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## Recommendation to Use the Ethernet Control Word

### Abstract

The pseudowire (PW) encapsulation of Ethernet, as defined in RFC 4448, specifies that the use of the control word (CW) is optional. In the absence of the CW, an Ethernet PW packet can be misidentified as an IP packet by a label switching router (LSR). This may lead to the selection of the wrong equal-cost multipath (ECMP) path for the packet, leading in turn to the misordering of packets. This problem has become more serious due to the deployment of equipment with Ethernet Media Access Control (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 PW CW in all but exceptional circumstances.

This document updates RFC 4448.

### Status of This Memo

This is an Internet Standards Track document.

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Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at <https://www.rfc-editor.org/info/rfc8469>.

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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 then, if it is, 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 PW packet can be misidentified as an IP packet by a label switching router (LSR) selecting the ECMP path based on the five-tuple. This may lead to the selection of the wrong ECMP path for the packet, leading in turn to the misordering 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. These errors occur when a forwarder incorrectly assumes that the packet is IP and applies a forwarding policy based on fields in the PW payload.

IPv4 and IPv6 packets start with the values 0x4 and 0x6, respectively. Misidentification can arise if an Ethernet PW packet without a CW is carrying an Ethernet packet with a destination address that starts with either of these values.

This problem has recently become more serious for a number of reasons. First, the IEEE Registration Authority Committee (RAC) has assigned Ethernet MAC addresses that start with 0x4 or 0x6, and equipment that uses MAC addresses in these series has been deployed in networks. Second, concerns over privacy have led to the use of MAC address randomization, which assigns local MAC addresses randomly for privacy. Random assignment results in addresses starting with one of these two values approximately one time in eight.

The use of the Ethernet PW CW addresses this problem.

This document RECOMMENDS the use of the Ethernet PW CW in all but exceptional circumstances.

## 2. Specification of Requirements

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

### 3. Background

Ethernet PW encapsulation is specified in [RFC4448]. Of particular relevance is Section 4.6, part of which is quoted below for the convenience of the reader. Note that RFC 4448 uses the citation [PWE3-CW] to refer to [RFC4385] and the citation [VCCV] to refer to the document that was eventually published as [RFC5085].

The control word defined in this section is based on the Generic PW MPLS Control Word as defined in [PWE3-CW]. 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 [VCCV].

[PWE3-CW] 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.

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

Since that time, the RAC has issued Ethernet MAC addresses that start with 0x4 or with 0x6. Therefore, 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 to try 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 posting on the NANOG email list highlighted this problem:

[<https://mailman.nanog.org/pipermail/nanog/2016-December/089395.html>](https://mailman.nanog.org/pipermail/nanog/2016-December/089395.html)

#### 4. Recommendation

The ambiguity between an MPLS payload that is an Ethernet PW and one that is an IP packet is resolved when the Ethernet PW CW is used. This document updates [RFC4448] to state that both the ingress provider edge (PE) and the egress PE SHOULD support the Ethernet PW CW and that, if supported, the CW MUST be used.

Where the application of ECMP to Ethernet PW traffic is required and where both the ingress and the egress PEs support Entropy Label Indicator / Entropy Label (ELI/EL) [RFC6790] and Flow-Aware Transport of Pseudowires (FAT PW) [RFC6391], then either method may be used. The use of both methods on the same PW is not normally necessary and should be avoided unless circumstances require it. In the case of multi-segment PWs, if ELI/EL is used, then it SHOULD be used on every segment of the PW. The method by which usage of ELI/EL on every segment is guaranteed is out of the scope of this document.

#### 5. Equal-Cost Multipath (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 of Pseudowires over an MPLS Packet Switched Network, specified in [RFC6391], or
- o Label Switched Path (LSP) entropy labels, specified in [RFC6790].

RFC 6391 works by increasing the entropy of the bottom-of-stack label. It requires that both the ingress and egress PEs 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.

RFC 6790 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 EL and the ELI and that sufficient LSRs on the LSP are able to perform ECMP based on the EL.

In both cases, there are considerations in getting Operations, Administration, and Maintenance (OAM) packets to follow the same path as a data packet. This is described in detail in 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.

The PW label is pushed before the LSP label. As the ELI/EL labels are part of the LSP layer rather than part of the PW layer, they are pushed after the PW label has been pushed.

## 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, RSVP-TE [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

In some cases, the inclusion of a CW in the PW is determined by equipment configuration. Furthermore, it is possible that the default configuration in such cases is to disable use of the CW. Care needs to be taken to ensure that software that implements this recommendation does not depend on existing configuration settings that prevent the use of a CW. It is recommended that platform software emit a rate-limited message indicating that the CW can be used but is disabled due to existing configuration.

Instead of including a payload type in the packet, MPLS relies on the control plane to signal the payload type that follows the bottom of the label stack. Some LSRs attempt to deduce the packet type by MPLS

payload inspection, in some cases looking past the PW CW. If the payload appears to be IP or IP carried in an Ethernet header, they perform an ECMP calculation based on what they assume to be the five-tuple fields. However, deduction of the payload type in this way is not an exact science, and where a packet that is not IP is mistaken for an IP packet, the result can be packets delivered out of order. Misordering of this type can be difficult for an operator to diagnose. When enabling capability that allows information gleaned from packet inspection past the PW CW to be used in any ECMP calculation, operators should be aware that this may cause Ethernet frames to be delivered out of order despite the presence of the CW.

## 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 has no IANA actions.

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