

MPLS Working Group
Internet-Draft
Intended status: Standards Track
Expires: 24 July 2026

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20 January 2026

Post-Stack MPLS Network Action (MNA) Solution
draft-ietf-mpls-mna-ps-hdr-06

Abstract

This document defines the Post-Stack MPLS Network Action (MNA) solution for carrying Network Actions and Ancillary Data after the MPLS label stack, based on the In-Stack MNA solution defined in "MPLS Network Action (MNA) Sub-Stack Solution." MPLS Network Actions can be used to influence packet forwarding decisions, carry additional Operations, Administration, and Maintenance information in the MPLS packet, or perform user-defined operations. This solution document addresses the Post-Stack network action and Post-Stack data-specific requirements found in RFC 9613. This document follows the framework specified in RFC 9789.

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1. Introduction

[RFC3032] defines the encoding of the MPLS label stack, the basic structure used to define a forwarding path. Forthcoming applications require MPLS packets to perform special network actions and carry optional Ancillary Data (AD) that can affect the packet forwarding decision or trigger Operations, Administration, and Maintenance (OAM) logging, for example. AD can be used to carry additional information, such as data for In Situ OAM (IOAM) as described in [RFC9791].

In some cases, more AD may be required than can be carried in the MPLS header, so these kinds of network actions and their AD are encoded after the Bottom of Stack (BOS). This network action with AD is called the Post-Stack MNA.

This document defines the Post-Stack MPLS Network Action (MNA) solution for carrying Network Actions and Ancillary Data after the MPLS label stack. The solution is based on the In-Stack MNA solution defined in [I-D.ietf-mpls-mna-hdr]. The solution addresses the Post-Stack network action and Post-Stack data-specific requirements found in [RFC9613]. This document follows the framework specified in [RFC9789].

2. Conventions Used in This Document

2.1. Requirements 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 terminology defined in [RFC9789] and [RFC9613] are used in this document.

Abbreviation	Meaning	Reference
AD	Ancillary Data	[RFC9613]
bSPL	Base Special Purpose Label	[RFC9017]
BOS	Bottom Of Stack	[RFC3032]
HBH	Hop-By-Hop Scope	[RFC9789]
I2E	Ingress-To-Egress Scope	[RFC9789]
IHS	I2E, HBH, or Select Scope	[I-D.ietf-mpls-mna-hdr]
ISD	In-Stack Data	[RFC9613]
LSE	Label Stack Entry	[RFC3032]
MNA	MPLS Network Actions	[RFC9789]
NAI	Network Action Indicator	[RFC9613]
NAL	Network Action Length	[I-D.ietf-mpls-mna-hdr]
NAS	Network Action Sub-Stack	[RFC9789]
NASL	Network Action Sub-Stack Length	[I-D.ietf-mpls-mna-hdr]
OAM	Operations, Administration, and Maintenance	[RFC6291]
P bit	Post-Stack MPLS Header Presence	This document

	Bit	
PSD	Post-Stack Data	[RFC9613] and [RFC9789]
PSMH	Post-Stack MPLS Header	This document
TC	Traffic Class	[RFC5462]
TTL	Time To Live	[RFC3032]

Table 1: Abbreviations

3. Overview

The Post-Stack MNA solution contains two main parts:

- * Post-Stack MPLS Header Presence Bit Carried in In-Stack MNA Sub-Stack
- * Post-Stack MPLS Header Encoding that includes Post-Stack MPLS Header Type and Post-Stack Network Actions

3.1. Post-Stack MPLS Header Presence Bit Carried in In-Stack MNA Sub-Stack

Bit 20 in LSE Format B carried in the In-Stack Network Action Sub-Stack (NAS) described in [I-D.ietf-mpls-mna-hdr] is defined as the P bit in this document to indicate the presence of the Post-Stack MPLS Header in the packet after the BOS.

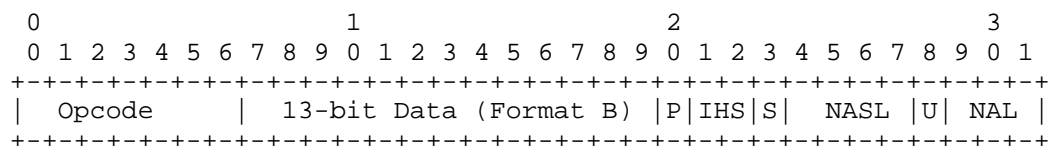


Figure 1: Post-Stack MPLS Header Presence Bit Carried in In-Stack MNA Sub-Stack

The following flags are carried in In-Stack NAS as defined in [I-D.ietf-mpls-mna-hdr] and shown in Figure 1. These flags are also applicable to Post-Stack MNA:

- * IHS (2 Bit): Indicates the combined scope of the In-Stack and the Post-Stack Network Actions. In-Stack NAS for each scope with P bit set has its corresponding Post-Stack MPLS Header.

- * U (1 Bit): Indicates the combined Unknown Action Handling of the In-Stack and the Post-Stack Network Actions.

3.2. Post-Stack MPLS Header Encoding

The Post-Stack MPLS Header (PSMH) for MNA is encoded after the Bottom of the Stack (BOS), either immediately after the BOS (i.e., start offset of 0) or after any other Post-Stack headers that follow the BOS (i.e., start offset of non-zero), as described in Section 4.

The PSMH for MNA carries one or more Post-Stack Network Actions and their Ancillary Data.

The PSMH for MNA consists of two main parts:

- * Post-Stack MPLS Header Type
- * Post-Stack Network Action Encoding

3.2.1. Post-Stack MPLS Header Type

The Post-Stack MPLS Header type is the top-header for all the Post-Stack Network Actions that are encoded in the PSMH for each scope as shown in Figure 2.

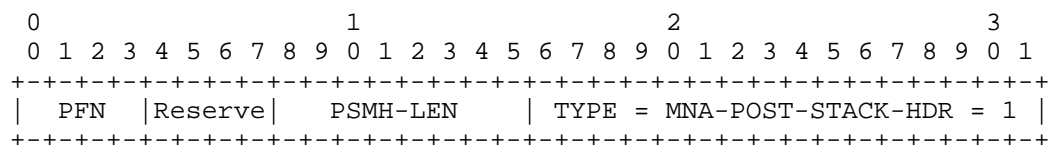


Figure 2: Post-Stack MPLS Header Type

- * PFN (4 bits): The Post-Stack First Nibble (PFN) [RFC9790] identifies the start of the PSMH. The PFN is set to 0x00b for the Post-Stack MPLS header.
- * Reserve (4 bits): Reserved bits.
- * PSMH-LEN (8 bits): The PSMH total length in 4-octet units that includes Post-Stack Network Actions. The length excludes the 4-byte PSMH type header.
- * TYPE (16 bits): Type is set to 1 to indicate Post-Stack MPLS Header Type for MNA. See Section 8.2. Note that other types of Post-Stack headers (besides MNA) can be defined in the future and is outside the scope of this document.

3.2.2. Post-Stack Network Action Encoding

The format shown in Figure 3, encodes a single Post-Stack Network Action. By repeating this format, multiple Post-Stack Network Actions and their corresponding Ancillary Data can be encoded.

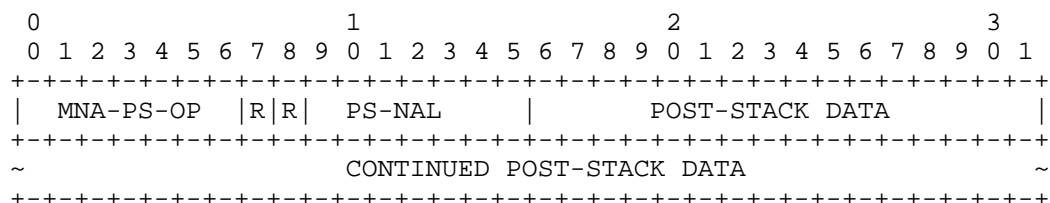


Figure 3: Post-Stack Network Action Encoding

- * MNA-PS-OP (7 bits): Post-Stack Network Action Opcode. See Section 8.3.
- * R (2 bits): Reserved bits.
- * PS-NAL (7 bits): Post-Stack Network Action Length in 4-octet units. This excludes the first 4-octets starting with MNA-PS-OP.
- * POST-STACK DATA (16 bits): Post-Stack Data associated with the Post-Stack Network Action.
- * CONTINUED POST-STACK DATA: Further Post-Stack Data associated with the Post-Stack Network Action, as indicated by the value of PS-NAL. The padding rules for Post-Stack Data that does not fill a multiple of 32-bit units are described in the document that defines the NA indicated by the MNA-PS-OP value.

3.2.3. Example MPLS Packet with Post-Stack MPLS Header for MNA

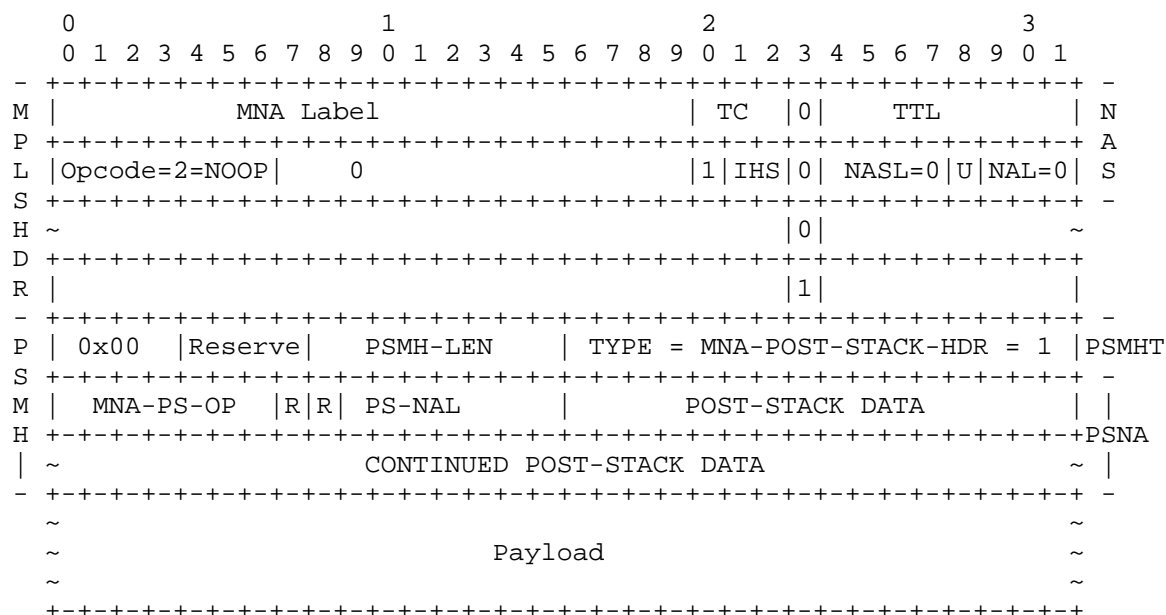


Figure 4: Example MPLS Packet with Post-Stack MPLS Header for MNA

An example of an MPLS packet encoding that carries an MPLS header and a Post-Stack MPLS header for the MNA Post-Stack Header type is shown in Figure 4. The encoding contains the following fields.

- * MPLS HDR: MPLS Header containing an MPLS label stack and MNA Sub-Stacks (NAS).
- * NAS: Network Action Sub-Stack. It has the P bit set to 1 to indicate the presence of a Post-Stack MPLS header for the MNA Post-Stack Header type in the packet. An MPLS packet may carry more than one NAS, not shown in Figure 4.
- * PSMH: Post-Stack MPLS Header. This includes the Post-Stack MPLS header type (PSMHT) and Post-Stack network actions (PSNA).
- * PSMHT: Post-Stack MPLS Header Type. This includes the type of Post-Stack MPLS header, version, and Post-Stack MPLS Header length. In this example, the type is set to the MNA Post-Stack Header.
- * PSNA: Post-Stack Network Actions. Applicable only when the type is set to the MNA Post-Stack Header. An MPLS packet may have more than one Post-Stack Network Action, not shown in Figure 4.

4. In-Stack Network Action Special Opcodes

4.1. In-Stack Network Action Opcode for PSMH Start Offset for MNA

Opcode: TBA2

Purpose: This opcode carries the start offset of the PSMH for MNA from the BOS.

LSE Format: B or C (defined in [I-D.ietf-mpls-mna-hdr])

Data: The data value of the LSE contains the offset from the MPLS BOS in 4-octet units.

Scope: This opcode can be used with any scope.

This opcode allows the existing Post-Stack Headers (PSHs) [RFC9790], e.g., the Generic Control Word (0000b) [RFC4385] and G-ACh (0001b) [RFC5586], and any other PSH defined in the future to be placed immediately after the BOS.

If in the given NAS, the P bit is set and the PSMH Start Offset opcode is absent, the PSMH is encoded immediately after the MPLS BOS. A data value of 1 indicates that the PSMH starts at 4-octets after the BOS.

4.2. In-Stack Network Action Opcode for Offset of End of Post-Stack MPLS Header for MNA

Opcode: TBA3

Purpose: This opcode carries the offset of the end of the Post-Stack MPLS Header for MNA from the BOS.

LSE Format: B or C (defined in [I-D.ietf-mpls-mna-hdr])

Data: The data value of the LSE contains the offset from the MPLS BOS in 4-octet units. A data value of 5 indicates that the Post-Stack MPLS Header ends at 20-octets after the BOS.

Scope: This opcode can be used with any scope.

The offset of the end of the PSMH for MNA and the offset of the start of the PSMH for MNA allow the NAS parser implementation to know the size of the PSMH without having to parse the PSMH (e.g., for Readable Label Depth with Post-Stack MPLS Header checks).

5. Procedure

5.1. Processing Rules for P Bit

The P bit MUST be set to 1 in an In-Stack Network Action Sub-Stack when the corresponding Post-Stack MPLS Header is added in the packet.

By default, the PSMH starts immediately after the BOS. The offset of the PSMH that does not start immediately after the BOS is indicated using the PSMH Start Offset Opcode TBA2.

The P bit MUST be set to 1 when the network action with opcode TBA2 is added to the In-Stack Network Action Sub-Stack. The node that recognizes the network action with Opcode TBA2 MUST process the packet according to the U flag if the P bit is not set.

The P bit MUST be set to 1 when the network action with opcode TBA3 is added to the In-Stack Network Action Sub-Stack. The node that recognizes the network action with Opcode TBA3 MUST process the packet according to the U flag if the P bit is not set.

The node that supports the P bit, processes the Post-Stack Network Actions in the Post-Stack MPLS Header as defined in this document. Conversely, the node that does not support the P bit skips processing the Post-Stack MPLS Header altogether.

5.2. Network Action Processing Order

The Post-Stack Network Actions are processed in the same order they are encoded after the BOS. By default, they are processed after the In-Stack Network Actions in the Network Action Sub-Stack. However, Post-Stack Network Action Opcodes for applications (such as IOAM as described in [RFC9791]) can be added to the In-Stack Network Action Sub-Stack to process Post-Stack Network Actions in a certain order with respect to the Opcodes in the In-Stack Network Action Sub-Stack.

5.3. Node Capability Signaling

The ingress node that is adding a Post-Stack MPLS Header MUST ensure that the egress node is capable of Post-Stack MNA processing and can remove the PSMH from the packet.

- * Each participating node MUST signal the Post-Stack network actions that it supports to the encapsulating node.

- * Each participating node MUST signal its "Readable Label Depth including Post-Stack MPLS Header" that can be encoded by the encapsulating node. Note that the "Readable Label Depth" defined in [I-D.ietf-mpls-mna-hdr] is extended in this document to include the length of the Post-Stack MPLS Header.

The above capability signaling will be added in the appropriate protocols. Signaling details are outside the scope of this document.

6. Node Responsibilities

This section defines the specific responsibilities for nodes along an MPLS path for processing a Post-Stack MPLS Header.

6.1. Encapsulating Node Responsibilities

The encapsulating node MAY add a Post-Stack MPLS Header to the packet in accordance with its policies, the placement restrictions, and the limitations.

The encapsulating node MUST NOT add a Post-Stack MPLS Header to the packet if the decapsulating node does not support Post-Stack MPLS Header.

If the encapsulating node is also a transit node, then it MUST also respect transit node responsibilities.

The encapsulating node MUST add the Post-Stack MPLS Header in the same order as the corresponding In-Stack NAS in the MPLS header.

6.2. Transit Node Responsibilities

A transit node MAY modify the Ancillary Data in the Post-Stack MPLS Header.

A transit node MUST respect the Unknown Action Handling flag encoded in the corresponding NAS when processing the PSMH.

A transit node that removes an NAS with the Select scope, MUST also remove the associated PSMH.

6.3. Penultimate Node Responsibilities

In addition to the transit node responsibilities above, the penultimate node MUST NOT remove an HBH or I2E NAS [I-D.ietf-mpls-mna-hdr] and the associated PSMH when the NAS is exposed after removing the forwarding (transport) label. This allows the egress node to receive and process the NAS and the associated PSMH.

6.4. Decapsulating Node Responsibilities

The decapsulating node MUST remove the Post-Stack MPLS Headers from the packet when it removes the NASes.

7. Security Considerations

The security considerations in [RFC3032], [RFC9789], and [I-D.ietf-mpls-mna-hdr] also apply to this document.

System designers must be aware that information included in Post-Stack Ancillary Data may be transmitted "in the clear." Network actions that require the exchange of sensitive data, must be defined in such a way that the data is encrypted in transit.

8. IANA Considerations

8.1. First Nibble for Post-Stack MPLS Header

This document requests that IANA update the the "Post-Stack First Nibble" registry created by [RFC9790] to include the PFN value 0x00b for the Post-Stack MPLS Header.

Protocol	Value	Description	Reference
PSMH	0x00	Post-Stack MPLS Header	This document

Table 2: Post-Stack First Nibble Registry

8.2. Post-Stack MPLS Header Types Registry

This document requests that IANA create a new registry with the name "Post-Stack MPLS Header Types" as follows. The registration procedure for this registry is "IETF Review", "Experimental Use" and "Private Use". The fields are "Type" (integer), "Description" (string), and "Reference" (string).

The assignments for this registry are:

Type	Description	Reference
0	Reserved, not to be assigned	This document
1-65520	IETF Review	This document
65521-65524	Experimental Use	This document
65525-65535	Private Use	This document

Table 3: Post-Stack MPLS Header Types Registry

The initial assignment for this registry is:

Type	Description	Reference
1	Post-Stack MPLS Header Type For MNA	This document

Table 4: Post-Stack MPLS Header Types

8.3. Network Action Opcodes

IANA maintains the "Network Action Opcodes" registry that will be created by [I-D.ietf-mpls-mna-hdr]. IANA is requested to perform two actions for this registry:

1. Assign two code points for network actions defined in this document.
2. Add a new column to indicate whether network action opcodes may be used In-Stack or Post-Stack.

The resulting entries in the registry are as follows:

Opcode	Description	In-Stack Only, Post-Stack Only, In-Stack and Post-Stack	Reference
0	Reserved	Not Applicable	[I-D.ietf-mpls-mna-hdr]
1	Flag-Based Network Action Indicators without AD	In-Stack Only	[I-D.ietf-mpls-mna-hdr]
2	No operation Opcode	In-Stack and Post-Stack	[I-D.ietf-mpls-mna-hdr]
TBA2	Offset of Start of Post-Stack MPLS Header	In-Stack Only	This document
TBA3	Offset of End of Post-Stack MPLS Header	In-Stack Only	This document
127	Opcode Range Extension Beyond 127	In-Stack and Post-Stack	[I-D.ietf-mpls-mna-hdr]

Table 5: Network Action Opcodes

9. References

9.1. Normative References

[I-D.ietf-mpls-mna-hdr]

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9.2. Informative References

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Appendix A. Appendix A: Examples

A.1. Examples of Post-Stack MPLS Header Encoding

A.1.1. NAS that only Indicates Post-Stack MPLS Header

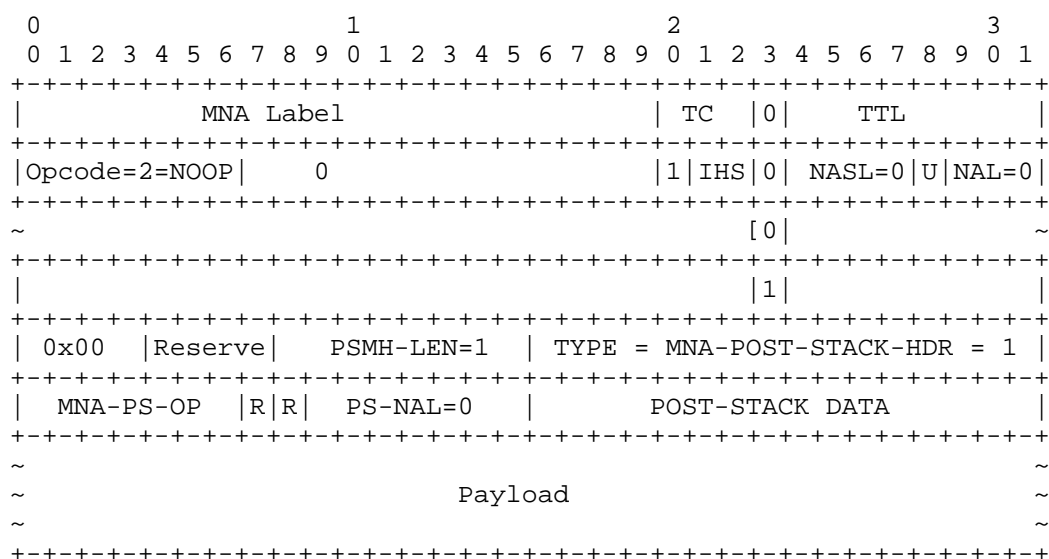


Figure 5: NAS that only indicates Post-Stack MPLS Header

In some cases, the NAS may encode only the presence of Post-Stack MPLS Header. The Post-Stack MPLS Header starts immediately after the BOS.

A.1.2. NAS that Indicates Post-Stack MPLS Header Start Offset

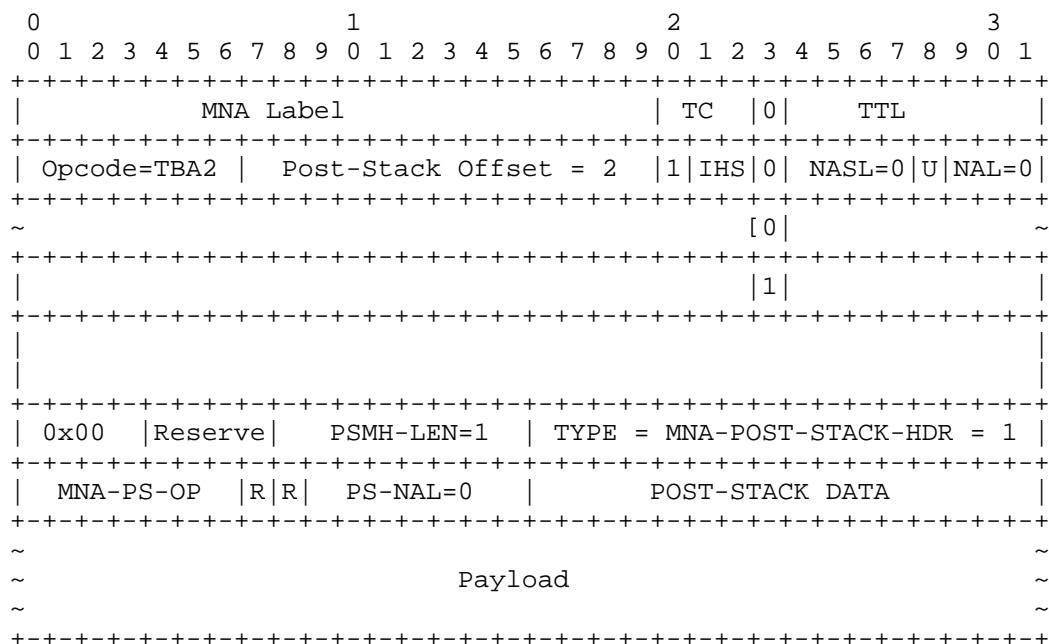


Figure 6: NAS Indicates Post-Stack MPLS Header Start Offset

The NAS may encode the start offset of the Post-Stack MPLS Header with a non-zero value, for example, when it is after another header such as G-ACh or Control Word header. In this example, the PSMH starts at an offset of 8 bytes after the BoS.

A.1.3. Post-Stack Network Actions with Two Opcodes

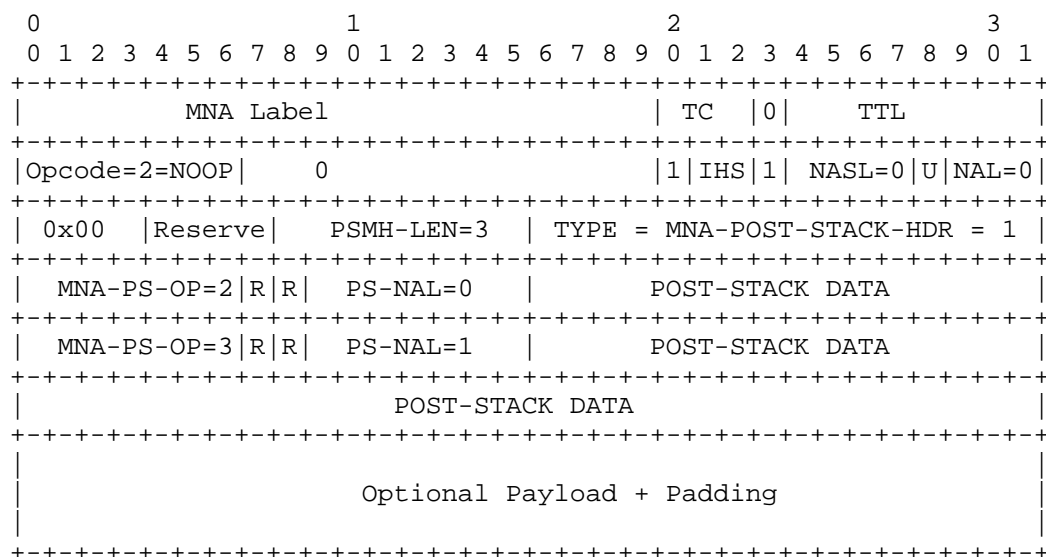


Figure 7: Post-Stack NA with Two Opcodes

This is an example where the Post-Stack MPLS Header encodes two different Post-Stack Network Actions.

Details:

PSMH-LEN=3: This is the total length of Post-Stack MPLS Header.

MNA-PS-OP=2: Post-Stack NA Opcode 2.

PS-NAL=0: Post-Stack Network Action does not contain any additional data.

MNA-PS-OP=3: Post-Stack NA Opcode 3.

PS-NAL=1: Post-Stack Network Action contains 1 additional 4-octet Ancillary Data.

A.1.4. Post-Stack Network Action with two Different Scopes

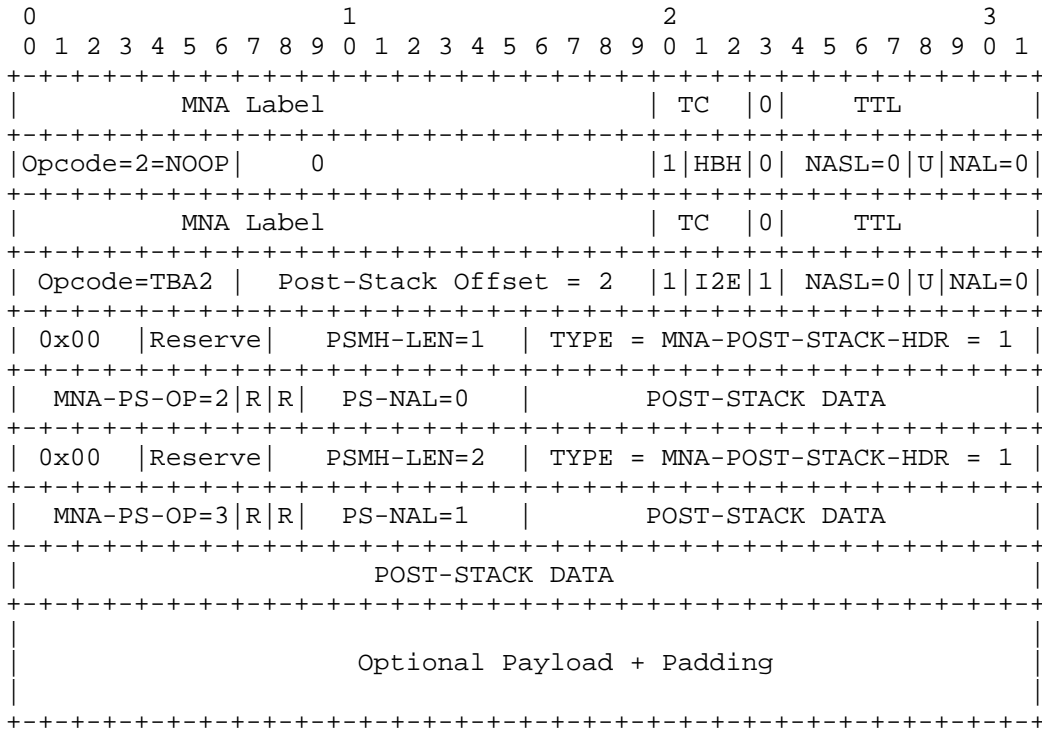


Figure 8: Post-Stack NA with two Different Scopes

This is an example of Post-Stack MPLS Header encoding, that encodes two different different scoped Post-Stack Network Actions. The first scope is Hop-By-Hop and the second scope is Ingress-To-Egress.

Details:

The offset of the Hop-By-Hop scoped Post-Stack Network Action is 0.

Opcode TBA2 carries the offset of the Ingress-To-Egress scoped Post-Stack Network Action. The data is 2, i.e., the Post-Stack MPLS Header starts 8 bytes after the MPLS Bottom of Stack.

A.2. Examples of In-Stack and Post-Stack Network Actions

A.2.1. NAS with In-Stack and Post-Stack NAs

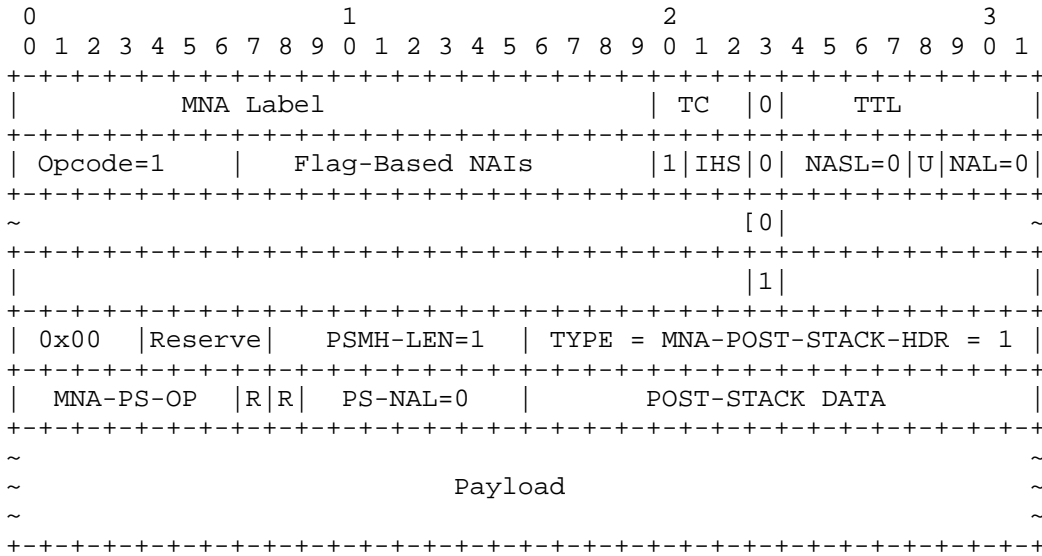


Figure 9: NAS with In-Stack and Post-Stack NAs

In some cases, the NAS may encode In-Stack NAs and indicate the presence of a Post-Stack MPLS Header. The IHS field indicates the scope of both the In-Stack and Post-Stack NAs.

A.2.2. NASes with Different In-Stack and Post-Stack Scopes

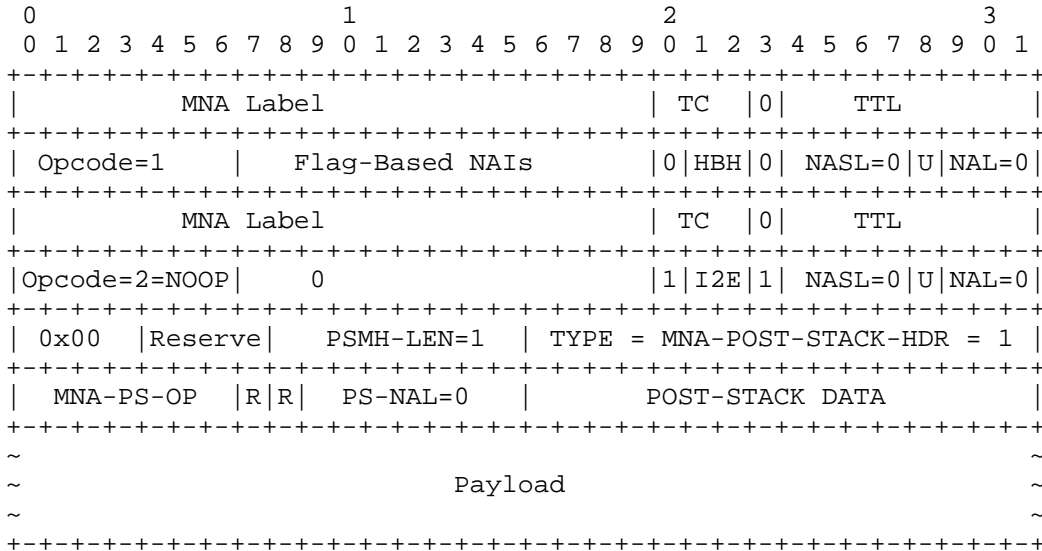


Figure 10: NASes with Different In-Stack and Post-Stack Scopes

In some cases, the label stack may need to carry In-Stack NASs with Hop-By-Hop scope and Post-Stack NASs with I2E scope. In this case, there will be two NASes in the label stack. In this case, the first NAS will encode the In-Stack NA with the Hop-By-Hop scope and the second NAS will encode the presence of I2E-scoped Post-Stack NASs.

Acknowledgments

The authors would like to thank the authors and contributors of the draft-ietf-mpls-mna-hdr as this document borrows some text from the earlier version of that document. The authors would like to thank Greg Mirsky, Loa Andersson, Haoyu Song, Adrian Farrel, Yao Liu, and Joel Halpern for reviewing this document and providing many useful comments.

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