      Signaling Root-Initiated Point-to-Multipoint Pseudowire Using LDP

Abstract

   This document specifies a mechanism to signal Point-to-Multipoint
   (P2MP) Pseudowire (PW) trees using LDP. Such a mechanism is suitable
   for any Layer 2 VPN service requiring P2MP connectivity over an IP or
   MPLS-enabled PSN. A P2MP PW established via the proposed mechanism
   is root initiated. This document updates RFC 7385 by reassigning the
   reserved value 0xFF to be the wildcard transport tunnel type.

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.

   Information about the current status of this document, any errata,
   and how to provide feedback on it may be obtained at
   https://www.rfc-editor.org/info/rfc8338.

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1. Introduction

   A Point-to-Multipoint (P2MP) Pseudowire (PW) emulates the essential
   attributes of a unidirectional P2MP Telecommunications service such
   as P2MP ATM over PSN. A major difference between a Point-to-Point
   (P2P) PW outlined in [RFC3985] and a P2MP PW is that the former is
   intended for bidirectional service whereas the latter is intended for
   both unidirectional and, optionally, bidirectional service.
   Requirements for P2MP PWs are described in [RFC7338]. P2MP PWs can
   be constructed as either Single Segment Pseudowires (P2MP SS-PWs) or
   Multi-Segment Pseudowires (P2MP MS-PWs) as mentioned in [RFC7338].
   P2MP MS-PW is outside the scope of this document. A reference model
   or a P2MP PW is depicted in Figure 1. A transport Label Switched
   Path (LSP) associated with a P2MP SS-PW SHOULD be a P2MP MPLS LSP
   (i.e., P2MP Traffic Engineering (TE) tunnel established via RSVP-TE
   [RFC4875] or P2MP LSP established via Multipoint LDP (mLDP)
   [RFC6388]) spanning from the Root PE (Provider Edge) to the Leaf

   PE(s) of the P2MP SS-PW tree. For example, in Figure 1, PW1 can be
   associated with a P2MP TE tunnel or P2MP LSP setup using mLDP
   originating from PE1 and terminating at PE2, PE3, and PE4.

```
               |<-------------P2MP PW---------------->|
       Native  |                                      |  Native
       Service |     |<--PSN1->|       |<--PSN2->|     |  Service
        (AC)   V     V         V       V         V     V   (AC)
          |  +-----+         +------+        +------+  |
          |  |     |         |  P1  |========|T-PE2 |AC3 |    +---+
          |  |     |         |      .......PW1.........>|-------->|CE3|
          |  |T-PE1|=========|      .  |========|      |  |    +---+
          |  |  .......PW1........   |  |========|      +------+  |
          |  |  .  |=========|    .  |  |        +------+  |
          |  |  .  |         |    .  |========|T-PE3 |AC4 |    +---+
    +---+ |AC1|  .  |         |    .......PW1.........>|-------->|CE4|
    |CE1|------>|...  |       |       |========|      |  |    +---+
    +---+ |     |  .  |       +------+        +------+  |
          |     |  .  |       +------+        +------+  |
          |     |  .  |========|  P2  |========|T-PE4 |AC5 |    +---+
          |     |  .......PW1.............PW1.........>|-------->|CE5|
          |     |     |========|       |========|      |  |    +---+
          |  +-----+         +------+        +------+  |
```
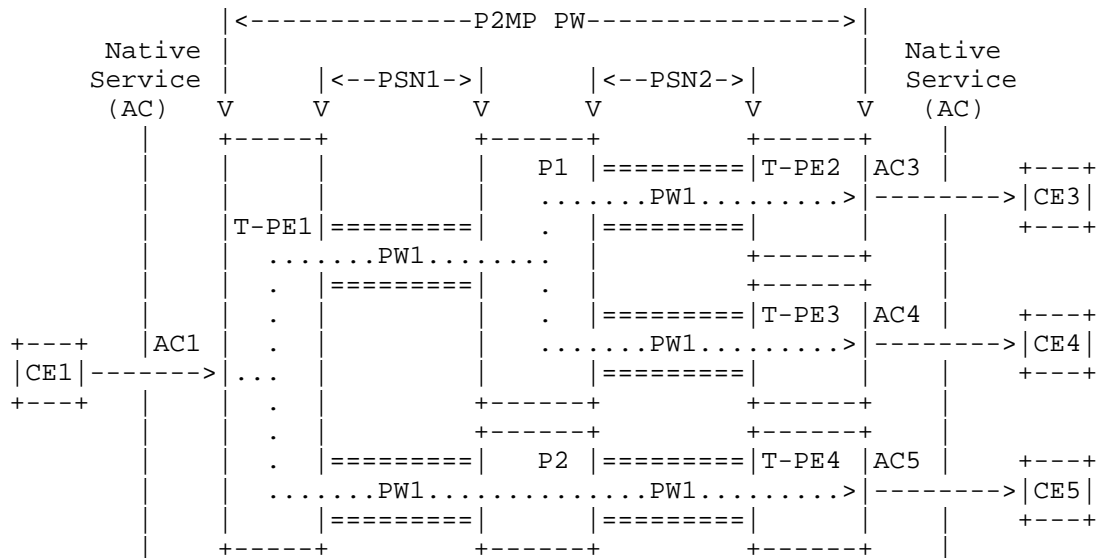
                          Figure 1: P2MP PW

   Mechanisms for establishing a P2P SS-PW using LDP are described in
   [RFC8077]. This document specifies a method of signaling P2MP PW
   using LDP. In particular, this document defines a new Forwarding
   Equivalence Class (FEC), TLVs, parameters, and status codes to
   facilitate LDP signaling and maintaining P2MP PWs.

   As outlined in [RFC7338], even though the traffic flow from a Root PE
   (R-PE) to Leaf PE(s) (L-PEs) is P2MP in nature, it may be desirable
   for any L-PE to send unidirectional P2P traffic destined only to the
   R-PE. The proposed mechanism takes such an option into
   consideration.

   The P2MP PW requires an MPLS LSP to carry the PW traffic, and the
   MPLS packets carrying the PW upstream label will be encapsulated
   according to the methods described in [RFC5332].

2. Terminology

2.1. Requirements Language

   The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",
   "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and
   "OPTIONAL" in this document are to be interpreted as described in
   BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all
   capitals, as shown here.

2.2. Abbreviations

   AGI: Attachment Group Identifier

   CE: Customer Edge

   FEC: Forwarding Equivalence Class

   L-PE: Leaf PE (egress PE)

   LDP: Label Distribution Protocol

   LSP: Label Switched Path

   mLDP: Multipoint Label Distribution Protocol (for P2MP/MP2MP LSP)

   MS-PW: Multi-Segment Pseudowire

   P2MP: Point-to-Multipoint

   P2P: Point-to-Point

   PE: Provider Edge

   PSN: Packet Switched Network

   PW: Pseudowire

   R-PE: Root PE (ingress PE, PE initiating P2MP PW setup)

   S-PE: Switching Provider Edge (of MS-PW)

   SS-PW: Single-Segment Pseudowire

   TE: Traffic Engineering

3. Signaling P2MP PW

   In order to advertise labels as well as exchange PW-related LDP
   messages, PEs must establish LDP sessions among themselves. A PE
   discovers other PEs that are to be connected via P2MP PWs either via
   manual configuration or autodiscovery [RFC6074].

   An R-PE and each L-PE MUST be configured with the same FEC as defined
   in Section 3.2.

   P2MP PW requires that there be an active P2MP PSN LSP set up between
   an R-PE and L-PE(s). Note that the procedure to set up the P2MP PSN
   LSP is different depending on the signaling protocol used (RSVP-TE or
   mLDP).

   In the case of mLDP, a Leaf PE can decide to join the P2MP LSP at any
   time. In the case of RSVP-TE, the P2MP LSP is set up by the R-PE,
   generally at the initial service provisioning time. It should be
   noted that local policy can override any decision to join, add, or
   prune existing or new L-PEs from the tree. In any case, the PW setup
   can ignore these differences and simply assume that the P2MP PSN LSP
   is available when needed.

   P2MP PW signaling is initiated by the R-PE, which sends a separate
   P2MP PW LDP Label Mapping Message to each of the L-PE(s) belonging to
   that P2MP PW. This Label Mapping Message will contain the following:

   1. A FEC TLV containing a P2MP PW Upstream FEC Element that includes
       a Transport LSP sub-TLV.

   2. An Interface Parameters TLV, as described in [RFC8077].

   3. A PW Group ID TLV, as described in [RFC8077].

   4. A label TLV for the upstream-assigned label used by an R-PE for
       the traffic going from the R-PE to L-PE(s).

   The R-PE imposes the upstream-assigned PW label on the outbound
   packets sent over the P2MP PW; using this label, an L-PE identifies
   the inbound packets arriving over the P2MP PW.

Additionally, the R-PE MAY send Label Mapping Messages to one or more
L-PEs to signal a unidirectional P2P PW(s). The L-PE(s) can use such
a PW(s) to send traffic to the R-PE. This optional Label Mapping
Message will contain the following:

1. A P2P PW Downstream FEC Element

2. A label TLV for the downstream-assigned label used by the
    corresponding L-PE to send traffic to the R-PE

The LDP liberal label retention mode MUST be used; per requirements
specified in [RFC5036], the Label Request message MUST also be
supported.

The upstream-assigned label is allocated according to the rules in
[RFC5331].

When an L-PE receives a PW Label Mapping Message, it MUST verify the
associated P2MP PSN LSP is in place. If the associated P2MP PSN LSP
is not in place and its type is LDP P2MP LSP, the L-PE MUST attempt
to join the P2MP LSP associated with the P2MP PW. If the associated
P2MP PSN LSP is not in place, and its type is RSVP-TE P2MP LSP, the
L-PE SHOULD wait till the P2MP transport LSP is signaled. If an L-PE
fails to join the P2MP PSN LSP, that L-PE MUST not enable the PW and
MUST notify the user. In this case, a PW status message with status
code of 0x00000008 (Local PSN-facing PW (ingress) Receive Fault) MUST
also be sent to the R-PE.

3.1. PW Ingress-to-Egress Incompatibility Issues

   If an R-PE signals a PW with a PW Type, Control Word (CW) mode, or
   interface parameters that a particular L-PE cannot accept, then the
   L-PE MUST NOT enable the PW and should notify the user. In this
   case, a PW status message with status code of 0x00000001 (Pseudowire
   Not Forwarding) MUST also be sent to the R-PE.

   Note that this procedure does not apply if the L-PE was not
   provisioned with this particular P2MP PW. In this case, according to
   the LDP liberal label retention rules, no action is taken.

3.2. P2MP PW FEC

   [RFC8077] specifies two types of LDP FEC elements used to signal P2P
   PWs: "PWid FEC Element" and "Generalized PWid FEC Element". This
   document uses two FEC elements: "P2MP PW Upstream FEC Element" and
   "P2P PW Downstream FEC Element". These FEC elements are associated
   with a mandatory upstream-assigned label and an optional downstream-
   assigned label, respectively.

3.2.1. P2MP PW Upstream FEC Element

   The FEC type for the P2MP PW Upstream FEC Element is encoded as
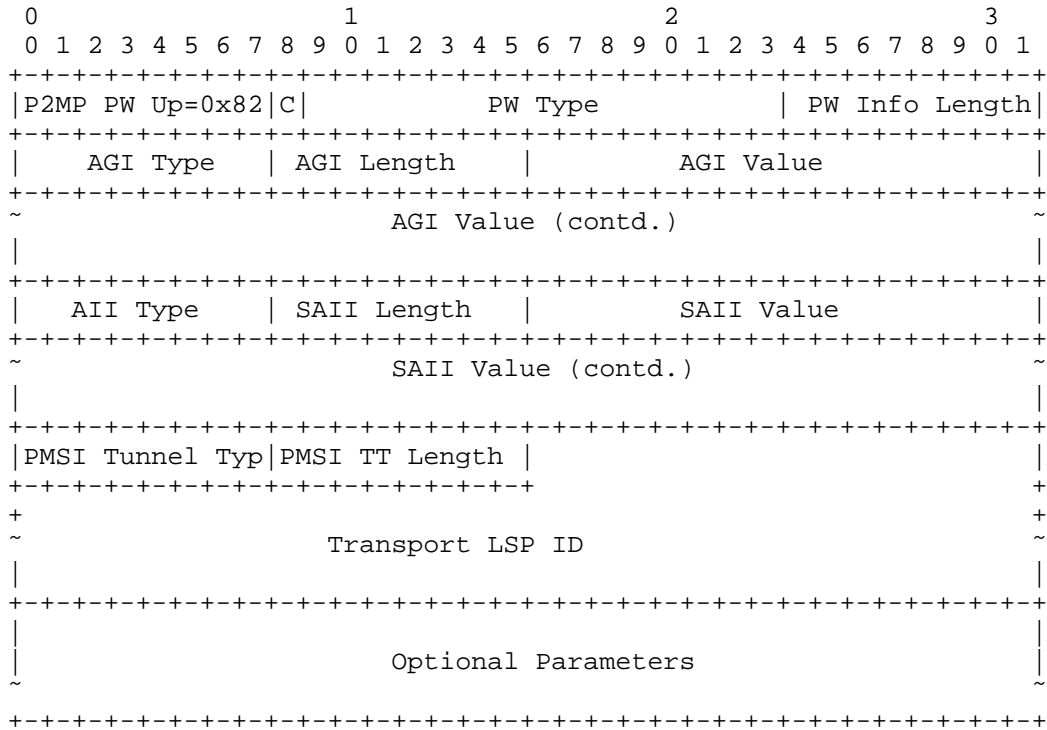   follows:

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|P2MP PW Up=0x82|C|          PW Type            | PW Info Length|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    AGI Type   | AGI Length    |          AGI Value            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                       AGI Value (contd.)                      ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    AII Type   | SAII Length   |          SAII Value           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
~                      SAII Value (contd.)                      ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|PMSI Tunnel Typ|PMSI TT Length |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               +
+                                                               +
~                      Transport LSP ID                         ~
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                   Optional Parameters                         |
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

               Figure 2: P2MP PW Upstream FEC Element

   * P2MP PW Up:

      8-bit representation for the P2MP PW Upstream FEC type.

   * C bit:

      A value of 1 or 0 indicating whether a control word is present or
      absent for the P2MP PW.

   * PW Type:

      15-bit representation of PW Type as specified in [RFC8077].

   * PW Info Length:

      Sum of the AGI Length, SAII Length, PMSI Tunnel Type Length, and
      Optional Parameters fields in octets. If this value is 0, then it
      references all PWs using the specified group ID. In this case,
      there are neither other FEC element fields (AGI Type, SAII Value,
      etc.) present, nor any interface parameters TLVs. Alternatively,
      typed wildcard FEC described in Section 2.3, can be used to
      achieve the same or to have better filtering.

   * AGI:

      An Attachment Group Identifier TLV can be used to uniquely
      identify a VPN or Virtual Private LAN Service (VPLS) instance
      associated with the P2MP PW. This has the same format as the
      Generalized PWid FEC Element [RFC8077].

   * SAII Value:

      A Source Attachment Individual Identifier is used to identify the
      root of the P2MP PW. The root is represented using AII Type 2
      format specified in [RFC5003]. Note that the SAII can be omitted
      by simply setting the length and type to zero.

      The P2MP PW is identified by the Source Attachment Identifier
      (SAI). If the AGI is non-null, the SAI is the combination of the
      SAII and the AGI, if the AGI is null, the SAI is the SAII.

   * PMSI Tunnel Info:

      The PMSI Tunnel Info is the combination of the PMSI Tunnel Type,
      PMSI Tunnel Type Length (shown in the figure as PMSI TT Length),
      and Transport LSP ID fields.

      A P2MP PW MUST be associated with a transport LSP, which can be
      established using RSVP-TE or mLDP.

   * PMSI Tunnel Type:

      The PMSI Tunnel Type is defined in [RFC6514].

      When the type is set to mLDP P2MP LSP, the Tunnel Identifier is a
      P2MP FEC Element as defined in [RFC6388]. The new mLDP Opaque
      Value Element type for the L2VPN-MCAST application TLV (as
      specified in the IANA Considerations section (Section 7)) MUST be
      used.

   * Transport LSP ID:

      This is the Tunnel Identifier that is defined in [RFC6514].

      An R-PE sends a Label Mapping Message as soon as the transport LSP
      ID associated with the P2MP PW is known (e.g., via configuration)
      regardless of the operational state of that transport LSP.

      Similarly, an R-PE does not withdraw the labels when the
      corresponding transport LSP goes down. Furthermore, an L-PE
      retains the P2MP PW labels regardless of the operational status of
      the transport LSP.

      Note that a given transport LSP can be associated with more than
      one P2MP PW; in which case, P2MP PWs will be sharing the same R-PE
      and L-PE(s). An R-PE may also have many P2MP PWs with disjoint
      L-PE sets.

      In the case of LDP P2MP LSP, when an L-PE receives the Label
      Mapping Message, it can initiate the process of joining the P2MP
      LSP tree associated with the P2MP PW.

      In the case of RSVP-TE P2MP LSP, only the R-PE initiates the
      signaling of P2MP LSP.

   * Optional Parameters:

      The Optional Parameter field can contain some TLVs that are not
      part of the FEC, but are necessary for the operation of the PW.
      This proposed mechanism uses two such TLVs: the Interface
      Parameters TLV and the PW Group ID TLV.

      The Interface Parameters TLV and PW Group ID TLV specified in
      [RFC8077] can also be used in conjunction with P2MP PW FEC in a
      label message. For the PW Group ID TLV, the sender and receiver
      of these TLVs should follow the same rules and procedures
      specified in [RFC8077]. For the Interface Parameters TLV, the
      procedure differs from the one specified in [RFC8077] due to
      specifics of P2MP connectivity. When the interface parameters are
      signaled by an R-PE, each L-PE must check if its configured
      value(s) is less than or equal to the threshold value provided by
      the R-PE (e.g., MTU size (Ethernet), max number of concatenated
      ATM cells, etc.). For other interface parameters, like CEP/TDM
      Payload Bytes, the value MUST exactly match the values signaled by
      the R-PE.

A multicast traffic stream associated with a P2MP PW can be
selective or inclusive. To support the former, this document
defines a new optional Selective Tree Interface Parameter sub-TLV,
as described in the IANA Considerations section (Section 7) and
according to the format described in [RFC8077]. The value of the
sub-TLV contains the source and the group for a given multicast
tree, as shown in Figure 3. Also, if a P2MP PW is associated with
multiple selective trees, the corresponding Label Mapping Message
will carry more than one instance of this sub-TLV. Furthermore,
in the absence of this sub-TLV, the P2MP PW is associated with all
multicast traffic streams originating from the root.

```
+-----------------------------------------+
|          Sub-TLV Type (1 Octet)         |
+-----------------------------------------+
|            Length (1 Octet)             |
+-----------------------------------------+
| Multicast Source Length (1 Octet)       |
+-----------------------------------------+
| Multicast Source (variable length)      |
+-----------------------------------------+
| Multicast Group Length (1 Octet)        |
+-----------------------------------------+
| Multicast Group (variable length)       |
+-----------------------------------------+
```
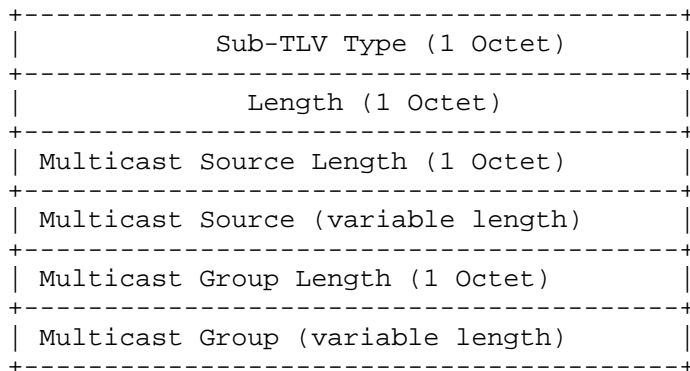
Figure 3: Selective Tree Interface Parameter Sub-TLV Value

Note that since the LDP Label Mapping Message is only sent by the
R-PE to all the L-PEs, it is not possible to negotiate any
interface parameters.

3.2.2. P2P PW Downstream FEC Element

   The optional P2P PW Downstream FEC Element is encoded 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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |P2P PWDown=0x84|C|              PW Type            | PW Info Length|
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    AGI Type   |     Length    |           AGI Value           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                       AGI Value (contd.)                      ~
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    AII Type   |     Length    |           SAII Value          |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   ~                      SAII Value (contd.)                      ~
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
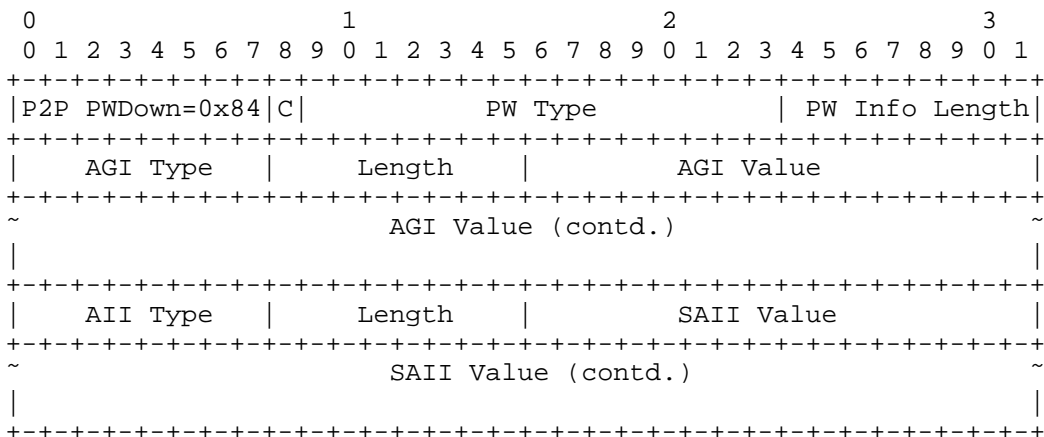
                Figure 4: P2P PW Downstream FEC Element

   The definition of the fields in the P2P PW Downstream FEC Element is
   the same as those of P2MP PW Upstream FEC Element, shown in Figure 2.

3.3. Typed Wildcard FEC Format for a New FEC

   [RFC5918] defines the general notion of a Typed Wildcard FEC Element;
   it requires FEC designers to specify a Typed Wildcard FEC Element for
   newly defined FEC element types. This document uses two FEC
   elements: "P2MP PW Upstream" and "P2P PW Downstream". Hence,
   definition of their Typed Wildcard format is required.

   [RFC6667] defines the Typed Wildcard FEC Element format for other PW
   FEC Element types (PWid and Generalized PWid FEC Element) in
   Section 3 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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |Typed Wcard=0x5|Type=PW FEC    |    Len = 3    |R|   PW Type   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     . . .     | PMSI Tun Type |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
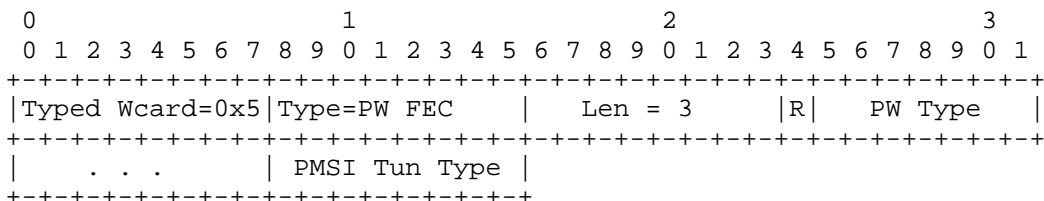
             Figure 5: Typed Wildcard Format for P2MP PW FEC Elements

[RFC6667] specifies that the Type field can be either the "PWid"
(0x80) or "Generalized PWid" (0x81) FEC Element type. This document
reuses the existing Typed Wildcard format specified in [RFC6667] and
illustrated in Figure 5 and extends the definition of the Type field
to also include the P2MP PW Upstream FEC Element and P2P PW
Downstream FEC Element types. This document adds an additional field
called the "PMSI Tunnel Type". This document reserves PMSI Tunnel
Type 0xFF to mean "wildcard transport tunnel type". The PMSI Tunnel
Type field only applies to the Typed Wildcard P2MP PW Upstream FEC
Element and MUST be set to "wildcard" for "P2P PW Downstream FEC
Element" typed wildcard.

3.4. Group ID Usage

   The PW Group ID TLV as defined in [RFC8077] contains a group ID
   capable of indicating an arbitrary group membership of a P2MP PW.
   This group ID can be used in LDP "wildcard" status and withdraw label
   messages, as described in [RFC8077].

3.5. Generic Label TLV

   As in the case of P2P PW signaling, P2MP PW labels are carried within
   the Generic Label TLV contained in the LDP Label Mapping Message. A
   Generic Label TLV is formatted and processed as per the rules and
   procedures specified in [RFC8077]. For a given P2MP PW, a single
   upstream-assigned label is allocated by the R-PE and is advertised to
   all L-PEs using the Generic Label TLV in Label Mapping Messages
   containing the P2MP PW Upstream FEC Element.

   The R-PE can also allocate a unique label for each L-PE from which it
   intends to receive P2P traffic. Such a label is advertised to the
   L-PE using the Generic Label TLV and P2P PW Downstream FEC Element in
   Label Mapping Messages.

4. LDP Capability Negotiation

   The capability of supporting P2MP PWs MUST be advertised to all LDP
   peers. This is achieved by using the methods in [RFC5561] to
   advertise the LDP P2MP PW Capability TLV. If an LDP peer supports
   the dynamic capability advertisement, this can be done by sending a
   new Capability message with the S bit set for the P2MP PW Capability
   TLV. If the peer does not support dynamic capability advertisement,
   then the P2MP PW Capability TLV MUST be included in the LDP
   Initialization message during session establishment. A Label
   Switched Router (LSR) having P2MP PW capability MUST recognize both
   the P2MP PW Upstream FEC Element and P2P PW Downstream FEC Element in
   LDP label messages.

In line with requirements listed in [RFC5561], the following TLV is
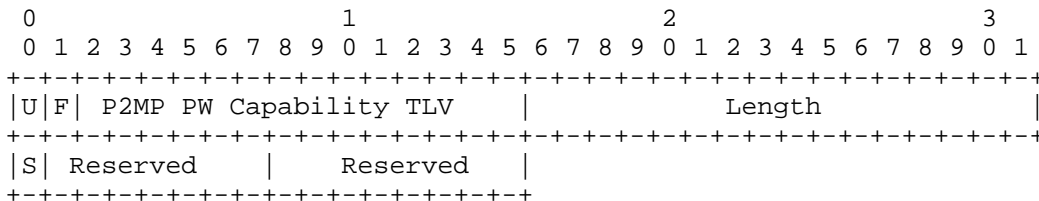defined to indicate the P2MP PW capability:

```
 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| P2MP PW Capability TLV    |              Length           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|S| Reserved      |   Reserved    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

                 Figure 6: LDP P2MP PW Capability TLV

   * U bit:

      The Unknown bit [RFC5036] SHOULD be 1 (ignore if not understood).

   * F bit:

      The Forward unknown bit [RFC5036] SHOULD be 0 (don't forward if
      not understood).

   * P2MP PW Capability TLV Code Point:

      The TLV type, which identifies a specific capability. Note that
      the P2MP PW Capability Code Point appears in the IANA
      Considerations section (Section 7).

   * S bit:

      The State Bit indicates whether the sender is advertising or
      withdrawing the P2MP PW capability. The State bit is used as
      follows:

      1 - The TLV is advertising the capability specified by the P2MP PW
          Capability TLV Code Point.

      0 - The TLV is withdrawing the capability specified by the P2MP PW
          Capability TLV Code Point.

   * Length:

      MUST be set to 2 (octet).

5. P2MP PW Status

   In order to support the proposed mechanism, an LSR MUST be capable of
   handling PW status. As such, the PW status negotiation procedures
   described in [RFC8077] are not applicable to P2MP PW. An LSR MUST
   NOT claim to be P2MP PW capable by sending an LDP P2MP PW Capability
   TLV if it is not also capable of handling PW status.

   Once an L-PE successfully processes a Label Mapping Message for a
   P2MP PW, it MUST send appropriate PW status according to the
   procedure specified [RFC8077] to report the PW status. If no PW
   status notification is required, then no PW status notification is
   sent (for example, if the P2MP PW is established and operational with
   a status code of 0x00000000 (Success), a PW status message is not
   necessary). A PW status message sent from an L-PE to an R-PE MUST
   contain the P2P PW Downstream FEC Element to identify the PW.

   An R-PE also sends PW status to L-PE(s) to reflect its view of a P2MP
   PW state. Such a PW status message contains a P2MP PW Upstream FEC
   Element to identify the PW.

   Connectivity status of the underlying P2MP LSP that the P2MP PW is
   associated with can be verified using LSP ping and traceroute
   procedures described in [RFC6425].

6. Security Considerations

   In general, the security measures described in [RFC8077] are adequate
   for this protocol. However, the use of MD5 as the method of securing
   an LDP control plane is no longer considered adequately secure.
   Implementations should be written in such a way that they can migrate
   to a more secure cryptographic hash function when the next
   authentication method to be used in the LDP might not be a simple
   hash-based authentication algorithm.

7. IANA Considerations

7.1. FEC Type Name Space

   This document uses two FEC element types, 0x82 and 0x84, in the
   "Forwarding Equivalence Class (FEC) Type Name Space" registry for the
   Label Distribution Protocol (LDP) [RFC5036]. IANA has added this
   document as a reference for the following entries:

   Value   Hex   Name   Reference
   ------ ----- ----------------------------   --------------------
    130   0x82   P2MP PW Upstream FEC Element   [RFC8338] [RFC7358]
    132   0x84   P2P PW Downstream FEC Element   [RFC8338] [RFC7358]

7.2. LDP TLV Type

   This document defines a new LDP TLV type in the "TLV Type Name Space"
   registry [RFC5036].   IANA has assigned the following value:

   TLV Type Description
   -------- ---------------------
   0x0703   P2MP PW Capability TLV

7.3. mLDP Opaque Value Element TLV Type

   IANA has assigned a new mLDP Opaque Value Element Type in the "LDP MP
   Opaque Value Element basic type" registry [RFC6388] as follows:

   TLV Type Description
   -------   --------------------------
     13   L2VPN-MCAST application TLV

   Length: 4

   Value: A 32-bit integer, unique in the context of the
             root, as identified by the root's address.

7.4. Selective Tree Interface Parameter Sub-TLV Type

   IANA has assigned a sub-TLV from the "Pseudowire Interface Parameters
   Sub-TLV type Registry" [RFC4446] as follows:

   TLV Type Description
   -------- ---------------------------------
   0x1B   Selective Tree Interface Parameter

7.5. Wildcard PMSI Tunnel Type

   IANA has modified an entry in the "P-Multicast Service Interface
   Tunnel (PMSI Tunnel) Tunnel Types" registry within the "Border
   Gateway Protocol (BGP) Parameters" registry [RFC7385]. Value 0xFF,
   which was previously marked as "Reserved", has been updated as
   follows:

   Value   Meaning   Reference
   -----   ------------------------------ ---------
   0xFF   wildcard transport tunnel type [RFC8338]

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