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Use of Ethernet Control Word RECOMMENDED
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Abstract

The pseudowire (PW) encapsulation of Ethernet, as defined in RFC4448, specifies that the use of the control word (CW) is optional. In the absence of the CW an Ethernet pseudowire packet can be misidentified as an IP packet by a label switching router (LSR). This in turn may lead to the selection of the wrong equal-cost-multi-path (ECMP) path for the packet, leading in turn to the mis-ordering of packets. This problem has become more serious due to the deployment of equipment with Ethernet MAC addresses that start with 0x4 or 0x6. The use of the Ethernet PW CW addresses this problem. This document recommends the use of the Ethernet pseudowire control word in all but exceptional circumstances.

This document updates RFC4448.

Status of This Memo

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1. Introduction

The pseudowire(PW) encapsulation of Ethernet, as defined in RFC4448, specifies that the use of the control word (CW) is optional. It is common for label switching routers (LSRs) to search past the end of the label stack to determine whether the payload is an IP packet, and if the payload is an IP packet, to select the next hop based on the so called "five-tuple" (IP source address, IP destination address, protocol/next-header, transport layer source port and transport layer destination port). In the absence of a PW CW an Ethernet pseudowire packet can be misidentified as an IP packet by a label switching router (LSR) selecting the ECMP path based on the five-tuple. This in turn may lead to the selection of the wrong equal-cost-multi-path (ECMP) path for the packet, leading in turn to the mis-ordering of packets. Further discussion of this topic is published in [RFC4928].

Flow misordering can also happen in a single path scenario when traffic classification and differential forwarding treatment mechanisms are in use. This occurs when a forwarder incorrectly assumes that the packet is IP and applies forwarding policy based on fields in the PW payload.

This problem has recently become more serious for a number of reasons. Firstly due to the deployment of equipment with Ethernet MAC addresses that start with 0x4 or 0x6 assigned by the IEEE RAC. Secondly, concerns over privacy have led to the use of MAC address randomization which assigns local MAC addresses randomly for privacy. Random assignment produces addresses starting with one of the two values about 1/8 of the time.

The use of the Ethernet PW CW addresses this problem.

This document recommends the use of the Ethernet pseudowire control word in all but exceptional circumstances.

2. Specification of Requirements

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

3. Background

Ethernet pseudowire encapsulation is specified in [RFC4448]. In particular the reader is drawn to section 4.6, part of which is quoted below for the convenience of the reader:

"The control word defined in this section is based on the Generic PW MPLS Control Word as defined in [RFC4385]. It provides the ability to sequence individual frames on the PW, avoidance of equal-cost multiple-path load-balancing (ECMP) [RFC2992], and Operations and Management (OAM) mechanisms including VCCV [RFC5085].

"[RFC4385] states, "If a PW is sensitive to packet misordering and is being carried over an MPLS PSN that uses the contents of the MPLS payload to select the ECMP path, it MUST employ a mechanism which prevents packet misordering." This is necessary because ECMP implementations may examine the first nibble after the MPLS label stack to determine whether the labeled packet is IP or not. Thus, if the source MAC address of an Ethernet frame carried over the PW without a control word present begins with 0x4 or 0x6, it could be mistaken for an IPv4 or IPv6 packet. This could, depending on the configuration and topology of the MPLS network, lead to a situation where all packets for a given PW do not follow the same path. This may increase out-of-order frames on a given PW, or cause OAM packets to follow a different path than actual traffic (see Section 4.4.3, "Frame Ordering").

"The features that the control word provides may not be needed for a given Ethernet PW. For example, ECMP may not be present or active on a given MPLS network, strict frame sequencing may not be required, etc. If this is the case, the control word provides little value and is therefore optional. Early Ethernet PW implementations have been deployed that do not include a control word or the ability to process one if present. To aid in backwards compatibility, future implementations MUST be able to send and receive frames without the control word present."

At the time when pseudowires were first deployed, some equipment of commercial significance was unable to process the Ethernet Control Word. In addition, at that time it was considered that no Ethernet MAC address had been issued by the IEEE Registration Authority Committee (RAC) that starts with 0x4 or 0x6, and thus it was thought to be safe to deploy Ethernet PWs without the CW.

Since that time the RAC has issued Ethernet MAC addresses start with 0x4 or 0x6 and thus the assumption that in practical networks there would be no confusion between an Ethernet PW packet without the CW and an IP packet is no longer correct.

Possibly through the use of unauthorized Ethernet MAC addresses, this assumption has been unsafe for a while, leading some equipment

vendors to implement more complex, proprietary, methods to discriminate between Ethernet PW packets and IP packets. Such mechanisms rely on the heuristics of examining the transit packets in trying to find out the exact payload type of the packet and cannot be reliable due to the random nature of the payload carried within such packets.

A recent posting on the Nanog email list has highlighted this problem:

<https://mailman.nanog.org/pipermail/nanog/2016-December/089395.html>

RFC EDITOR Please delete this paragraph.

Kramdown does not include references when they are only found in literal text so I include them here: [RFC4385] [RFC2992] [RFC5085] as a fixup.

4. Recommendation

The ambiguity between an MPLS payload that is a Ethernet PW and one that is an IP packet is resolved when the Ethernet PW control word is used. This document updates RFC4448 [RFC4448] to state that where both both the ingress PE and the egress PE support the Ethernet pseudowire control word, then the CW MUST be used.

5. Equal Cost Multi-path (ECMP)

Where the volume of traffic on an Ethernet PW is such that ECMP is required then one of two methods may be used:

- o Flow-Aware Transport (FAT) of Pseudowires over an MPLS Packet Switched Network specified in [RFC6391], or
- o LSP entropy labels specified [RFC6790]

RFC6391 works by increasing the entropy of the bottom of stack label. It requires that both the ingress and egress provider edge (PE)s support this feature. It also requires that sufficient LSRs on the LSP between the ingress and egress PE be able to select an ECMP path on an MPLS packet with the resultant stack depth.

RFC6790 works by including an entropy value in the LSP part of the label stack. This requires that the Ingress and Egress PEs support the insertion and removal of the entropy label (EL) and the entropy label indicator, and that sufficient LSRs on the LSP are able to preform ECMP based on the EL.

In both cases there considerations in getting Operations, Administration, and Maintenance (OAM) packets to follow the same path as a data packet. This is described in detail section 7 of [RFC6391], and section 6 of RFC6790. However in both cases the situation is improved compared to the ECMP behavior in the case where the Ethernet PW CW was not used, since there is currently no known method of getting a PW OAM packet to follow the same path as a PW data packet subjected to ECMP based on the five tuple of the IP payload.

6. Mitigations

Where it is not possible to use the Ethernet PW CW, the effects of ECMP can be disabled by carrying the PW over a traffic engineered path that does not subject the payload to load balancing (for example [RFC3209]). However such paths may be subjected to link bundle load balancing and of course the single LSP has to carry the full PW load.

7. Operational Considerations

CW presence on the PW is controlled by the configuration and may be subject to default operational mode of not being enabled. Care needs to be taken to ensure that software that implements this recommendation does not depend on existing configuration setting that prevents the use of control word. It is recommended that platform software emits a rate limited message indicating that CW can be used but is disabled due to existing configuration.

To remove this problem in the long term, and hence to reduce the operational cost of investigating problems associated with the incorrect forwarding of Ethernet packets over PWs not using the CW, it is RECOMMENDED that equipment that does not support the CW be phased out of operational use.

8. Security Considerations

This document expresses a preference for one existing and widely deployed Ethernet PW encapsulation over another. These methods have identical security considerations, which are discussed in [RFC4448]. This document introduces no additional security issues.

9. IANA Considerations

This document makes no IANA requests.

10. Acknowledgements

The authors thank Job Snijders for drawing attention to this problem. The authors also thank Pat Thaler for clarifying the matter of local MAC address assignment.

11. References

11.1. Normative References

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- [RFC6790] Kompella, K., Drake, J., Amante, S., Henderickx, W., and L. Yong, "The Use of Entropy Labels in MPLS Forwarding", RFC 6790, DOI 10.17487/RFC6790, November 2012, <<http://www.rfc-editor.org/info/rfc6790>>.

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- [RFC3209] Awduche, D., Berger, L., Gan, D., Li, T., Srinivasan, V., and G. Swallow, "RSVP-TE: Extensions to RSVP for LSP Tunnels", RFC 3209, DOI 10.17487/RFC3209, December 2001, <<http://www.rfc-editor.org/info/rfc3209>>.
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YANG Data Model for PW Protocol
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Abstract

This document defines a YANG data model for PW configuration and operation.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

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1. Introduction

YANG[RFC6020] is a data definition language that was introduced to define the contents of a conceptual data store that allows networked devices to be managed using NETCONF ([RFC6241]). YANG ([RFC6020]) is a modular language that represents data structures in an XML or JSON tree format, and is used as a data modeling language for the NETCONF.

This document defines a YANG data model for PW configuration and operation. It includes point-to-point SS-PWs and MS-PWs that are signaled via LDP, and also for static provisioned (MPLS-TP) SS-PWs and MS-PWs.

2. SS-PW

This container defines all the configuration parameters related to ss-pw.

It includes pw name, peer ip, tunnel parameters, pw-type, parameters associated with interface, parameters associated with LDP pw and parameters associated with static pw.

3. MS-PW

This container defines all the configuration parameters related to ms-pw.

It includes ms-pw name, list of pw-segment-a and list of pw-segment-z.

4. Design of the Data Model

```

module: ietf-pw
  +--rw pwe3
    +--rw ss-pw
      +--rw ss-pw* [name]
        +--rw name string
        +--rw peer-ip? inet:ip-address
        +--rw cw-capable? cw-capable-type
        +--rw type? pw-type
        +--rw tunnel* [tunnel-id]
          | +--rw tunnel-id string
        +--rw leaf-type? pw-type
        +--rw autodiscovery-enable? boolean
        +--rw interfaces
          +--rw interface* [name]
            +--rw name if:interface-ref
            +--rw mtu? uint32
            +--rw fcs-retention-indicator? uint16
            +--rw vccv-parameter
              | +--rw cc? cc-type
              | +--rw cv? cv-type
            +--rw requested-vlan-id? uint32
            +--rw frag-indicator? uint32
            +--rw interface-description? string
            +--rw (pw-emu-type)?
              +--:(tdm)
                +--rw bit-rate? uint32
                +--rw payload-bytes? uint16
                +--rw cells-per-packet? uint16
                +--rw tdm-options
                  | +--rw rtp? pw-rtp-flag
                  | +--rw timestamp-mode? pw-timestamp-mode
                  | +--rw frequency? uint16
                  | +--rw ssrc? uint32
                  | +--rw payload-type? uint8
                  | +--rw cas? uint8
                  | +--rw sp? uint8
                +--rw cep-option
                  +--rw ais? uint8
                  +--rw une? uint8
                  +--rw rtp? uint8
                  +--rw ebm? uint8
                  +--rw async-t3? uint8
                  +--rw async-e3? uint8
                  +--rw cep-type? uint16
              +--:(fr)
                +--rw fr-dlci-len? uint16

```

```

|         |         +---:(atm)
|         |         +---rw max-atm-cells?                uint16
+---rw (pw-type)?
|         +---:(ldp-pw)
|         |         +---rw (fec-type)?
|         |         +---:(generalized-pwid-fec-type)
|         |         |         +---rw agi?                string
|         |         |         +---rw source-AII?          string
|         |         |         +---rw target-AII?          string
|         |         +---:(pwid-fec)
|         |         +---rw pw-id?                        uint32
+---:(static-pw)
|         +---rw static-pw-id?                uint32
|         +---rw transmit-label?              uint32
|         +---rw receive-label?               uint32
+---rw ms-pw
|         +---rw ms-pw* [name]
|         |         +---rw name                string
|         |         +---rw pw-segment-a* [name]
|         |         |         +---rw name        string
|         |         +---rw pw-segment-z* [name]
|         |         +---rw name                string

```

5. PW YANG Data Model

```

<CODE BEGINS> file "ietf-pw.yang"
module ietf-pw {
  namespace "urn:ietf:params:xml:ns:yang:ietf-pw";
  prefix "pw";

  import ietf-inet-types {
    prefix "inet";
  }

  import ietf-interfaces {
    prefix "if";
  }

  organization "ietf";
  contact "ietf";
  description "pw";

  revision "2017-05-05" {
    description "02 revision.";
    reference "draft-chen-pals-pw-yang-02.txt";
  }
  revision "2016-10-05" {

```

```
        description "01 revision.";
        reference "draft-chen-pals-pw-yang-01.txt";
    }
revision "2016-03-30" {
    description "Initial revision of pw model.";
    reference "draft-chen-pals-pw-yang-00.txt";
}
/* typedefs */

typedef cw-capable-type {
    type enumeration {
        enum "non-preferred" {
            description "No preference for control-word";
        }
        enum "preferred" {
            description "Prefer to have control-word negotiation";
        }
    }
    description "control-word capable preference type";
}

typedef cc-type {
    type enumeration {
        enum pw-ach {
            description "PWE3 Control Word with 0001b as first nibble (PW-AC
H, see [RFC4385])";
        }
        enum alert-label {
            description "MPLS Router Alert Label";
        }
        enum ttl {
            description "MPLS PW Label with TTL == 1";
        }
    }
    description "The defined values for CC(Control Channel) Types for MPLS P
Ws.";
}

typedef cv-type {
    type enumeration {
        enum ICMP-ping {
            description "ICMP-ping.";
        }
        enum LSP-ping {
            description "LSP-ping";
        }
        enum BFD-basic-ip {
            description "BFD basic ip";
        }
        enum BFD-basic-raw {
```

```
        description "BFD basic raw ";
    }
    enum BFD-signalling-ip {
        description "BFD signalling ip";
    }
    enum BFD-signalling-raw {
        description "BFD signalling raw";
    }
}
}
description "The defined values for CV(Connectivity Verification) Types
for MPLS PWs";
}

typedef pw-type {
    type enumeration {
        enum unknown {
            value 0 ;
            description "The PW type is unknown";
        }
        enum dlciOld {
            value 1 ;
            description "The PW type is dlciOld";
        }
        enum atmSdu {
            value 2 ;
            description "The PW type is atmSdu";
        }
        enum atmCell {
            value 3 ;
            description "The PW type is atmCell";
        }
        enum vlan {
            value 4 ;
            description "The PW type is vlan";
        }
        enum ethernet {
            value 5 ;
            description "The PW type is ethernet";
        }
        enum hdlc {
            value 6 ;
            description "The PW type is hdlc";
        }
        enum ppp {
            value 7 ;
            description "The PW type is ppp";
        }
        enum sdhCESoM {
```

```
        value 8 ;
        description "The PW type is sdhCESoM";
    }
    enum atmVCCn {
        value 9 ;
        description "The PW type is atmVCCn";
    }
    enum atmVPCn {
        value 10 ;
        description "The PW type is atmVPCn";
    }
    enum ipL2 {
        value 11 ;
        description "The PW type is ipL2";
    }
    enum atmVCC1 {
        value 12 ;
        description "The PW type is atmVCC1";
    }
    enum atmVPC1 {
        value 13 ;
        description "The PW type is atmVPC1";
    }
    enum atmPDU {
        value 14 ;
        description "The PW type is atmPDU";
    }
    enum frPort {
        value 15 ;
        description "The PW type is frPort";
    }
    enum sdhCEoP {
        value 16 ;
        description "The PW type is sdhCEoP";
    }
    enum saTopE1 {
        value 17 ;
        description "The PW type is saTopE1";
    }
    enum saTopT1 {
        value 18 ;
        description "The PW type is saTopT1";
    }
    enum saTopE3 {
        value 19 ;
        description "The PW type is saTopE3";
    }
}
```

```
        enum saTopT3 {
            value 20 ;
            description "The PW type is saTopT3";
        }
        enum ceSoPSNB {
            value 21 ;
            description "The PW type is ceSoPSNB";
        }
        enum tdmAAL1 {
            value 22 ;
            description "The PW type is tdmAAL1";
        }
        enum ceSoPSNC {
            value 23 ;
            description "The PW type is ceSoPSNC";
        }
        enum tdmAAL2 {
            value 24 ;
            description "The PW type is tdmAAL2";
        }
        enum dlciNew {
            value 25 ;
            description "The PW type is dlciNew";
        }
    }
    description "The PW type of the PW.";
}

typedef pw-rtp-flag {
    type enumeration {
        enum UNUSE {
            value 0 ;
            description 'Not use the rtp header.' ;
        }
        enum USE {
            value 1 ;
            description 'Use the rtp header.' ;
        }
        enum UNKNOWN {
            value 3 ;
            description 'The usage of the rtp header is unknown.' ;
        }
    }
    description 'The use flag of rtp header.' ;
}

typedef pw-timestamp-mode {
    type enumeration {
```



```
enum Absolute {
    value 0 ;
    description 'The timestamp mode is absolute.' ;
}
enum Differential {
    value 1 ;
    description 'The timestamp mode is differential .' ;
}
enum UNKNOWN {
value 3 ;
    description 'The timestamp mode is unknown.' ;
}
description 'The timestamp mode of TDM service.' ;
}

container pwe3 {
    description "configure pw";
    container ss-pw {
        description "configure ss-pw";
        list ss-pw {

            key "name";
            leaf name {
                type string;
                description "ss-pseudowire name";
            }
            leaf peer-ip {
                type inet:ip-address;
                description "peer IP address";
            }
            leaf cw-capable {
                type cw-capable-type;
                default "preferred";
                description "control-word negotiation preference";
            }
            leaf type {
                type pw-type;
                description "pseudo-wire type";
            }

            list tunnel {
                key "tunnel-id";
                leaf tunnel-id {
                    type string;
                    description "tunnel identifier";
                }
                description "tunnel list";
            }
        }
    }
}
```

```
    }

    leaf leaf-type {
      type pw-type;
      description "pseudo-wire type";
    }
    leaf autodiscovery-enable{
type boolean;
      description "enable the auto-discovery";
    }

    container interfaces {
      description "Interfaces";
      list interface{
        key "name";
        leaf name {
          type if:interface-ref;
          description "Interfaces used for pw";
        }
        leaf mtu {
          type uint32;
          description "pseudowire mtu";
        }
        leaf fcs-retention-indicator {
          type uint16;
          description "The negotiated fcs retention indicator of the PW";
        }
      }
      container vccv-parameter {
        description "vccv-parameter";
        leaf cc {
          type cc-type;
          description "Control Channel Types";
        }
        leaf cv {
          type cv-type;
          description "Connectivity Verification Types";
        }
      }
    }

    leaf requested-vlan-id {
      type uint32;
      description "The local requested VLAN ID of the PW";
    }

    leaf frag-indicator {
      type uint32;
      description "The local fragmentation indicator of the PW";
    }
  }
```

```
    leaf interface-description {
        type string {
            length 0..81;
        }
        description "The local interface description of the PW";
    }

    choice pw-emu-type {
        description "The emulation type of the PW. It could be tdm, fr and
        atm. There are different interface parameters for different emulation types";

        case tdm {
            leaf bit-rate {
                type uint32;
                description "The local bit rate of the PW";
            }

            leaf payload-bytes {
                type uint16;
                description "The local payload bytes of the PW";
            }

            leaf cells-per-packet {
                type uint16;
                description "The local TDMoIP AAL1 cells per packet of the PW";
            }

            container tdm-options {
                description "The TDM Options parameter of the PW";
                leaf rtp {
                    type pw-rtp-flag;
                    description "The local rtp header usage";
                }
                leaf timestamp-mode {
                    type pw-timestamp-mode;
                    description "The local timestamp mode";
                }
                leaf frequency {
                    type uint16;
                    description "The local frequency of timestamping clock";
                }
                leaf ssrc {
                    type uint32;
                    description "The local value of the Synchronization source ID";
                }
                leaf payload-type {
                    type uint8;
                    description "The local payload type in the RTP header expected by the PW endpoint distributing this FEC";
                }
            }
        }
    }
};
```

```

    leaf cas {
        type uint8 ;
        description "The local cas of the PW";
    }
    leaf sp {
        type uint8 ;
        description "The local sp of the PW";
    }
}

    container cep-option {
description "The CEP Options parameter of the PW";
    leaf ais {
        type uint8;
        description "The local ais of CEP Options parameter of the P
W";
    }
    leaf une {
        type uint8;
        description "The local une of CEP Options parameter of the P
W";
    }
    leaf rtp {
        type uint8;
        description "The local rtp of CEP Options parameter of the P
W";
    }
    leaf ebm {
        type uint8;
        description "The local ebm of CEP Options parameter of the P
W";
    }
    leaf async-t3 {
        type uint8;
        description "The local async-t3 of CEP Options parameter of
the PW";
    }
    leaf async-e3 {
        type uint8;
        description "The local async-e3 of CEP Options parameter of
the PW";
    }
    leaf cep-type {
        type uint16;
        description "The local cep type of CEP Options parameter of
the PW";
    }
}
}

    case fr {
description "The emulation type of the PW is fr";
    leaf fr-dlci-len {
        type uint16;
        description "The local fr dlci length of the PW";
    }
}

```

```
    }
    case atm {
      description "The emulation type of the PW is atm";
      leaf max-atm-cells {
        type uint16;
        description "The local max atm cells of the PW";
      }
    }
  }
  description "interface list";
}

choice pw-type {
  description "A choice of pseudowire type";
  case ldp-pw {
    choice fec-type {
      description "fec type";
      case generalized-pwid-fec-type {
        leaf agi {
          type string;
          description "Attachment Group Identifier";
        }
        leaf source-AII {
          type string;
          description "Source Attachment individual identifier";
        }
        leaf target-AII {
          type string;
          description "Target Attachment individual identifier";
        }
      }
      case pwid-fec {
        leaf pw-id {
          type uint32;
          description "pseudowire id";
        }
      }
    }
  }
  case static-pw {
    leaf static-pw-id {
      type uint32;
      description "pseudowire id";
    }
    leaf transmit-label {
      type uint32;
    }
  }
}
```

```
        description "transmit lable";
      }
      leaf receive-label {
        type uint32;
        description "receive label";
      }
    }
  }

  description "ss-pw list";
}

  container ms-pw {
    description "configure ms-pw";
    list ms-pw {
key "name";
leaf name {
  type string;
  description "ms-pseudowire name";
}
      list pw-segment-a{
        key "name";
        leaf name {
          type string;
description "pseudowire segment a name";
        }
        description "pw segment-a list";
      }
      list pw-segment-z{
        key "name";
        leaf name {
          type string;
description "pseudowire segment z name";
        }
        description "pw segment-z list";
      }
    }
    description "ms-pw list";
  }
}

<CODE ENDS>
```

6. Security Considerations

TBD.

7. Acknowledgements

TBD.

8. IANA Considerations

This document requires no IANA Actions. Please remove this section before RFC publication.

9. References

9.1. Normative references

- [RFC4447] Martini, L., Ed., Rosen, E., El-Aawar, N., Smith, T., and G. Heron, "Pseudowire Setup and Maintenance Using the Label Distribution Protocol (LDP)", RFC 4447, DOI 10.17487/RFC4447, April 2006, <<http://www.rfc-editor.org/info/rfc4447>>.
- [RFC6020] Bjorklund, M., Ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC 6020, DOI 10.17487/RFC6020, October 2010, <<http://www.rfc-editor.org/info/rfc6020>>.
- [RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol (NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <<http://www.rfc-editor.org/info/rfc6241>>.
- [RFC7267] Martini, L., Ed., Bocci, M., Ed., and F. Balus, Ed., "Dynamic Placement of Multi-Segment Pseudowires", RFC 7267, DOI 10.17487/RFC7267, June 2014, <<http://www.rfc-editor.org/info/rfc7267>>.

9.2. Informative references

- [I-D.ietf-bess-l2vpn-yang] Shah, H., Brissette, P., Chen, I., Hussain, I., Wen, B., and K. Tiruveedhula, "YANG Data Model for MPLS-based L2VPN", draft-ietf-bess-l2vpn-yang-05 (work in progress), March 2017.

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ZTE Corporation
December 11, 2017

YANG Data Model for PW Protocol
draft-chen-pals-pw-yang-03.txt

Abstract

This document defines a YANG data model for PW configuration and operation.

Status of This Memo

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1. Introduction

YANG[RFC6020] is a data definition language that was introduced to define the contents of a conceptual data store that allows networked devices to be managed using NETCONF ([RFC6241]). YANG ([RFC6020]) is a modular language that represents data structures in an XML or JSON tree format, and is used as a data modeling language for the NETCONF.

This document defines a YANG data model for PW configuration and operation. It includes point-to-point SS-PWs and MS-PWs that are signaled via LDP, and also for static provisioned (MPLS-TP) SS-PWs and MS-PWs.

2. SS-PW

This container defines all the configuration parameters related to ss-pw.

It includes pw name, peer ip, tunnel parameters, pw-type, parameters associated with interface, parameters associated with LDP pw and parameters associated with static pw.

3. MS-PW

This container defines all the configuration parameters related to ms-pw.

It includes ms-pw name, list of pw-segment-a and list of pw-segment-z.

4. Design of the Data Model

```

module: ietf-pw
  +--rw pwe3
    +--rw ss-pw
      +--rw ss-pw* [name]
        +--rw name string
        +--rw peer-ip? inet:ip-address
        +--rw cw-capable? cw-capable-type
        +--rw type? pw-type
        +--rw tunnel* [tunnel-id]
          | +--rw tunnel-id string
        +--rw leaf-type? pw-type
        +--rw autodiscovery-enable? boolean
        +--rw interfaces
          +--rw interface* [name]
            +--rw name if:interface-ref
            +--rw mtu? uint32
            +--rw fcs-retention-indicator? uint16
            +--rw vccv-parameter
              | +--rw cc? cc-type
              | +--rw cv? cv-type
            +--rw requested-vlan-id? uint32
            +--rw frag-indicator? uint32
            +--rw interface-description? string
            +--rw (pw-emu-type)?
              +--:(tdm)
                +--rw bit-rate? uint32
                +--rw payload-bytes? uint16
                +--rw cells-per-packet? uint16
                +--rw tdm-options
                  | +--rw rtp? pw-rtp-flag
                  | +--rw timestamp-mode? pw-timestamp-mode
                  | +--rw frequency? uint16
                  | +--rw ssrc? uint32
                  | +--rw payload-type? uint8
                  | +--rw cas? uint8
                  | +--rw sp? uint8
                +--rw cep-option
                  +--rw ais? uint8
                  +--rw une? uint8
                  +--rw rtp? uint8
                  +--rw ebm? uint8
                  +--rw async-t3? uint8
                  +--rw async-e3? uint8
                  +--rw cep-type? uint16
              +--:(fr)
                | +--rw fr-dlci-len? uint16

```

```

|         |         +---:(atm)
|         |         +---rw max-atm-cells?          uint16
+---rw (pw-type)?
|         +---:(ldp-pw)
|         |         +---rw (fec-type)?
|         |         +---:(generalized-pwid-fec-type)
|         |         |         +---rw agi?          string
|         |         |         +---rw source-AII?   string
|         |         |         +---rw target-AII?   string
|         |         +---:(pwid-fec)
|         |         +---rw pw-id?                  uint32
+---:(static-pw)
|         +---rw static-pw-id?          uint32
|         +---rw transmit-label?       uint32
|         +---rw receive-label?        uint32
+---rw ms-pw
|         +---rw ms-pw* [name]
|         |         +---rw name          string
|         |         +---rw pw-segment-a* [name]
|         |         |         +---rw name      string
|         |         +---rw pw-segment-z* [name]
|         |         +---rw name          string

```

5. PW YANG Data Model

```

<CODE BEGINS> file "ietf-pw.yang"
module ietf-pw {
  namespace "urn:ietf:params:xml:ns:yang:ietf-pw";
  prefix "pw";

  import ietf-inet-types {
    prefix "inet";
  }

  import ietf-interfaces {
    prefix "if";
  }

  organization "ietf";
  contact "ietf";
  description "pw";
  revision "2017-04-28" {
    description "02 revision.";
    reference "draft-chen-pals-pw-yang-02.txt";
  }
  revision "2016-10-05" {

```

```
        description "01 revision.";
        reference "draft-chen-pals-pw-yang-01.txt";
    }
revision "2016-03-30" {
    description "Initial revision of pw model.";
    reference "draft-chen-pals-pw-yang-00.txt";
}
/* typedefs */

typedef cw-capable-type {
    type enumeration {
        enum "non-preferred" {
            description "No preference for control-word";
        }
        enum "preferred" {
            description "Prefer to have control-word negotiation";
        }
    }
    description "control-word capable preference type";
}

typedef cc-type {
    type enumeration {
        enum pw-ach {
            description "PWE3 Control Word with 0001b as first nibble (PW-AC
H, see [RFC4385])";
        }
        enum alert-label {
            description "MPLS Router Alert Label";
        }
        enum ttl {
            description "MPLS PW Label with TTL == 1";
        }
    }
    description "The defined values for CC(Control Channel) Types for MPLS P
Ws.";
}

typedef cv-type {
    type enumeration {
        enum ICMP-ping {
            description "ICMP-ping.";
        }
        enum LSP-ping {
            description "LSP-ping";
        }
        enum BFD-basic-ip {
            description "BFD basic ip";
        }
        enum BFD-basic-raw {
```

```
        description "BFD basic raw ";
    }
    enum BFD-signalling-ip {
        description "BFD signalling ip";
    }
    enum BFD-signalling-raw {
        description "BFD signalling raw";
    }
}
}
description "The defined values for CV(Connectivity Verification) Types
for MPLS PWs";
}

typedef pw-type {
    type enumeration {
        enum unknown {
            value 0 ;
            description "The PW type is unknown";
        }
        enum dlciOld {
            value 1 ;
            description "The PW type is dlciOld";
        }
        enum atmSdu {
            value 2 ;
            description "The PW type is atmSdu";
        }
        enum atmCell {
            value 3 ;
            description "The PW type is atmCell";
        }
        enum vlan {
            value 4 ;
            description "The PW type is vlan";
        }
        enum ethernet {
            value 5 ;
            description "The PW type is ethernet";
        }
        enum hdlc {
            value 6 ;
            description "The PW type is hdlc";
        }
        enum ppp {
            value 7 ;
            description "The PW type is ppp";
        }
        enum sdhCESoM {
```

```
        value 8 ;
        description "The PW type is sdhCESoM";
    }
    enum atmVCCn {
        value 9 ;
        description "The PW type is atmVCCn";
    }
    enum atmVPCn {
        value 10 ;
        description "The PW type is atmVPCn";
    }
    enum ipL2 {
        value 11 ;
        description "The PW type is ipL2";
    }
    enum atmVCC1 {
        value 12 ;
        description "The PW type is atmVCC1";
    }
    enum atmVPC1 {
        value 13 ;
        description "The PW type is atmVPC1";
    }
    enum atmPDU {
        value 14 ;
        description "The PW type is atmPDU";
    }
    enum frPort {
        value 15 ;
        description "The PW type is frPort";
    }
    enum sdhCEoP {
        value 16 ;
        description "The PW type is sdhCEoP";
    }
    enum saTopE1 {
        value 17 ;
        description "The PW type is saTopE1";
    }
    enum saTopT1 {
        value 18 ;
        description "The PW type is saTopT1";
    }
    enum saTopE3 {
        value 19 ;
        description "The PW type is saTopE3";
    }
}
```

```
        enum saTopT3 {
            value 20 ;
            description "The PW type is saTopT3";
        }
        enum ceSoPSNB {
            value 21 ;
            description "The PW type is ceSoPSNB";
        }
        enum tdmAAL1 {
            value 22 ;
            description "The PW type is tdmAAL1";
        }
        enum ceSoPSNC {
            value 23 ;
            description "The PW type is ceSoPSNC";
        }
        enum tdmAAL2 {
            value 24 ;
            description "The PW type is tdmAAL2";
        }
        enum dlciNew {
            value 25 ;
            description "The PW type is dlciNew";
        }
    }
    description "The PW type of the PW.";
}

typedef pw-rtp-flag {
    type enumeration {
        enum UNUSE {
            value 0 ;
            description 'Not use the rtp header.' ;
        }
        enum USE {
            value 1 ;
            description 'Use the rtp header.' ;
        }
        enum UNKNOWN {
            value 3 ;
            description 'The usage of the rtp header is unknown.' ;
        }
    }
    description 'The use flag of rtp header.' ;
}

typedef pw-timestamp-mode {
    type enumeration {
```



```
enum Absolute {
    value 0 ;
    description 'The timestamp mode is absolute.' ;
}
enum Differential {
    value 1 ;
    description 'The timestamp mode is differential .' ;
}
enum UNKNOWN {
value 3 ;
    description 'The timestamp mode is unknown.' ;
}
description 'The timestamp mode of TDM service.' ;
}

container pwe3 {
    description "configure pw";
    container ss-pw {
        description "configure ss-pw";
        list ss-pw {

            key "name";
            leaf name {
                type string;
                description "ss-pseudowire name";
            }
            leaf peer-ip {
                type inet:ip-address;
                description "peer IP address";
            }
            leaf cw-capable {
                type cw-capable-type;
                default "preferred";
                description "control-word negotiation preference";
            }
            leaf type {
                type pw-type;
                description "pseudo-wire type";
            }
        }

        list tunnel {
            key "tunnel-id";
            leaf tunnel-id {
                type string;
                description "tunnel identifier";
            }
            description "tunnel list";
        }
    }
}
```

```
    }

    leaf leaf-type {
      type pw-type;
      description "pseudo-wire type";
    }
    leaf autodiscovery-enable{
type boolean;
      description "enable the auto-discovery";
    }

    container interfaces {
      description "Interfaces";
      list interface{
        key "name";
        leaf name {
          type if:interface-ref;
          description "Interfaces used for pw";
        }
        leaf mtu {
          type uint32;
          description "pseudowire mtu";
        }
        leaf fcs-retention-indicator {
          type uint16;
          description "The negotiated fcs retention indicator of the PW";
        }
      }
      container vccv-parameter {
        description "vccv-parameter";
        leaf cc {
          type cc-type;
          description "Control Channel Types";
        }
        leaf cv {
          type cv-type;
          description "Connectivity Verification Types";
        }
      }
    }

    leaf requested-vlan-id {
      type uint32;
      description "The local requested VLAN ID of the PW";
    }

    leaf frag-indicator {
      type uint32;
      description "The local fragmentation indicator of the PW";
    }
  }
```

```

    leaf interface-description {
        type string {
            length 0..81;
        }
        description "The local interface description of the PW";
    }

    choice pw-emu-type {
        description "The emulation type of the PW. It could be tdm, fr and
        atm. There are different interface parameters for different emulation types";

        case tdm {
            leaf bit-rate {
                type uint32;
                description "The local bit rate of the PW";
            }

            leaf payload-bytes {
                type uint16;
                description "The local payload bytes of the PW";
            }

            leaf cells-per-packet {
                type uint16;
                description "The local TDMoIP AAL1 cells per packet of the PW";
            }

            container tdm-options {
                description "The TDM Options parameter of the PW";
                leaf rtp {
                    type pw-rtp-flag;
                    description "The local rtp header usage";
                }
                leaf timestamp-mode {
                    type pw-timestamp-mode;
                    description "The local timestamp mode";
                }
                leaf frequency {
                    type uint16;
                    description "The local frequency of timestamping clock";
                }
                leaf ssrc {
                    type uint32;
                    description "The local value of the Synchronization source ID";
                }
                leaf payload-type {
                    type uint8;
                    description "The local payload type in the RTP header expected by the PW endpoint distributing this FEC";
                }
            }
        }
    }

```

```

    leaf cas {
        type uint8 ;
        description "The local cas of the PW";
    }
    leaf sp {
        type uint8 ;
        description "The local sp of the PW";
    }
}

    container cep-option {
description "The CEP Options parameter of the PW";
    leaf ais {
        type uint8;
        description "The local ais of CEP Options parameter of the P
W";
    }
    leaf une {
        type uint8;
        description "The local une of CEP Options parameter of the P
W";
    }
    leaf rtp {
        type uint8;
        description "The local rtp of CEP Options parameter of the P
W";
    }
    leaf ebm {
        type uint8;
        description "The local ebm of CEP Options parameter of the P
W";
    }
    leaf async-t3 {
        type uint8;
        description "The local async-t3 of CEP Options parameter of
the PW";
    }
    leaf async-e3 {
        type uint8;
        description "The local async-e3 of CEP Options parameter of
the PW";
    }
    leaf cep-type {
        type uint16;
        description "The local cep type of CEP Options parameter of
the PW";
    }
}
}

    case fr {
description "The emulation type of the PW is fr";
    leaf fr-dlci-len {
        type uint16;
        description "The local fr dlci length of the PW";
    }
}

```

```

    }
    case atm {
      description "The emulation type of the PW is atm";
      leaf max-atm-cells {
        type uint16;
        description "The local max atm cells of the PW";
      }
    }
  }
  description "interface list";
}

choice pw-type {
  description "A choice of pseudowire type";
  case ldp-pw {
    choice fec-type {
      description "fec type";
      case generalized-pwid-fec-type {
        leaf agi {
          type string;
          description "Attachment Group Identifier";
        }
        leaf source-AII {
          type string;
          description "Source Attachment individual identifier";
        }
        leaf target-AII {
          type string;
          description "Target Attachment individual identifier";
        }
      }
      case pwid-fec {
        leaf pw-id {
          type uint32;
          description "pseudowire id";
        }
      }
    }
  }
  case static-pw {
    leaf static-pw-id {
      type uint32;
      description "pseudowire id";
    }
    leaf transmit-label {
      type uint32;
    }
  }
}

```

```
        description "transmit lable";
      }
      leaf receive-label {
        type uint32;
        description "receive label";
      }
    }

    description "ss-pw list";
  }
}

container ms-pw {
  description "configure ms-pw";
  list ms-pw {
key "name";
leaf name {
  type string;
  description "ms-pseudowire name";
}
    list pw-segment-a{
      key "name";
      leaf name {
        type string;
      }
      description "pseudowire segment a name";
    }
    description "pw segment-a list";
  }
  list pw-segment-z{
    key "name";
    leaf name {
      type string;
    }
    description "pseudowire segment z name";
  }
  description "pw segment-z list";
}
description "ms-pw list";
  }
}
}

<CODE ENDS>
```

6. Security Considerations

TBD.

7. Acknowledgements

TBD.

8. IANA Considerations

This document requires no IANA Actions. Please remove this section before RFC publication.

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9.1. Normative references

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