Network Working Group Y. Jiang, Ed.
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E. Mallette, Ed.
Charter Communications
Y. Shen
Juniper Networks
W. Cheng
China Mobile
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Multi-chassis Passive Optical Network (PON) Protection in MPLS
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Abstract

Multi-Protocol 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. Multi-homing support is needed on the MPLS-enabled PON OLT to provide resiliency for provided services. This document describes the multi-chassis PON protection architecture in MPLS and also specifies the Inter-Chassis Communication Protocol (ICCP) extension to support it.

Status of this Memo

This Internet-Draft will expire on March 28, 2017.

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1. Introduction

Multi-Protocol Label Switching (MPLS) is being extended to the edge of operator networks, as is described in the Multi-Segment Pseudowires 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 (1Gbps or even 10Gbps) 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 network 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 hangs 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 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, Digital Subscriber Line (DSL) and Multi-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 DOCSIS Remote PHY device [remote-phy], and it may further be attached with dozens of Customer Premise 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) are 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.

Inter-Chassis Communication Protocol (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 (PW) redundancy 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	Multi-Protocol Label Switching
PON	Passive Optical Network
RG	Redundancy Group

2. ICCP Protocol Extensions

2.1. Multi-chassis PON Application TLVs

A set of multi-chassis PON application Type-Length-Values (TLVs) are defined in the following sub-sections.

2.1.1.   PON Connect TLV

This TLV is included in the Redundancy Group (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=0xTBD1               |    Length                   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |      Protocol Version          |A|         Reserved            |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Optional Sub-TLVs                           |
   ~                                                                ~
   |                                                                |
   +                                 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |             ...                 |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits, both are set to 0.

- Type, set to 0xTBD1 for "PON Connect TLV".

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

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

- 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.

- Reserved, Reserved for future use, and MUST be set to zero.

- 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
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | Sub-TLV Type  |    Length     |    Variable Length Value      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         Variable Length Value                 |
   |                             "                                 |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- The Optional Sub-TLV Type values will be allocated by IANA in a registry of name "TLV Type Name Space" for Label Distribution Protocol (LDP) Parameters. Processing of the Sub-TLV Types should continue when unknown Sub-TLV Type parameters are encountered, and they MUST be silently ignored.

- The Length field is defined as the length of the Sub-TLV Type including the Sub-TLV Type field and Length field itself.

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=0xTBD2             |    Length                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Optional Sub-TLVs                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits, both are set to 0.

- Type, set to 0xTBD2 for "PON Disconnect TLV".

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

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

2.1.3.   PON System Configuration TLV

The "PON System 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=0xTBD3             |    Length                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         System ID                             |
   |                                                              |
   |                                                              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     System Priority           |             Port ID           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits, both are set to 0.

- Type, set to 0xTBD3 for "PON System Configuration TLV".

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

- System ID, 8 octets encoding the System ID used by the OLT, which is the Chassis 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.

- 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.

- Port ID, 2 octets 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=0xTBD4             |    Length                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                              ROID                             |
   |                                                               |
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Local PON Port state                       |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                    Remote PON Port state                      |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits, both are set to 0.

- Type, set to 0xTBD4 for "PON State TLV"

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

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

- 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).

- 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 ONUs 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 Fig.2 and Fig.3 (their PON access segments are the same as in Fig.1 and thus omitted for simplification). OLTs with MPLS functionality are connected to a single PE (Fig.2) or dual home PEs (Fig.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 which 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. The working OLT then 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 its own protection mechanism such as 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 VCCV 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 Fig. 2, a service is provisioned with a working PW and a protection PW, both PW 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.

In the case of Fig.3, PW-RED State TLV as described in Section 7.1 of [RFC7275] can be used by PE1 to notify PE2 the faults in all the scenarios, and PE2 operates the same as described in Section 5.1 to 5.3.

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 which 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

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

0xTBD1	PON Connect TLV
0xTBD2	PON Disconnect TLV
0xTBD3	PON Configuration TLV
0xTBD4	PON State TLV

[Note to IANA, to be removed by the RFC Editor: consecutive values in the IETF Review range are requested.]

7. References

7.1. Normative References

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7.2. Informative References

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Contributors

The following people made significant contributions to this document:

Chengbin Shen
China Telecom
1835 South Pudong Road
Shanghai 200122, China
Email: shencb@sttri.com.cn

Guangtao Zhou
China Unicom
No.9 Shouti South Road
Beijing 100048, China
Email: zhouguangtao@chinaunicom.cn

Authors' Addresses

Yuanlong Jiang (Editor)
Huawei Technologies Co., Ltd.
Bantian, Longgang district
Shenzhen 518129, China
Email: jiangyuanlong@huawei.com

Yong Luo
Huawei Technologies Co., Ltd.
Bantian, Longgang district
Shenzhen 518129, China
Email: dennis.luoyong@huawei.com

Edwin Mallette (Editor)
Charter Communications
4145 S. Falkenburg Road
Tampa, FL 33578 USA
Email: edwin.mallette@gmail.com

Yimin Shen
Juniper Networks
10 Technology Park Drive
Westford, MA 01886, USA
Email: yshen@juniper.net

Weiqiang Cheng
China Mobile
No.32 Xuanwumen West Street
Beijing 100053, China
Email: chengweiqiang@chinamobile.com