type to determine the meaning of the address format of the AII, irrespective of the number of segments in the MS-PW.

A unique combination Global ID, Prefix, and AC ID parts of the AII type 2 will be assigned to each AC. In general the same global ID and prefix will be assigned for all ACs belonging to the same T-PE, however this is not a strict requirement. A particular T-PE might have more than one prefix assigned to it, and likewise a fully qualified AII with the same Global ID/Prefix but different AC IDs might belong to different T-PEs.

For the purpose of MS-PW the AII MUST be globally unique across all interconnected PW domains.

5.2. S-PE addressing

The T-PE may elect to select a known specific path along a set of S-PEs for a specific PW. This requires that each S-PE be uniquely addressable in terms of pseudo wires. For this purpose at least one AI address of the format similar to AII type 2 [RFC5003] composed of the Global ID, and Prefix part only MUST be assigned to each S-PE.
6. Dynamic placement of MS-PWs

[PW-SEG] describes a procedure for connecting multiple pseudo wires together. This procedure requires each S-PE to be manually configured with the information required to terminate and initiate the SS-PW part of the MS-PW. The procedures in the following sections describe an method to extend [PW-SEG] by allowing the automatic selection of pre-defined S-PEs, and automatically setting up a MS-PW between two T-PEs.

6.1. Pseudo wire routing procedures

The AII type 2 described above contains a Global ID, Prefix, and AC ID. The TAI is used by S-PEs to determine the next SS-PW destination for LDP signaling.

Once an S-PE receives a MS-PW label mapping message containing a TAI with an AII that is not locally present, the S-PE performs a lookup in a local Layer 2 AII PW routing table. If this lookup results in an IP address of the next PE that advertised reachability information for the AII in question, then the S-PE will initiate the necessary LDP messaging procedure for setting up the next PW segment. If the AII PW routing table lookup does not result in a IP address of the next PE, the destination AII has become unreachable, and the PW MUST fail to setup. In this case the next PW segment is considered unprovisioned, and a label release MUST be returned to the T-PE with a status message of "AII Unreachable".

If the TAI of a MS-PW label mapping message, received by a PE, contains the prefix of a locally provisioned prefix on that PE, but an AC ID that is not provisioned, then the LDP liberal label retention procedures apply, and the label mapping message is retained.

To allow for dynamic end-to-end signaling of MS-PWs, information must be present in S-PEs to support the determination of the next PW signaling hop. Such information can be provisioned (static route equivalent) on each S-PE system or disseminated via regular routing protocols (e.g. BGP).

6.1.1. AII PW routing table Lookup aggregation rules

All PEs capable of dynamic multi segment pseudowire path selection, must build a PW routing table to be used for PW next hop selection.

The PW addressing scheme (AII type 2 in [RFC5003]) consists of a
Global Id, a 32 bit prefix and a 32 bit Attachment Circuit ID.

An aggregation scheme similar with the one used for classless IPv4 addresses can be employed. An (8 bits) length mask is specified as a number ranging from 0 to 96 that indicates which Most Significant Bits (MSB) are relevant in the address field when performing the PW address matching algorithm.

```
0        31 32    63 64    95 (bits)
+-----------+--------+--------+
| Global ID | Prefix | AC ID  |
+-----------+--------+--------+
```

During the signaling phase, the content of the (fully qualified) TAIL type 2 field from the FEC129 TLV is compared against routes from the PW Routing table. Similar with the IPv4 case, the route with the longest match is selected, determining the next signaling hop and implicitly the next PW Segment to be signaled.

6.1.2. PW Static Route

For the purpose of determining the next signaling hop for a segment of the pseudo wire, the PEs MAY be provisioned with fixed route entries in the PW next hop routing table. The static PW entries will follow all the addressing rules and aggregation rules described in the previous sections. The most common use of PW static provisioned routes is this example of the "default" route entry as follows:

Global ID = 0 Prefix = 0 AC ID = 0 , Prefix Length = 0 Next Signaling Hop = S-PE1

6.1.3. Dynamic advertisement with BGP

Any suitable routing protocol capable of carrying external routing information may be used to propagate MS-PW path information among S-PE, and T-PE. However, T-PE, and S-PEs, MAY choose to use Boundary Gateway Protocol (BGP) [RFC4760] to propagate PW address information throughout the PSN.

Contrary to other l2vpn signaling methods that use BGP [L2-SIGNALING], in the case of the dynamically placed MS-PW if the source T-PE knows a priori (by provisioning) the address of the terminating T-PE. Hence there is no need to advertise a "fully qualified" 96 bit address on a per PW Attachment Circuit basis. Only the T-PE Global ID, Prefix, and prefix length needs to be advertised as part of well
known BGP procedures – see [RFC4760].

As PW Endpoints are provisioned in the T-PEs. The ST-PE will use this information to obtain the first S-PE hop (i.e., first BGP next hop) to where the first PW segment will be established. Any subsequent S-PEs will use the same information (i.e. the next BGP next-hop(s)) to obtain the next-signaling-hop(s) on the path to the TT-PE.

The PW dynamic path NLRI is advertised in BGP UPDATE messages using the MP_REACH_NLRI and MP_UNREACH_NLRI attributes [RFC4760]. The [AFI, SAFI] value pair used to identify this NLRI is (AFI=25, SAFI=6 (pending IANA allocation)).

The Next Hop field of MP_REACH_NLRI attribute shall be interpreted as an IPv4 address, whenever the length of the NextHop address is 4 octets, and as a IPv6 address, whenever the length of the NextHop address is 16 octets.

The NLRI field in the MP_REACH_NLRI and MP_UNREACH_NLRI is a prefix comprising an 8-octet Route Distinguisher, the Global ID, the Prefix, and the AC-ID, and encoded as defined in section 4 of [RFC4760].

This NLRI is structured as follows:

```
|Bit| Length| Route Dist | Global ID | Prefix | AC ID |
+---+--------+------------+-----------+--------+--------+
```

The Length field is the prefix length of the Route Distinguisher + Global ID + Prefix + AC-ID in bits.

Except for the default PW route, which is encoded as a 0 length prefix, the minimum value of the length field is 96 bits. Lengths of 128 bits to 159 bits are invalid as the AC ID field cannot be aggregated. The maximum value of the Length field is 160 bits. BGP advertisements received with invalid prefix lengths MUST be rejected as having a bad packet format.
6.2. LDP Signaling

The LDP signaling procedures are described in [RFC4447] and expanded in [PW-SEG]. No new LDP Signaling components are required for setting up a dynamically placed MS-PW. However some optional signaling extensions are described below.

6.2.1. MS-PW Bandwidth Signaling

In the SS-PW case the PW QoS requirements may easily be met by selecting a MPLS PSN tunnel at the S-PE that meets the PW QoS requirements. However in the case of an automatically placed MS-PW the QoS requirements for a SS-PW not initiating on a T-PE MAY need to be indicated along with the MS-PW addressing. This is accomplished by including an OPTIONAL PW Bandwidth TLV. The PW Bandwidth TLV is specified as follows:

```
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----------------------------------------------+
| 1 | 0 |  PW BW TLV (0x096E) |         TLV Length          |
+-----------------------------------------------+
|                     Forward SENDER_TSPEC         |
+-----------------------------------------------+
|                     Reverse SENDER_TSPEC        |
+-----------------------------------------------+
```

The complete definitions of the content of the SENDER_TSPEC objects are found in [TSPEC] section 3.1. The forward SENDER_TSPEC refers to the data path in the direction of ST-PE to TT-PE. The reverse SENDER_TSPEC refers to the data path in the direction TT-PE to ST-PE.

In the forward direction, after a next hop selection is determined, a T/S-PE SHOULD reference the forward SENDER_TSPEC object to determine an appropriate PSN tunnel towards the next signaling hop. If such a tunnel exists, the MS-PW signaling procedures are invoked with the inclusion of the PW Bandwidth TLV. When the PE searches for a PSN tunnel, any tunnel which points to a next hop equivalent to the next hop selected will be included in the search.(The LDP address TLV is used to determine the next hop equivalence)

When an S/T-PE receives a PW Bandwidth TLV, once the PW next hop is selected, the S/T-PE MUST request the appropriate resources from the PSN. The resources described in the reverse SENDER_TSPEC are allocated from the PSN toward the originator of the message or previous hop. When resources are allocated from the PSN for a
specific PW, then the PSN SHOULD account for the PW usage of the resources.

In the case where PSN resources towards the previous hop are not available the following procedure MUST be followed:
  - i. The PSN MAY allocate more QoS resources, e.g. Bandwidth, to the PSN tunnel.
  - ii. The S-PE MAY attempt to setup another PSN tunnel to accommodate the new PW QoS requirements.
  - iii. If the S-PE cannot get enough resources to setup the segment in the MS-PW a label release MUST be returned to the previous hop with a status message of "Bandwidth resources unavailable"

In the latter case, the T-PE receiving the status message MUST also withdraw the corresponding PW label mapping for the opposite direction if it has already been successfully setup.

If an ST-PE receives a label mapping message the following procedure MUST be followed:

If the ST-PE has already sent a label mapping message for this PW then the ST-PE must check that this label mapping message originated from the same LDP peer to which the corresponding label mapping message for this particular PW was sent. If it is the same peer, the PW is established. If it is a different peer, then ST-PE MUST send a label release message, with a status code of "Duplicate AII" to the PE that originate the LDP label mapping message.

If the PE has not yet sent a label mapping message for this particular PW, then it MUST send the label mapping message to this same LDP peer, regardless of what the PW TAI routing lookup result is.

6.2.2. Active/Passive T-PE Election Procedure

When a MS-PW is signaled, Each T-PE might independently start signaling the MS-PW, this could result in a different path selected for each T-PE PW. To avoid this situation one of the T-PE MUST start the PW signaling (active role), while the other waits to receive the LDP label mapping before sending the respective PW LDP label mapping message. (passive role). The Active T-PE (the ST-PE) and the passive T-PE (the TT-PE) MUST be identified before signaling is initiated for a given MS-PW.

The determination of which T-PE assume the active role SHOULD be done as follows: the SAII and TAI are compared as unsigned integers, if
the SAII is bigger than the T-PE assumes the active role.

The selection process to determine which T-PE assumes the active role MAY be superseded by manual provisioning.

6.2.3. Detailed Signaling Procedures

On receiving a label mapping message, the S-PE MUST inspect the FEC TLV. If the receiving node has no local AII matching the TAI for that label mapping then the S-PE will check if the FEC is already installed for the forward direction:
- If it is already installed, and the received mapping was received from the same LDP peer where the forward LDP label mapping was sent, then this label mapping represents signaling in the reverse direction for this MS-PW segment.
- Otherwise this represents signaling in the forward direction.

For the forward direction:
  -i. Determine the next hop S-PE or T-PE according to the procedures above.
  -ii. Check that a PSN tunnel exists to the next hop S-PE or T-PE. If no tunnel exists to the next hop S-PE or T-PE the S-PE MAY attempt to setup a PSN tunnel.
  -iii. Check that a PSN tunnel exists to the previous hop. If no tunnel exists to the previous hop S-PE or T-PE the S-PE MAY attempt to setup a PSN tunnel.
  -iv. If the S-PE cannot get enough PSN resources to setup the segment to the next or previous S-PE or T-PE, a label release MUST be returned to the T-PE with a status message of "Resources Unavailable".
  -v. If the label mapping message contains a Bandwidth TLV, allocate the required resources on the PSN tunnels in the forward and reverse directions according to the procedures above.
  -vi. Allocate a new PW label for the forward direction.
  -vii. Install the FEC for the forward direction.
  -viii. Send the label mapping message with the new forward label and the FEC to the next hop S-PE/T-PE.

For the reverse direction:
  -i. Install the received FEC for the reverse direction.
  -ii. Determine the next signaling hop by referencing the LDP sessions used to setup the LSP in the Forward direction.
  -iii. Allocate a new PW label for the reverse direction.
-iv. Install the FEC for the reverse direction.
-v. Send the label mapping message with a new label and the FEC to the next hop S-PE/ST-PE.

6.2.4. Support for Explicit PW Path

The Explicit Route TLV format defined in [RFC3212] section 4.1 MAY be used to signal an explicit path for a MS-PW. An Explicit PW path may be required to provide a simple solution for 1:1 protection with diverse primary and backup path or to enable controlled signaling (strict or loose) for special PWs. Details of its usage to be provided in a future study.

7. Failure Handling Procedures

7.1. PSN Failures

Failures of the PSN tunnel MUST be handled by PSN mechanisms. If the PSN is unable to re-establish the PSN tunnel, then the S-PE SHOULD follow the procedures defined in Section 8 of [PW-SEG].

7.2. S-PE Reachability Failures

For defects in an S-PE, the procedures defined in [PW-SEG] SHOULD be followed. However in general an established MS-PW will not be affected by changes in L2 PW reachability information.

T-PEs that receive a label release message with a status of "AII Unreachable" MUST re-attempt to establish the PW immediately. However the T-PE MUST throttle its PW setup message retry attempts with an exponential backoff in situations where PW setup messages are being constantly released. It is also recommended that a T-PE detecting such a situation take action to notify an operator.

If there is a change in the L2 PW reachability information in the forward direction only, the T-PE MAY elect to tear down the MS-PW by sending a label withdraw message and re-establish the MS-PW. In the same case, an S-PE MAY do the same by sending a label withdraw message in the forward direction, and a label release message in the opposite direction along the MS-PW.

A change in L2 reachability information in the reverse direction has no effect on an MS-PW.
8. Operations and Maintenance (OAM)

The OAM procedures defined in [PW-SEG] may be used also for MS-PWs. A PW switching point TLV is used [PW-SEG] to record the switching points that the PW traverses.

In the case of a MS-PW where the PW Endpoints are identified though using a globally unique, FEC 129-based AII addresses, there is no PWID defined on a per segment basis. Each individual PW segment is identified by the address of adjacent S-PE(s) in conjunction with the SAI and TAI. In this case, the following type MUST be used in place of type 0x01 in the PW switching point TLV:

<table>
<thead>
<tr>
<th>Type</th>
<th>Length</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x06</td>
<td>12</td>
<td>L2 PW address of PW Switching Point</td>
</tr>
</tbody>
</table>

The above field MUST be included together with type 0x02 in the TLV once per individual PW Switching Point following the same rules and procedures as described in [PW-SEG].

9. Security Considerations

This document specifies only extensions to the protocols already defined in [RFC4447], and [PW-SEG]. Each such protocol may have its own set of security issues, but those issues are not affected by the extensions specified herein. Note that the protocols for dynamically distributing PW Layer 2 reachability information may have their own security issues, however those protocols specifications are outside the scope of this document.

10. IANA Considerations

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

<table>
<thead>
<tr>
<th>TLV type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x096E</td>
<td>Bandwidth TLV</td>
</tr>
</tbody>
</table>
10.1. LDP Status Codes

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 have been pre-allocated:

<table>
<thead>
<tr>
<th>Range/Value</th>
<th>E</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00000037</td>
<td>0</td>
<td>Bandwidth resources unavailable</td>
<td>RFCxxxx</td>
</tr>
<tr>
<td>0x00000038</td>
<td>0</td>
<td>Resources Unavailable</td>
<td>RFCxxxx</td>
</tr>
<tr>
<td>0x00000039</td>
<td>0</td>
<td>AII Unreachable</td>
<td>RFCxxxx</td>
</tr>
<tr>
<td>0x0000003A</td>
<td>0</td>
<td>PW Loop Detected</td>
<td>RFCxxxx</td>
</tr>
</tbody>
</table>

10.2. BGP SAFI

IANA needs to allocate a new BGP SAFI for "Network Layer Reachability Information used for Dynamic Placement of Multi-Segment Pseudowires" from the IANA "Subsequence Address Family Identifiers (SAFI)" registry. The following value has been pre-allocated:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Network Layer Reachability Information used for Dynamic Placement of Multi-Segment Pseudowires</td>
<td>[RFCxxxx]</td>
</tr>
</tbody>
</table>

11. Normative References


12. Informative References


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