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STP Application of ICCP
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Abstract

Inter-Chassis Communication Protocol (ICCP) supports the inter-chassis redundancy mechanism which achieves high network availability.

In this document, the PEs in a Redundant Group (RG) running ICCP are used to offer multi-homed connectivity to Spanning Tree Protocol (STP) networks. The ICCP TLVs for the STP application are defined, therefore PEs from the RG can make use of these TLVs to synchronize the state and configuration data of the STP network.

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Table of Contents

1. Introduction

Inter-Chassis Communication Protocol (ICCP) specifies a multi-chassis redundant mechanism, which enables PEs located in multi-chassis to act as a single Redundant Group (RG).

This document introduces Spanning Tree Protocol (STP) as a new application of ICCP. When a bridge network running STP is connected to a RG, the RG members should pretend to be a single root bridge to participate the operations of the STP. STP relevant information need be exchanged and synchronized among the RG members. ICCP TLVs for the Spanning Tree Protocol application are specified for this purpose.

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 RFC 2119 [RFC2119].

1.2. Terminology

STP: Spanning Tree Protocol
MSTP: Multiple Spanning Tree Protocol
DSLAM: Digital Subscriber Line Access Multiplexer
MST: Multiple Spanning Trees
CIST: Common and Internal Spanning Tree
MSTI: Multiple Spanning Tree Instance
BPDU: Bridge Protocol Data Unit

In this document, unless otherwise explicitly noted, when the term STP is used, it also covers MSTP.

2. The Use Case Scenario

In customers' broadband networks, bridged DSLAMs are usually geographically dispersed. It is a common case these DSLAMs are connected to carriers' L2VPN network at multiple points for the sake of reliability. Requirements from customers for this use case are listed as follows.

o These DSLAMs are running STP.

o These DSLAMs are not geographically close to each other. Multiple DSLAMs are connected to the carrier network at different locations.

o When one connection to the carrier network fails, customers wish a connection in another location can continue to work after the re-

convergence of the STP rather than compromising the whole STP network. The failure of the connection may be due to the failure of the PE, the AC or even the CE (a DSLAM) itself.

o Customers want to balance the load among those connections, therefore all those connections need be active.

In order to meet these requirements, the 'ICCP-STP' model is proposed in Section 2.1. It introduces STP as a new application of ICCP. A private implementation is depicted in Section 2.2 to serve as a contrast. Its issues are analyzed.

2.1. STP as an Application of ICCP

```
+---------------+       +=============+
|               |       |             |
|               |       |             |
|       +---+   |       |  +------+   |
|   +---+CE1+<6>-------<5>+ PE1  |    |
|  <1>  +---+   |       |  +------+   |
| +-+-+         |       |     ||      |
| |CE3|         |       |     || ICCP |
| +-+-+         |       |     ||      |
|  <2>  +---+   |       |  +------+   |
|   +---+CE2+<3>-------<4>+ PE2  |    |
|       +---+   |       |  +------+   |
|               |       |             |
| Multi-homed   |       |             |
| STP Network   |       |             |
+---------------+       +=============+
```

Figure 2.1: A STP network is multi-homed to an RG running ICCP.

Figure 2.1 shows an example topology of this model. With ICCP, the whole RG will be virtualized to be a single bridge. The RG pretends that the ports connected to the STP network (port <4>, <5>) are from the same bridge. All these ports emit configuration BPDU with the highest root priority to trigger the construction of the spanning tree. In this way, the STP will always broken a loop within the multi-homed STP network.

Each RG member has its BridgeIdentifier (the MAC address). The least significant one is elected as the BridgeIdentifier of the 'vitualized root bridge'.

2.2. A Private Solution: The BPDU Tunneling Model

```
             +---------------+       +=============+
             |               |       |             |
             |               |       |             |
             |       +---+   |       |  +-----+    |
             |   +---+CE1+<6>-------<5>+ PE1 |     |
             |  <1>  +---+   |       |  +-----+    |
             | +-+-+         |       |     ||BPDU  |
             | |CE3|         |       |     ||tunnel|
             | +-+-+         |       |     ||      |
             |  <2>  +---+   |       |  +-----+    |
             |   +---+CE2+<3>-------<4>+ PE2 |     |
             |       +---+   |       |  +-----+    |
             |               |       |             |
             | Multi-homed   |       |             |
             | STP Network   |       |             |
             +---------------+       +=============+
```

Figure 2.2: The BPDU Tunneling Model

Figure 2.2 shows an example network of the 'BPDU tunneling' model. Two PEs tunnel BPDUs of the STP network over PW. The OAM designed in RFC 7023 can be adopted for the interworking between MPLS and Ethernet.

In this model, the ports connected to the STP network at the PEs' side are non-bridge ports (e.g., port <4>, <5>). The tunnel between PE1 and PE2 is a transparent tunnel of BPDUs. For CE1 and CE2, they regard that there is a direct link between them. Issues of this model are listed as follows.

o Assume port <1> was blocked according to the STP calculation. Now, suppose link CE3-CE2 fails, port <2> is blocked while port <1> is unblocked. Since the BPDUs is just tunneled, PE2 is unaware of this change. It may continue to send traffic to CE3 via CE2 where a black-hole happens.

   In order to handle this issue, PEs have to snoop the Topology Change (TC) message of the STP network so the tunnel is not "transparent" to BPDUs anymore. When the TC event is sensed, these PEs should withdraw MAC addresses of those instances affected by the TC event across the carrier's network.

o When port <4> fails, CE1 is unaware. Suppose CE2 is the root bridge, port <6> has to wait for 3 STP HELLO Intervals (3*2s) and 2 Forwarding Delays (2*15s). The STP network takes at least 36 seconds to complete the convergence. The convergence process of the STP network is greatly slowed down. This actually changes the behavior of customers' STP networks.

In order to speed up the convergence, CE1 has to sense the state of the link between CE2 and PE2. The interworking PEs and CEs have to cope with various combinations of failures. There is no standard solution yet.

- o RFC 7023 is scoped to only single segment PWs [RFC6310][RFC 7023]. When the STP network is attached to more than two PEs, a full mesh PWs have to be set up. It's not clear yet what behaviors these PEs should have.

Compared with this 'BPDU tunneling' model, the advantage point of the "ICCP-STP" model is that PEs "participate" in the STP calculation, therefore we need not design the complex interworking mechanism.

3. Spanning Tree Protocol Application TLVs

This section discusses the ICCP TLVs for the Spanning Tree Protocol application.

3.1. STP Connect TLV

This TLV is included in the RG Connect message to signal the establishment of STP 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=TBD                |    Length                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Protocol Version         |A|          Reserved           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Optional Sub-TLVs                        |
~                                                               ~
|                                                               |
+                                 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|             ...                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP 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 particular protocol for the purposes of ICCP. This is set to 0x0001.

- A bit

  Acknowledgement Bit. Set to 1 if the sender has received a STP Connect TLV from the recipient. Otherwise, set to 0.

- Reserved

  Reserved for future use.

- Optional Sub-TLVs

  There are no optional Sub-TLVs defined for this version of the protocol.

3.2. STP Disconnect TLV

This TLV is used in an RG Disconnect Message to indicate that the connection for the STP 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=TBD                |    Length                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Optional Sub-TLVs                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Disconnect TLV"

- Length

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

- Optional Sub-TLVs

  The only optional Sub-TLV defined for this version of the protocol is the "STP Disconnect Cause" TLV defined next:

3.2.1. STP Disconnect Cause TLV

```
 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=TBD                |     Length                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                      Disconnect Cause String                  |
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Disconnect Cause TLV"

- Length

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

- Disconnect Cause String

  Variable length string specifying the reason for the disconnect. Used for network management.

3.3. STP Config TLVs

The STP Config TLVs are sent in the RG Application Data message. When a STP Config TLV is received by a peering RB member, it SHOULD synchronize the configuration information contained in the TLV. TLVs specified from section 3.3.1 through section 3.3.9 contains such kind of configuration information.

3.3.1. STP System Config

This TLV announces the local node's STP System Parameters to the RG peers.

```
    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=TBD                |    Length                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                              ROID                             |
   +                                                               +
   |                                                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                         MAC Address                           |
   +                               +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                               |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP System Config"

- Length

  Length of the MAC address, which is 6 octets.

-ROID

  As defined in the ROID section of [ICCP].

- MAC Address

  The MAC address of the sender. This MAC address is set to the BridgeIdentifier of the sender, as defined in [802.1q] section 13.23.2. The the least significant unsigned BridgeIdentifier is used as the MAC address of the Virtual Root Bridge mentioned in Section 2.1.

3.3.2. STP Topology Changed Instances

This TLV is used to report the Topology Changed Instances to other members in the RG. The receiver RG member SHOULD enforce the Topology Change to its port connected to the STP network, including the flush out of MAC addresses relevant to the instances listed in this TLV.

```
    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=TBD                |    Length                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                        InstanceID List                        |
   ~                                                               ~
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Topology Changed Instances"

- Length

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

- InstanceID List

  The list of the instances whose topology is changed as indicated by the Topology Change Notification (TCN) Messages as specified in [802.1q] section 13.14.

3.3.3. STP CIST Root Time

This TLV is used to report the Value of CIST Root Time to other members in the 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=TBD                |    Length                     |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |    MaxAge     |   MessageAge  |    FwdDelay   |   HelloTime   |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   | RemainingHops |
   +-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

set to TBD for "STP CIST Root Time"

- Length

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

- MaxAge

  The Maximum Age of this TLV.

- MessageAge

  The actual age of this TLV.

- FwdDelay

  The delay before the port enters the forwarding status.

- HelloTime

  The interval between two continuous configuration BPDUs.

- RemainingHops

  The remaining hops of this TLV

3.3.4. STP MSTI Root Time

This TLV is used to report the Value of MSTI Root Time to other members in the 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=TBD                |    Length                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         InstanceID            | RemainingHops |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP MSTI Root Time"

- Length

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

- InstanceID

  The instance identification number of the MSTI.

- remainingHops

  The remaining hops of this TLV

3.3.5. STP Region Name

This TLV is used to report the Value of Region Name to other members in the 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=TBD                |     Length                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Region Name                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Region Name"

- Length

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

- Region Name

  The Name of the MST Region.

3.3.6. STP Revision Level

This TLV is used to report the Value of Revision Level to other members in the 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=TBD                |    Length                     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |       Revision Level          |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Revision Level"

- Length

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

- Revision Level

  The Revision Level as specified in [802.1q] section 3.21;

3.3.7. STP Instance Priority

This TLV is used to report the Value of Instance Priority to other members in the 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=TBD                |    Length                     |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |  Pri  |      InstanceID       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Instance Priority"

- Length

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

- Pri

  The Instance Priority

- InstanceID

  The instance identification number of the MSTI.

3.3.8. STP Configuration Digest

This TLV is used to report the Value of STP VLAN Instance Mapping to other members in the 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=TBD                |     Length                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Configuration Digest                       |
~                                                               ~
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Configuration Digest"

- Length

  Length of the STP Configuration Digest which is 16 octets.

- Configuration Digest

  As specified in [802.1q] section 13.7.

3.4. STP Synchronization Request TLV

The STP Synchronization Request TLV is used in the RG Application Data message. This TLV is used by a device to request from its peer to re-transmit configuration or operational state. The following information can be requested:

- system configuration and/or state
- configuration and/or state for a specific port

The format of the TLV is as follows:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|U|F|   Type=TBD                |    Length                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Request Number           |C|S|    Request Type           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      Port Number              |             Actor Key         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Synchronization Request TLV"

- Length

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

  - Request Number

  2 octets. Unsigned integer uniquely identifying the request. Used to match the request with a response. The value of 0 is reserved for unsolicited synchronization, and MUST NOT be used in the STP Synchronization Request TLV.

- C Bit

  Set to 1 if request is for configuration data. Otherwise, set to 0.

- S Bit

  Set to 1 if request is for running state data. Otherwise, set to 0.

- Request Type

  14-bits specifying the request type, encoded as follows:

0x00 Request System Data
0x01 Request Port Data
0x3FFF Request All Data

- Port Number

  2 octets. When Request Type field is set to 'Request Port Data', this field encodes the STP Port Number for the requested port. When the value of this field is 0, it denotes that all ports, whose STP Key is specified in the "Actor Key" field, are being requested.

- Actor Key

  2 octets. STP Actor key for the corresponding port. When the value of this field is 0 (and the Port Number field is 0 as well), it denotes that information for all ports in the system is being requested.

3.5. STP Synchronization Data TLV

The STP Synchronization Data TLV is used in the RG Application Data message. A pair of these TLVs is used by a device to delimit a set of TLVs that are being transmitted in response to an STP Synchronization Request TLV. The delimiting TLVs signal the start and end of the synchronization data, and associate the response with its corresponding request via the 'Request Number' field.

The STP Synchronization Data TLVs are also used for unsolicited advertisements of complete STP configuration and operational state data. The 'Request Number' field MUST be set to 0 in this case.

This TLV has the following format:

- U and F Bits

  Both are set to 0.

- Type

  set to TBD for "STP Synchronization Data TLV"

- Length

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

  - Request Number

2 octets. Unsigned integer identifying the Request Number from the "STP Synchronization Request TLV" which solicited this synchronization data response.

- Flags

  2 octets, response flags encoded as follows:

  0x00 Synchronization Data Start
  0x01 Synchronization Data End

4. Security Considerations

This document raises no new security issues.

5. IANA Considerations

The types used by the application TLVs defined in Section 3 should be assigned.

Acknowledgements

The authors would like to thank the comments and suggestions from Gregory Mirsky.

6. References

6.1. Normative References

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[RFC7023] D. Mohan, Ed., N. Bitar, Ed., A. Sajassi, Ed., S. DeLord, P. Niger, R. Qiu., "MPLS and Ethernet Operations, Administration, and Maintenance (OAM) Interworking", RFC 7023, October 2013.

6.2. Informative References

[RFC6310] Aissaoui, M., Busschbach, P., Martini, L., Morrow, M., Nadeau, T., and Y(J). Stein, "Pseudowire (PW) Operations, Administration, and Maintenance (OAM) Message Mapping", RFC 6310, July 2011.

[802.1q] "IEEE Standard for Local and Metropolitan Area Networks---Virtual Bridged Local Area Networks.". IEEE Std 802.1 Q-2005, May 19, 2006.

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