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 MPLS Data Plane Encapsulation for In Situ OAM Data

Abstract

In Situ Operations, Administration, and Maintenance (IOAM) is used for recording and collecting operational and telemetry information while the packet traverses a path between two points in the network. This document defines how IOAM data fields are transported with MPLS data plane encapsulation using MPLS Network Action (MNA) and follows the MNA framework defined in draft-ietf-mpls-mna-fwk.

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1. Introduction

In Situ Operations, Administration, and Maintenance (IOAM) is used for recording and collecting operational and telemetry information while the packet traverses a path between two points in the network. The term "in-situ" refers to the fact that the IOAM data fields are added to the data packets rather than being sent within the probe packets specifically dedicated to OAM. The IOAM data fields are defined in [[RFC9197](#)]. The IOAM data fields are further updated in [[RFC9326](#)] for direct export use-cases.

This document defines how IOAM data fields are transported with MPLS data plane encapsulations using MPLS Network Action (MNA) and follows the framework defined in [[I-D.ietf-mpls-mna-fwk](#)].

[[I-D.jags-mpls-mna-hdr](#)] defines mechanisms for carrying MNA header and Network Actions Sub-Stack (NAS) above the Bottom of the label stack (BOS) and [[I-D.song-mpls-extension-header](#)] defines mechanisms for carrying Post-Stack Data (PSD) in MPLS extension headers (EHs) after the Bottom of the label stack. This document uses these two mechanisms and describes the procedures for carrying IOAM data fields in an MPLS header.

Note: This document uses MNA encoding solutions defined in Individual Internet Drafts as examples. The MNA encoding will be updated to align with the MNA solutions in the WG adopted Internet Drafts when they are available.

2. Conventions

2.1. Requirement Language

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](#)] [[RFC8174](#)] when, and only when, they appear in all capitals, as shown here.

2.2. Abbreviations

The MPLS Network Action (MNA) terminology defined in [[I-D.ietf-mpls-mna-fwk](#)] are used in this document.

Abbreviations used in this document:

PNI Post-Stack Network Action Presence Indicator (P flag)

ECMP Equal Cost Multi-Path

E2E Edge-To-Edge

HBH Hop-By-Hop

IHS Ingress-To-Egress (I2E), Hop-By-Hop (HBH) or Select Scope

IOAM In Situ Operations, Administration, and Maintenance

MPLS Multiprotocol Label Switching

MNA MPLS Network Action

NAI Network Action Indicator

NASL Network Action Sub-Stack Length

OAM Operations, Administration, and Maintenance

3. MPLS Extensions for IOAM Data Fields

3.1. IOAM Post-Stack Action Header

The IOAM Post-Stack Action Header (PAH) is defined using the specification from [[I-D.song-mpls-extension-header](#)].

The IOAM Post-Stack Action Header containing different Extension Headers (EHs) with IOAM-Data-Fields are added in the MPLS packet as shown in Figure 1. The IOAM-Data-Fields MUST follow the definitions corresponding to the IOAM-Option-Types (e.g., see Section 4.4 of [[RFC9197](#)] and Section 3 of [[RFC9326](#)]).

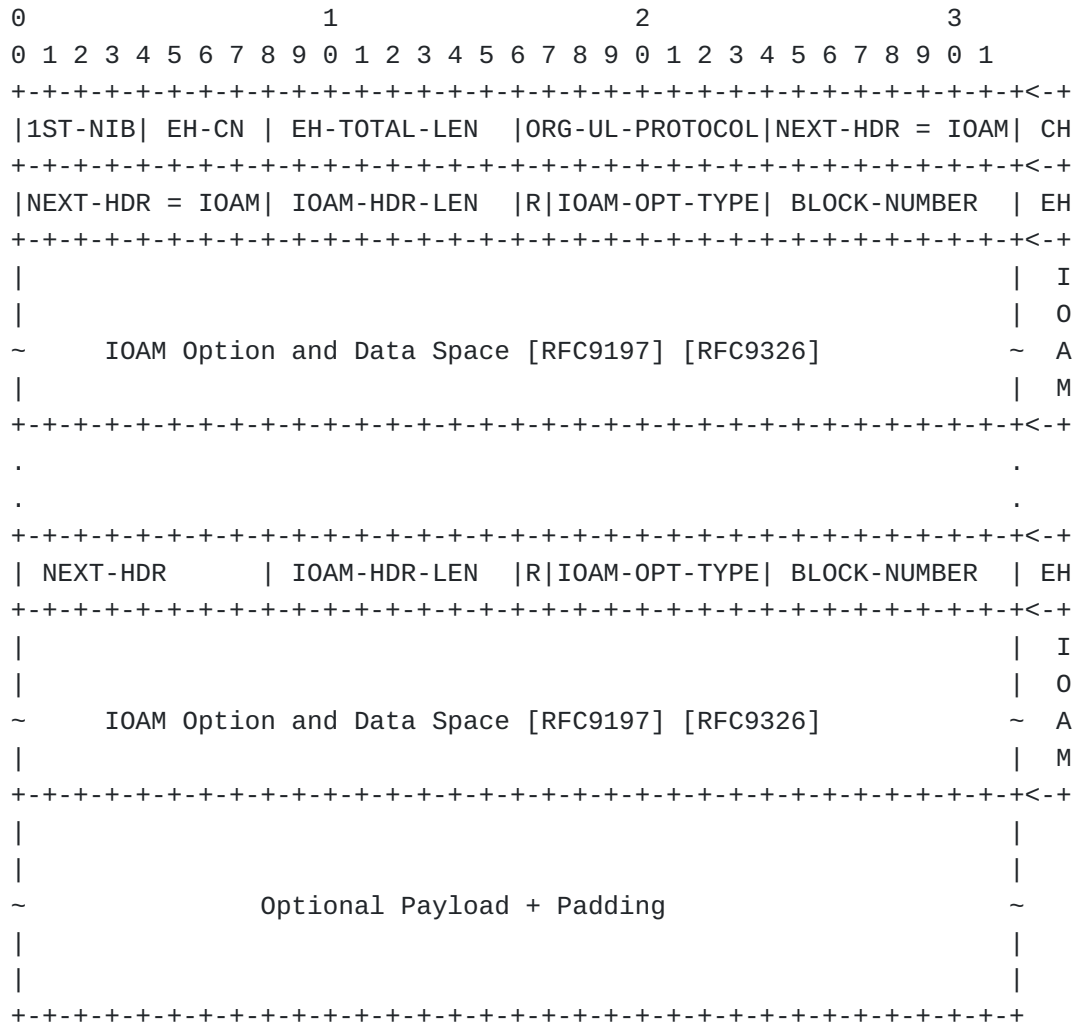


Figure 1: Post-Stack Action Header with IOAM Data Fields in Extension Headers

The 4-Octet Common Header (CH) is added with the following fields in the MPLS Post-Stack Action Header as defined in [\[I-D.song-mpls-extension-header\]](#):

1ST-NIBBLE (R): The first 4-bit is Reserved (value TBA3).

EH-CN (EHC): The EH Count, number of EHs carried in the Post-Stack Data of the packet.

EH-TOTAL-LEN (EHTL): Total Length of EHs in the Post-Stack Data of the packet in 4-octet units.

ORIG-UL-PROTOCOL (OUL): The Original Upper Layer Protocol.

NEXT-HDR (NH): The Next Header protocol. For IOAM as Next Header, value TBA2 is to be assigned by IANA.

An IOAM-Data-Field is added in an EH in the PAH containing the following fields:

IOAM-OPT-TYPE: 8-bit field defining the IOAM Option type, as defined in the "IOAM Option-Type Registry" specified in [\[RFC9197\]](#) and [\[RFC9326\]](#).

IOAM-HDR-LEN: 8-bit unsigned integer. Length of the IOAM Header in 4-octet units.

IOAM Option and Data Space: IOAM-Data-Fields as specified by the IOAM-OPT-Type field. IOAM-Data-Fields are defined corresponding to the IOAM-Option-Type (e.g., see Section 4.4 of [\[RFC9197\]](#) and Section 3 of [\[RFC9326\]](#)).

BLOCK-NUMBER: The Block Number can be used to aggregate the IOAM data collected in data plane, e.g., to compute measurement metrics for each block of a data flow. It is also used to correlate the IOAM data on different nodes.

3.2. MNA Header for Post-Stack Network Action Presence Indicator and Scope

The P flag for PNI (Post-Stack Network Action Presence Indicator) defined in [\[I-D.jags-mpls-mna-hdr\]](#) is used in this document to indicate the presence of IOAM Post-Stack Network Action and Ancillary Data.

A Post-Stack Network Action Presence Indicator (P flag) MUST be set to "1" to indicate the presence of IOAM-Data-Fields in the MPLS header.

The IHS scope field defined in [[I-D.jags-mpls-mna-hdr](#)] is used to indicate that E2E or HBH or Select processing is required for the Post-Stack Network Action and Ancillary Data.

If both edge and intermediate nodes need to process the IOAM data fields then IHS scope MUST be set to "HBH, value 0x1". If only edge nodes need to process the IOAM data fields then IHS scope MUST be set to "I2E, value 0x0". The HBH scope allows to skip the IOAM data processing on the intermediate nodes i.e., avoids the need to parse all IOAM-Data-Fields to detect the HBH option type.

The MNA Label used in this document is a Base Special Purpose Label (bSPL value TBA1 to be assigned by IANA), which is Network Action Sub-Stack Indicator [[I-D.jags-mpls-mna-hdr](#)].

Opcode 2 is used to carry the Flag-Based Network Action Indicators (NAIs) in the Ancillary Data field [[I-D.jags-mpls-mna-hdr](#)]. The Flag-Based Network Action Indicators can be set to 0x0 to indicate that no Network Action other than the Post-Stack Network Action(s) is required for the packet.

The U Flag for Unknown Action Handling is specified in [[I-D.jags-mpls-mna-hdr](#)].

The Network Action Sub-Stack Length (NASL) is set to 0 when no additional Label Stack Entry (LSE) is added after the LSE carrying the P Flag.

The MNA Label used in this document is a Base Special Purpose Label (bSPL value TBA1 to be assigned by IANA), which is the Network Action Sub-Stack Indicator [[I-D.jags-mpls-mna-hdr](#)].

4. Edge-To-Edge IOAM Network Action

4.1. MNA Header for Edge-To-Edge IOAM

The Post-Stack Network Action Presence Indicator (P flag) is set to "1" to indicate the presence of IOAM-Data-Fields and the IHS scope is set to "I2E, value 0x0" to indicate the scope of E2E IOAM-Data-Fields in the MPLS header as shown in Figure 2. Note that there may be additional Network Action (NA) LSEs added in the MNA Sub-Stack and NASL is updated based on the number of LSEs after the second LSE.

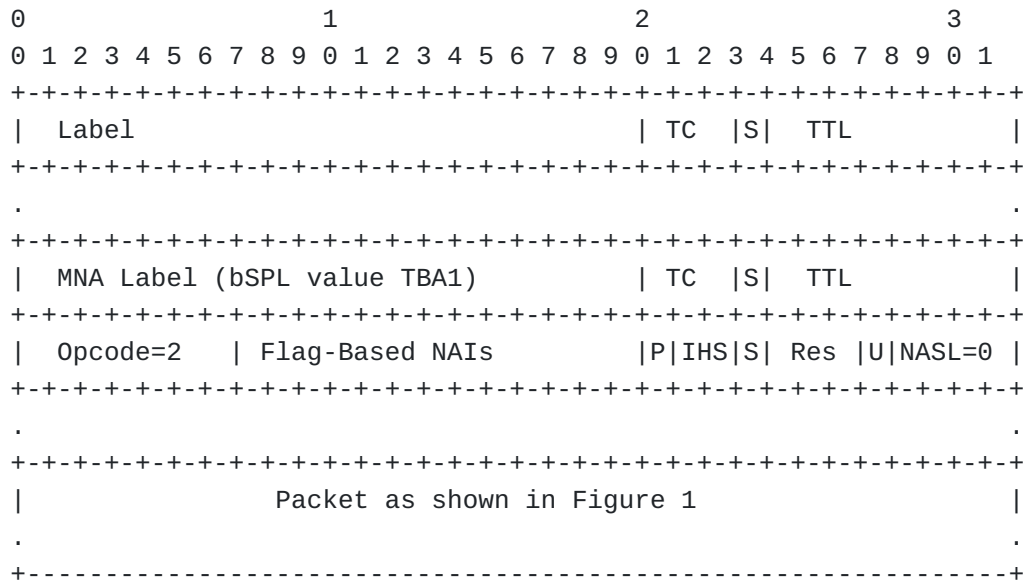


Figure 2: Example MNA Header for E2E IOAM

The E2E IOAM-Data-Fields carry the Option-Type(s) that require processing on the encapsulating and decapsulating nodes only. The IOAM Option-Type carried can be IOAM Edge-To-Edge Option-Type (value 3) defined in [RFC9197] as well as Direct Export (DEX) Option-Type (value 4) defined in [RFC9326]. The E2E IOAM-Data-Fields SHOULD NOT carry any IOAM Option-Type that require IOAM processing on the intermediate nodes as it will not be processed by them since IHS scope is set to "I2E, value 0x0".

4.2. Procedure for Edge-To-Edge IOAM Network Action

The E2E IOAM Network Action procedure is summarized as following:

- *The encapsulating node inserts an MNA header with the MNA Label (bSPL value TBA1) with the Post-Stack Network Action Presence Indicator (P flag) set to "1" and IHS scope set to "I2E, value 0x0" and one or more IOAM-Data-Fields in the Post-Stack Network Action Header in the MPLS packet.
- *The intermediate nodes do not process IOAM-Data-Fields.
- *The penultimate node MUST NOT remove the MNA Sub-Stack from the MPLS header so that the MNA Sub-Stack is received at the decapsulating node. This encapsulating node adds required MPLS header so that the received packet on the penultimate node does not have MNA Sub-Stack at the top of the Label stack.
- *The decapsulating node MAY punt a copy of the packet with the receive timestamp to the slow path for IOAM-Data-Fields processing when the node recognizes the P flag is set to "1". The receive timestamp is required by the various E2E OAM use-cases,

including streaming telemetry. Note that the packet is not necessarily punted to the control-plane.

*The decapsulating node processes the IOAM-Data-Fields using the procedures defined in [RFC9197]. An example of IOAM processing is to export the IOAM-Data-Fields, send IOAM-Data-Fields via streaming telemetry, etc.

*The decapsulating node MUST remove the IOAM-Data-Fields from the received packet. The decapsulated packet is forwarded downstream or terminated locally similar to the regular IOAM-Data-Fields.

5. Hop-By-Hop IOAM Network Action

5.1. MNA Header for Hop-By-Hop IOAM

The Post-Stack Network Action Presence Indicator (P flag) is set to "1" to indicate the presence of IOAM-Data-Fields and the IHS scope is set to "HBH, value 0x1" to indicate the scope of HBH IOAM-Data-Fields in the MPLS header as shown in Figure 3. Note that there may be additional Network Action (NA) LSEs added in the MNA Sub-Stack and NASL is updated based on the number of LSEs after the second LSE.

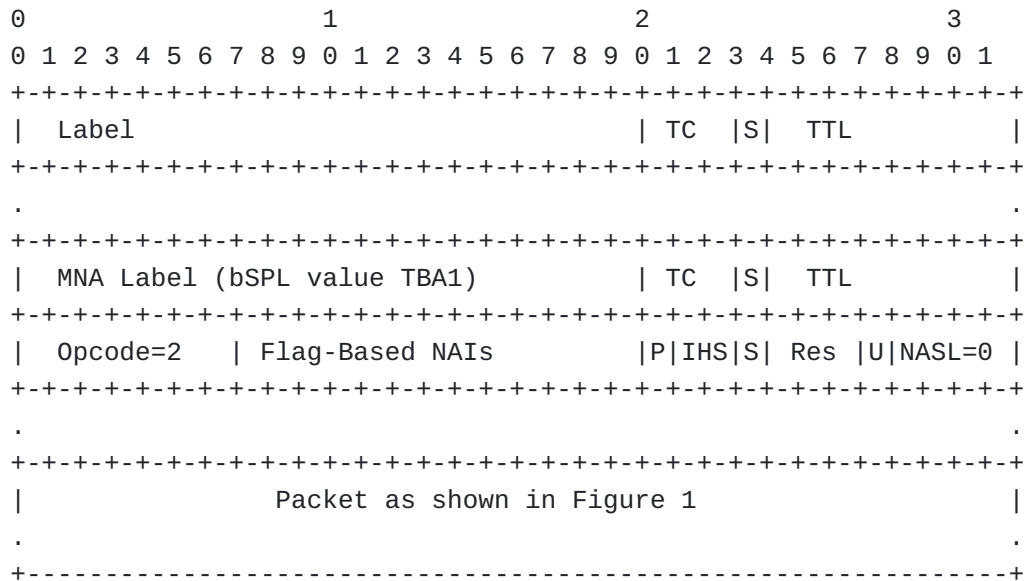


Figure 3: Example MNA Header for HBH IOAM

The HBH IOAM-Data-Fields carry the Option-Type(s) that require processing at the intermediate and/or encapsulating and decapsulating nodes. The IOAM Option-Type carried can be IOAM Pre-allocated Trace Option-Type (value 0), IOAM Incremental Trace Option-Type (value 1) and IOAM Proof of Transit (POT) Option-Type (value 2), and Edge-To-Edge Option-Type (value 3) defined in

[[RFC9197](#)] as well as Direct Export (DEX) Option-Type (value 4) defined in [[RFC9326](#)].

5.2. Procedure for Hop-By-Hop IOAM Network Action

The Hop-By-Hop IOAM Network Action procedure is summarized as following:

- *The encapsulating node inserts an MNA header containing MNA Label (bSPL value TBA1) with the Post-Stack Network Action Presence Indicator (P flag) and IHS scope set to "HBH, value 0x1" and one or more IOAM-Data-Fields in the Post-Stack Network Action Header in the MPLS packet.
- *The intermediate node enabled with HBH IOAM function processes the data packet including the IOAM-Data-Fields as defined in [[RFC9197](#)] and [[RFC9326](#)] when the node recognizes the HBH scope in the MPLS header.
- *The intermediate node MAY punt a copy of the packet with the receive timestamp to the slow path for IOAM-Data-Fields processing when the node recognizes the HBH scope. The receive timestamp is required by the various HBH OAM use-cases, including streaming telemetry. Note that the packet is not necessarily punted to the control-plane.
- *The intermediate node forwards a copy of the processed data packet downstream.
- *The processing on the penultimate node is same as E2E case.
- *The processing on the decapsulating node is same as E2E case.

5.3. Hop-By-Hop and Edge-To-Edge IOAM Extension Headers

Both HBH and E2E IOAM EHs may be added in an MPLS header. In this case the HBH IOAM EHs MUST be added after the BOS and before the E2E IOAM EHs. When an intermediate node that processes the HBH IOAM EHs, encounters the first E2E IOAM EH, it will stop processing of the E2E EH.

5.4. Procedure for Select IOAM Network Action

The procedure for carrying the IOAM EHs for Select Scope is the same as HBH Scope IOAM except the IHS scope is set to "Select, value 0x2". In this case, only the select nodes will process the IOAM-Data-Fields.

6. Considerations for IOAM

6.1. Considerations for ECMP

The encapsulating node needs to make sure the IOAM-Data-Fields do not start with a well-known IP Version Number (e.g. 0x4 for IPv4 and 0x6 for IPv6) as that can alter the hashing function for ECMP that uses the IP header. This is achieved by using the Common Header (CH) 1ST-NIBBLE field with a different IP Version Number (value TBA3) after the MPLS label stack.

6.2. Node Capability

The decapsulating node that has to remove the IOAM-Data-Fields and perform the IOAM function may not be capable of supporting it. The encapsulating node needs to know if the decapsulating node can support the IOAM function. The signaling extension for this capability exchange is outside the scope of this document.

The intermediate node that is not capable of supporting the IOAM functions defined in this document, can simply skip the IOAM processing.

The node that does not recognize the MNA Label received at the top of the label stack will drop the packet.

6.3. Nested MPLS Encapsulation

When a packet is received with MPLS Encapsulated IOAM Network Action, the nested MPLS encapsulating node that supports a different IOAM Network Action, the node MUST add a new MNA Label (with Sub-Stack) with the supported IOAM Network Action as part of the new MPLS encapsulation.

7. Security Considerations

The security considerations of IOAM in general are discussed in [[RFC9197](#)] and apply to the procedure defined in this document.

IOAM is considered a "per domain" feature, where one or several operators decide on configuring IOAM according to their needs. IOAM is intended for deployment in limited domains [[RFC8799](#)]. As such, it assumes that a node involved in IOAM operation has previously verified the integrity of the path. Still, operators need to properly secure the IOAM domain to avoid malicious configuration and use, which could include injecting malicious IOAM packets into the domain.

8. IANA Considerations

The MNA Label (bSPL) with value TBA1 is allocated by IANA as requested by [[I-D.jags-mpls-mna-hdr](#)].

The 1ST-NIBBLE field with value TBA3 in the Common Header is allocated by IANA as requested by [[I-D.song-mpls-extension-header](#)].

The encoding of Next-Header uses the same value registry for IPv4/IPv6 protocol numbers. The value TBA2 for IOAM as Next Header shall be assigned by IANA from the "Protocol Numbers" registry (<https://www.iana.org/assignments/protocol-numbers/protocol-numbers.xhtml>).

Decimal	Keyword	Protocol	IPv6 Extension Header	Reference
TBA2	IOAM	In Situ OAM	N	This document

Table 1: Assigned Internet Protocol Numbers

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