     Multi-Chassis Passive Optical Network (MC-PON) Protection in MPLS

Abstract

   Multiprotocol Label Switching (MPLS) is being extended to the edge of
   operator networks including the network access nodes. Separately,
   network access nodes such as Passive Optical Network (PON) Optical
   Line Terminations (OLTs) have evolved to support first-mile access
   protection, where one or more physical OLTs provide first-mile
   diversity to the customer edge. Multihoming support is needed on the
   MPLS-enabled PON OLT to provide resiliency for provided services.
   This document describes the Multi-Chassis PON (MC-PON) protection
   architecture in MPLS and also specifies the Inter-Chassis
   Communication Protocol (ICCP) extension to support it.

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
   http://www.rfc-editor.org/info/rfc8024.

Table of Contents

1. Introduction

   Multiprotocol Label Switching (MPLS) is being extended to the edge of
   operator networks, as is described in the multi-segment pseudowires
   (PWs) with Passive Optical Network (PON) access use case [RFC6456].
   Combining MPLS with Optical Line Termination (OLT) access further
   facilitates a low-cost, multi-service convergence.

   Tens of millions of Fiber-to-the-x (FTTx) (x = H for home, P for
   premises, C for curb) lines have been deployed over the years, with
   many of those lines being some PON variant. PON provides operators a
   cost-effective solution for delivering high bandwidth (1 Gbps or even
   10 Gbps) to a dozen or more subscribers simultaneously.

   In the past, access technologies such as PON and Digital Subscriber
   Line (DSL) are usually used for subscribers, and no redundancy is
   provided in their deployment.

   But, with the rapid growth of mobile data traffic, more and more Long
   Term Evolution (LTE) small cells and Wi-Fi hotspots are deployed.
   PON is considered a viable low-cost backhaul solution for these
   mobile services. Besides its high bandwidth and scalability, PON
   further provides frequency and time-synchronization features, e.g.,
   SyncE [G.8261] and IEEE 1588v2 [IEEE-1588] functionality, which can
   fulfill synchronization needs of mobile backhaul services.

   The Broadband Forum specifies reference architecture for mobile
   backhaul networks using MPLS transport in [TR-221] where PON can be
   the access technology.

   Unlike typical residential service where a single or handful of end-
   users hang off a single PON OLT port in a physical optical
   distribution network, a PON port that supports a dozen LTE small
   cells or Wi-Fi hotspots could be providing service to hundreds of
   simultaneous subscribers. Small-cell backhaul often demands the
   economics of a PON first mile and yet expects first-mile protection
   commonly available in a point-to-point access portfolio.

   Some optical layer protection mechanisms, such as Trunk and Tree
   protection, are specified in [IEEE-1904.1] to avoid a single point of
   failure in the access. They are called Type B and Type C protection,
   respectively, in [G.983.1].

   Trunk protection architecture is an economical PON resiliency
   mechanism, where the working OLT and the working link between the
   working splitter port and the working OLT (i.e., the working trunk

fiber) is protected by a redundant protection OLT and a redundant
trunk fiber between the protection splitter port and the protection
OLT; however, it only protects a portion of the optical path from OLT
to Optical Network Units (ONUs). This is different from the more
complex and costly Tree protection architecture where there is a
working optical distribution network path from the working OLT and a
complete protected optical distribution network path from the
protection OLT to the ONUs. Figure 1 depicts a typical scenario of
Trunk protection.

```
                      |                            |
                      |<--Optical Distribution Network->|
                      |                            |
                      |  branch            trunk    +-----+
              +-----+  fibers            fibers    |     |
    Base    ------|    |         |                |  .  OLT |
    Stations ------| ONU |\       |                |  ,'`| A |
            ------|    | \  V            V -'   +-----+
              +-----+    \          .'
                    .  \ +---------+ ,-'
              +-----+   .  \|       -'  Working
    Base    ------|    |  .     | Optical |
    Stations ------| ONU |---------| Splitter |
            ------|    |  .  /|     -,  Protection
              +-----+   .  /  +---------+ ''.,
                    /           `-,    +-----+
              +-----+  /                 ''.,|     |
    Base    ------|    |/                  | OLT |
    Stations ------| ONU |                  | B |
            ------|    |                  +-----+
              +-----+
```
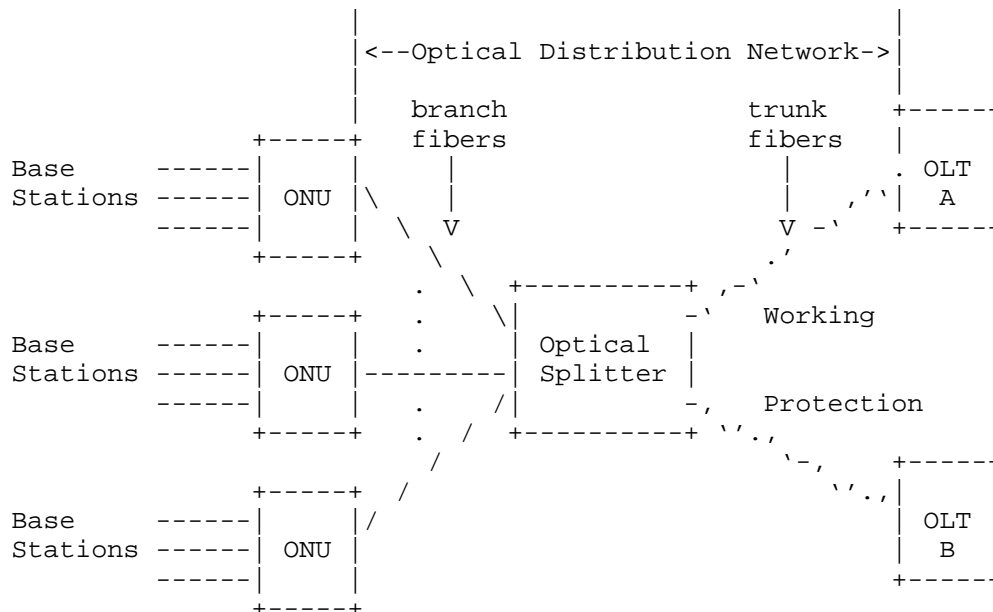
                 Figure 1: Trunk Protection Architecture in PON

   Besides small-cell backhaul, this protection architecture can also be
   applicable to other services, for example, DSL and Multiple System
   Operator (MSO) services. In that case, an ONU in Figure 1 can play
   the similar role as a Digital Subscriber Line Access Multiplexer
   (DSLAM) or a Data Over Cable Service Interface Specification (DOCSIS)
   Remote Physical Layer (PHY) device [remote-phy], and it may further
   be attached with dozens of Customer Premises devices.

   In some deployments, it is also possible that only some ONUs need to
   be protected.

   The PON architecture as depicted in Figure 1 can provide redundancy
   in its physical topology; however, all traffic, including link
   Operation Administration and Maintenance (OAM), is blocked on the

protection link, which frustrates end-to-end protection mechanisms
such as those specified in ITU-T G.8031 [G.8031]. Therefore, some
standard signaling mechanisms are needed between OLTs to exchange
information, for example, PON link status, registered ONU
information, and network status, so that protection and restoration
can be done rapidly and reliably, especially when the OLTs also
support MPLS.

ICCP [RFC7275] provides a framework for inter-chassis synchronization
of state and configuration data between a set of two or more Provider
Edges (PEs). Currently, ICCP only defines application-specific
messages for Pseudowire Redundancy (PW-RED) and Multi-Chassis LACP
(mLACP), but it can be easily extended to support PON as an
Attachment Circuit (AC) redundancy.

This document proposes the extension of ICCP to support multi-
chassis PON protection in MPLS.

1.1. Conventions Used in This Document

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].

1.2. Terminology

DSL: Digital Subscriber Line

FTTx: Fiber-to-the-x (FTTx) (x = H for home, P for premises, C for
      curb)

ICCP: Inter-Chassis Communication Protocol

OLT: Optical Line Termination

ONU: Optical Network Unit

MPLS: Multiprotocol Label Switching

PON: Passive Optical Network

RG: Redundancy Group

2. ICCP Protocol Extensions

2.1. Multi-Chassis PON Application TLVs

   A set of MC-PON application Type-Length-Values (TLVs) are defined in
   the following subsections.

2.1.1. PON Connect TLV

   This TLV is included in the RG Connect message to signal the
   establishment of PON application connection.

```
    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|   Type=0x200D           |          Length               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Protocol Version       |A|           Reserved           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Optional Sub-TLVs                         |
   ~                                                             ~
   |                                                             |
   +                              +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |            ...               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
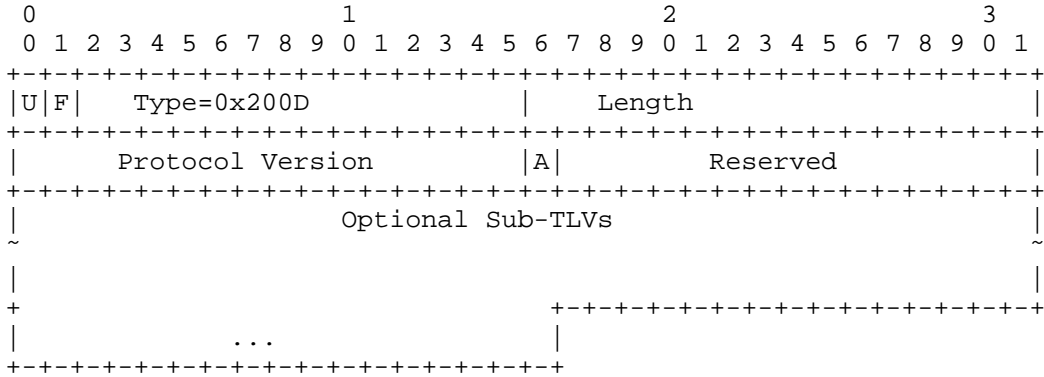
   o U and F bits: both are set to 0.

   o Type: set to 0x200D for "PON Connect TLV".

   o Length: length of the TLV in octets excluding the U-bit, F-bit,
      Type, and Length fields.

   o Protocol Version: the version of this PON-specific protocol for
      the purposes of inter-chassis communication. This is set to
      0x0001.

   o A bit: Acknowledgement bit. It MUST be set to 1 if the sender has
      received a PON Connect TLV from the recipient. Otherwise, set to
      0.

   o Reserved: reserved for future use and MUST be set to zero.

o Optional Sub-TLVs: there are no optional Sub-TLVs defined for this
   version of the protocol. The structure of optional Sub-TLVs is
   defined 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|     Sub-TLV Type        |           Length                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Variable Length Value                    |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
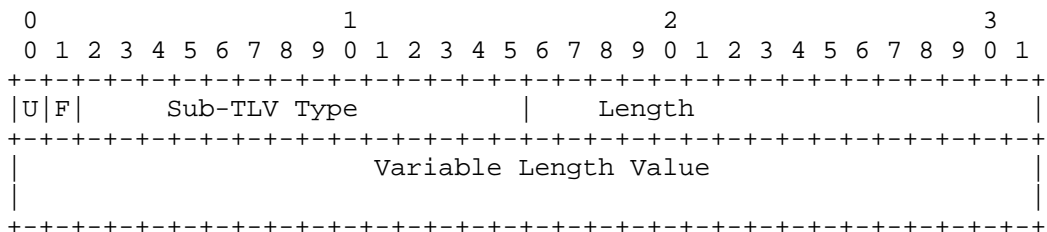
o U bit: set to 1. The unknown Sub-TLV is silently ignored.

o F bit: set to 0.

o The optional Sub-TLV Type values will be allocated by IANA in a
   registry named "ICC RG Parameter Types" for Pseudowire Name Spaces
   (PWE3).

o Length: length of the TLV in octets, excluding the U-bit, F-bit,
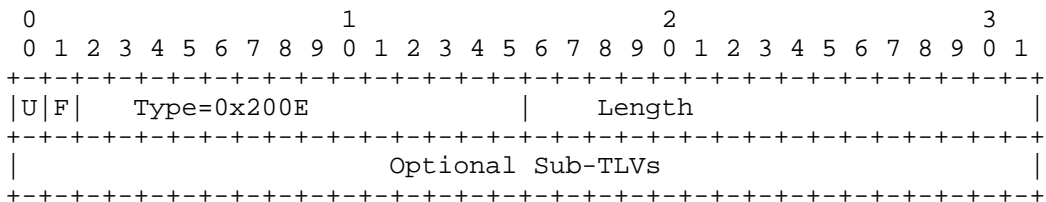   Type, and Length fields.

2.1.2. PON Disconnect TLV

   This TLV is included in the RG Disconnect message to indicate that
   the connection for the PON application is to be terminated.

```
 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|    Type=0x200E         |           Length                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Optional Sub-TLVs                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

o U and F bits: both are set to 0.

o Type: set to 0x200E for "PON Disconnect TLV".

o Length: length of the TLV in octets excluding the U-bit, F-bit,
   Type, and Length fields.

o Optional Sub-TLVs: there are no optional Sub-TLVs defined for this
   version of the protocol.

2.1.3. PON Configuration TLV

   The "PON Configuration TLV" is included in the "RG Application Data"
   message and announces an OLT's system parameters to other members in
   the same RG.

```
     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|   Type=0x200F             |            Length             |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                          System ID                            |
    |                                                               |
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |      System Priority          |            Port ID            |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
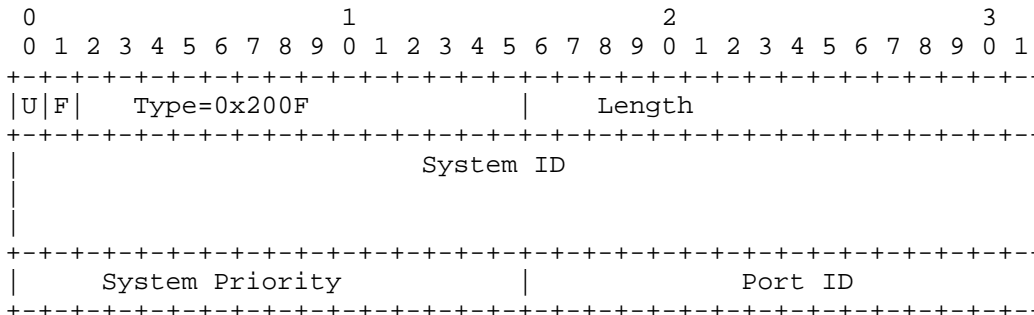
   o U and F bits: both are set to 0.

   o Type: set to 0x200F for "PON Configuration TLV".

   o Length: length of the TLV in octets excluding the U-bit, F-bit,
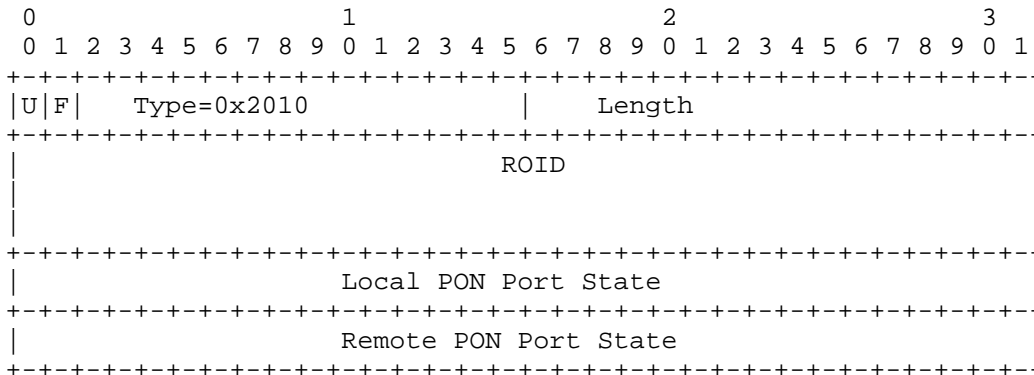   Type, and Length fields.

   o System ID: 8 octets encoding the System ID used by the OLT, which
      is the chassis Media Access Control (MAC) address. If a 6-octet
      System ID is used, the least significant 2 octets of the 8-octet
      field will be encoded as 0000.

   o System Priority: a 2-octet value assigned by management or
      administration policy; the OLT with the numerically lower value of
      System Priority has the higher priority.

   o Port ID: 2-octet PON Port ID.

2.1.4. PON State TLV

   The "PON State TLV" is included in the "RG Application Data" message
   and used by an OLT to report its PON states to other members in the
   same RG.

```
        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|    Type=0x2010            |           Length              |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                             ROID                             |
       |                                                              |
       |                                                              |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                    Local PON Port State                      |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
       |                    Remote PON Port State                     |
       +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

   o U and F bits: both are set to 0.

   o Type: set to 0x2010 for "PON State TLV".

   o Length: length of the TLV in octets excluding the U-bit, F-bit,
      Type, and Length fields.

   o ROID: Redundant Object ID (ROID) as defined in Section 4.3 of
      [RFC7275].

   o Local PON Port State: the status of the local PON port as
      determined by the sending OLT (PE). The last bit is defined as
      Fault indication of the PON Port associated with this PW (1 - in
      fault; 0 - in normal).

   o Remote PON Port State: the status of the remote PON port as
      determined by the remote peer of the sending OLT (i.e., the
      sending PE). The last bit is defined as Fault indication of the
      PON Port associated with this PW (1 - in fault; 0 - in normal).

3. Considerations on PON ONU Database Synchronization

   Without an effective mechanism to communicate the registered ONUs
   between the working and protection OLT, all registered ONUs would be
   de-registered and go through re-registration during a switchover,
   which would significantly increase protection time. To enable faster
   switchover capability, the working and protection OLTs need to know
   about the protected ONUs. To enable service continuity, a mechanism

needs to be employed such that the operational state and significant
configuration data of both the protected ONU and the services
provisioned to it can be distributed to the working and protection
OLT.

The specific ONU's configuration and operational data can be
synchronized by some policy mechanism or provisioned in the
management plane. Alternatively, said synchronization could occur by
some other signaling options. Describing how to synchronize the
configuration objects associated with both protected ONU as well as
the services constructed to the ONU (e.g., ONU MAC address, IPv4
addresses, IPv6 addresses, VLAN identifiers, etc.) is outside of the
scope of this document.

4. Multi-Chassis PON Application Procedures

Two typical MPLS protection network architectures for PON access are
depicted in Figures 2 and 3 (their PON access segments are the same
as in Figure 1 and thus omitted for simplification). OLTs with MPLS
functionality are connected to a single PE (Figure 2) or dual-homing
PEs (Figure 3), respectively, i.e., the working OLT to PE1 by a
working PW and the protection OLT to PE1 or PE2 by a protection PW;
thus, these devices constitute an MPLS network that provides PW
transport services between ONUs and a Customer Edge (CE), and the PWs
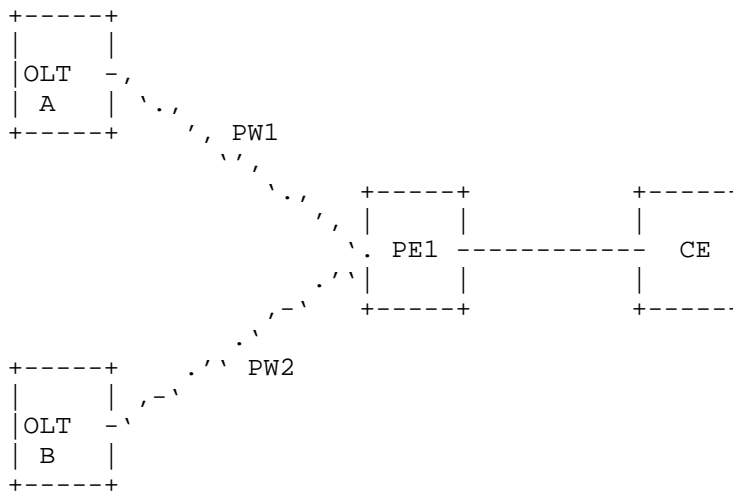can provide protection for each other.

```
              +-----+
              |     |
              |OLT  -,
              | A   | `.,
              +-----+    ', PW1
                        `',,
                          `.,   +-----+              +-----+
                            ', |     |              |     |
                              `. PE1 ------------  CE |
                            .'`|     |              |     |
                          ,-`   +-----+              +-----+
                        .`
              +-----+    .'` PW2
              |     | ,-`
              |OLT  -`
              | B   |
              +-----+
```
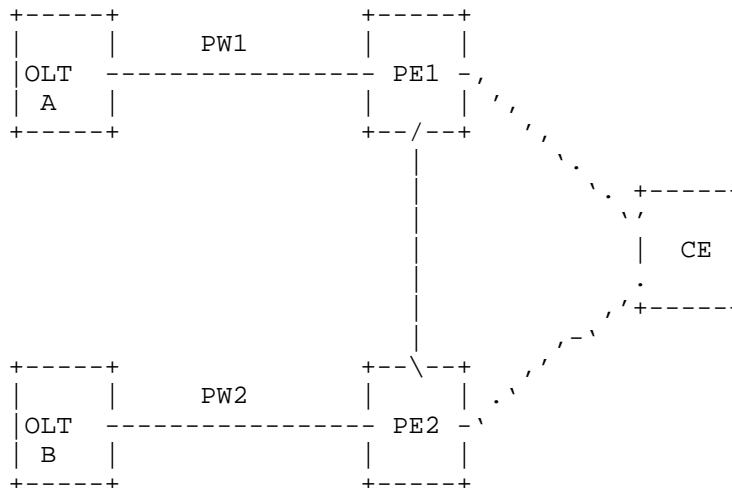
                Figure 2: An MPLS Network with a Single PE

```
      +-----+                 +-----+
      |     |      PW1        |     |
      |OLT  ---------------- PE1 -,
      | A   |                 |     | ',
      +-----+                 +--/--+    '',
                                 |           `.
                                 |             `. +-----+
                                 |            `,' |     |
                                 |               | CE  |
                                 |            .   |     |
                                 |          ,'+-----+
                                 |         ,-`
      +-----+                 +--\--+    ,'
      |     |      PW2        |     | .'
      |OLT  ---------------- PE2 -`
      | B   |                 |     |
      +-----+                 +-----+
```

                Figure 3: An MPLS Network with Dual-Homing PEs

   Faults may be encountered in PON access links or in the MPLS network
   (including the working OLT). Procedures for these cases are
   described in this section (it is assumed that both OLTs and PEs are
   working in the independent mode of PW redundancy [RFC6870]).

4.1. Protection Procedure upon PON Link Failures

   When a fault is detected on a working PON link, a working OLT
   switches to the corresponding protection PON link attached with its
   protection OLT, i.e., the working OLT turns off its faulty PON
   interface so that the protection trunk link to its protection OLT can
   be activated. Then, the working OLT MUST send an LDP fault
   notification message (i.e., with the status bit "Local AC (ingress)
   Receive Fault" being set) to its peer PE on the remote end of the PW.
   At the same time, the working OLT MUST send an ICCP message with PON
   State TLV with Local PON Port State being set to notify the
   protection OLT of the PON fault.

   Upon receiving a PON state TLV where Local PON Port State is set, a
   protection OLT MUST activate the protection PON link in the
   protection group and advertise a notification message for the
   protection PW with the Preferential Forwarding status bit of active
   to the remote PE.

   According to [RFC6870], the remote PE(s) can match the local and
   remote Preferential Forwarding status and select PW2 as the new
   active PW over which data traffic is sent.

4.2. Protection Procedure upon PW Failures

   Usually, MPLS networks have their own protection mechanism such as
   Label Switched Path (LSP) protection or Fast Reroute (FRR). But, in
   a link-sparse access or aggregation network where protection for a PW
   is impossible in its LSP layer, the following PW layer protection
   procedures can be enabled.

   When a fault is detected on its working PW (e.g., by Virtual Circuit
   Connectivity Verification (VCCV) Bidirectional Forwarding Detection
   (BFD)), a working OLT SHOULD turn off its associated PON interface
   and then send an ICCP message with PON State TLV with Local PON Port
   State being set to notify the protection OLT of the PON fault.

   Upon receiving a PON state TLV where Local PON Port State is set, the
   protection OLT MUST activate its PON interface to the protection
   trunk fiber. At the same time, the protection OLT MUST send a
   notification message for the protection PW with the Preferential
   Forwarding status bit of active to the remote PE, so that traffic can
   be switched to the protection PW.

4.3. Protection Procedure upon the Working OLT Failure

   As depicted in Figure 2, a service is provisioned with a working PW
   and a protection PW, and both PWs are terminated on PE1. If PE1 lost
   its connection to the working OLT, it SHOULD send an LDP notification
   message on the protection PW with the Request Switchover bit set.

   Upon receiving an LDP notification message from its remote PE with
   the Request Switchover bit set, a protection OLT MUST activate its
   optical interface to the protection trunk fiber and activate the
   associated protection PW, so that traffic can be reliably switched to
   the protection trunk PON link and the protection PW.

4.4. Protection Procedure for a Dual-Homing PE

   In the case of Figure 3, the PW-RED State TLV as described in
   Section 7.1 of [RFC7275] can be used by PE1 to notify PE2 of the
   faults in all the scenarios, and PE2 operates the same as described
   in Sections 4.1 to 4.3 of this document.

5. Security Considerations

   Similar to ICCP itself, this ICCP application SHOULD only be used in
   well-managed and highly monitored service provider PON access
   networks in a single administrative domain, including the
   implementation of rogue ONU attachment detection and mitigation via
   device authentication. Thus, many of the security considerations as
   described in [RFC7275] apply here as well.

   Again, similar to ICCP, activity on the attachment circuits may cause
   security threats or be exploited to create denial-of-service attacks.
   In many passive optical networks, the optical paths between OLT and
   ONUs traverse publicly accessible facilities including public
   attachments (e.g., telephone poles), which opens up the risk of
   excessive link bouncing by optical layer impairment. While ICCP for
   MC-PON interconnects in the MPLS domain and does not traverse the PON
   network, risks do include introduction of a malicious ONU that could
   cause, for example, excessive link bouncing. This link bouncing
   could result in increased ICCP exchanges similar to the malicious CE
   case described in [RFC7275]. Operators of such networks should take
   additional care to restrict unauthorized ONUs and to limit the impact
   of link bouncing at the OLT, as these could result in service
   impairment.

6. IANA Considerations

   IANA maintains a top-level registry called "Pseudowire Name Spaces
   (PWE3)". It has a subregistry called "ICC RG Parameter Types". The
   following values have been allocated from this subregistry:

      0x200D   PON Connect TLV
      0x200E   PON Disconnect TLV
      0x200F   PON Configuration TLV
      0x2010   PON State TLV

7. References

7.1. Normative References

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             Mobile Backhaul Networks", BBF TR-221, October 2011.

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