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MPLS Network Action for Stack Management
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Abstract

The MPLS Network Action (MNA) framework provides a general mechanism for the encoding and processing of network actions and their data. This document introduces a network action to the MPLS Network Action (MNA) framework for stack management operations including MOVE-N-LSE and POP-N-LSE. The MOVE-N-LSE operation elevates a specified number of LSEs within the stack and the POP-N-LSE operation removes a specified number of LSEs. The stack management operations can be used to facilitate various applications. As an example, a mechanism called HBH preservation which reduces the readable label depth (RLD) requirement in nodes is presented.

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at <https://uni-tue-kn.github.io/draft-ihle-mpls-mna-lse-operations/draft-ihle-mpls-mna-lse-operations.html>. Status information for this document may be found at <https://datatracker.ietf.org/doc/draft-ihle-mpls-mna-stack-management/>.

Discussion of this document takes place on the Multiprotocol Label Switching Working Group mailing list (<mailto:mpls@ietf.org>), which is archived at <https://mailarchive.ietf.org/arch/browse/mpls/>. Subscribe at <https://www.ietf.org/mailman/listinfo/mpls/>.

Source for this draft and an issue tracker can be found at <https://github.com/uni-tue-kn/draft-ihle-mpls-mna-lse-operations>.

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

The MPLS Network Action (MNA) framework encodes network actions and their parameters for processing by MPLS nodes.

[I-D.ietf-mpls-mna-hdr] defines the encoding of such network actions and their data as in-stack data (ISD) in a so-called Network Action Substack (NAS). These network actions are processed by all nodes on a path (hop-by-hop), by only selected nodes, or on an ingress-to-egress basis (I2E). This document introduces a network action for stack management operations. Those operations include a MOVE-N-LSE and a POP-N-LSE operation.

The MNA framework's processing introduces an increased stack size and parsing overhead for hardware. Here, redundant copies of HBH-scoped NAS may have to be inserted into the MPLS stack

[I-D.ietf-mpls-mna-hdr]. Further, nodes may have to parse LSEs irrelevant to them to find the HBH-scoped NAS in the stack [IhMe25-2]. This poses a challenge to nodes with a limited readable label depth (RLD). The MOVE-N-LSE operation can be leveraged to reduce the required RLD by reorganizing the MPLS stack during forwarding. With the MOVE-N-LSE operation, a number of LSEs from below the NAS is brought to the top-of-stack. An example for this is given in this document using a mechanism called HBH preservation [IhMe25-2]. With the POP-N-LSE operation, a number of LSEs below the NAS is popped.

Those stack management operations are not tied to specific use cases and may also be applied for various other use cases.

2. Conventions and Definitions

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.

2.1. Abbreviations

This document makes use of the terms defined in [I-D.ietf-mpls-mna-hdr].

Further abbreviations used in this document:

Abbreviation	Meaning	Reference
RLD	Readable Label Depth	[I-D.ietf-mpls-mna-fwk]

Table 1: Abbreviations.

3. Stack Management Operations

This section describes the stack management network action encoding and the processing in an LSR.

3.1. Network Action Encoding

The network action for stack management operations is encoded as follows:

- * Network action indication: The stack management network action is indicated by opcode TBA1.
- * Format: The stack management network action MUST be encoded using a Format B or a Format C LSE as defined in [I-D.ietf-mpls-mna-hdr], see Figure 1 and Figure 2.
- * Scope: The stack management network action can be used in any scope, i.e., in the select, HBH, and I2E scope. The scope depends on the use case.
- * Ancillary data: The stack management network action encodes the number of labels for each operation, i.e., the numbers MOVE-N and POP-N, in a four bit field of in-stack ancillary data.
 - In Format B, the four least-significant bits of the ancillary data field contain the value of MOVE-N. The next four bits contain the value of POP-N. All other ancillary data bits MUST be set to zero and are reserved for future use.
 - In Format C, the same encoding of POP-N-LSEs and MOVE-N-LSEs applies to the first data field of the LSE. The second data field, i.e., the 4-bit wide ancillary data field, MUST be set to zero and is reserved for future use.
- * Post-stack data: None.

Figure 1 and Figure 2 illustrate the stack management operation encoding in Format B and C.

```

      0               1               2               3
0  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
|Opcode=MGMT |Reserved | POP-N | MOVE-N|R|IHS|S|U| NASL  |NAL=0|
+-----+-----+-----+-----+-----+-----+-----+-----+

```

Figure 1: MNA for Stack Management Operations in Format B.

```

      0               1               2               3
0  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----+-----+-----+-----+-----+-----+-----+-----+
|Opcode=MGMT |      Reserved      | POP-N | MOVE-N|S|U|  Res  |NAL=0|
+-----+-----+-----+-----+-----+-----+-----+-----+

```

Figure 2: MNA for Stack Management Operations in Format C.

3.2. Processing

A node that processes the stack management network action **MUST** perform the MOVE-N-LSE and POP-N-LSE operation according to the corresponding parameter $N > 0$. If $N = 0$, the corresponding operation is not applied.

- * For $\text{MOVE-N} > 0$, MOVE-N LSEs below the NAS are brought to the top-of-stack.
- * For $\text{POP-N} > 0$, POP-N LSEs below the NAS are popped.

The ingress LER **MUST** ensure that no invalid state, e.g., a MOVE-N-LSE operation with $\text{MOVE-N} > \text{\#LSEs below the NAS}$, results from the processing of the stack management network action.

If multiple NAS containing the stack management network action are processed by a node, e.g., in a select-scoped and in an HBH-scoped NAS, the values for MOVE-N and POP-N of each NAS are summed up. The operation, i.e., pop or move, is then applied based on the summed up value.

4. Use Cases and Examples

This section illustrates each operation with an example.

4.1. MOVE-N-LSE

First, we describe the concept of HBH preservation. Then, we explain how the MOVE-N-LSE operation is used for this concept, and give an example.

4.1.1. HBH Preservation

In the MNA framework, each node must be able to access the HBH-scoped NAS. The HBH-scoped NAS must be within the RLD of each node. To achieve this, redundant copies of the NAS are placed at different positions in the MPLS stack [I-D.ietf-mpls-mna-hdr]. This increases the overall stack size. Further, routers must scan through unrelated stack entries to find the HBH-scoped NAS. This adds parsing overhead and is difficult on hardware with limited RLD.

The HBH preservation mechanism keeps the HBH-scoped NAS within reach of all nodes by placing the NAS always below the top-of-stack label. When a node pops the top label, it moves the next forwarding label below the NAS to the top. This prevents the NAS from being exposed and therefore, removed. Nodes can process it without scanning through unrelated labels. This avoids redundant copies and reduces RLD requirements [IhMe25-2].

4.1.2. MOVE-N-LSE Operation for HBH Preservation

The stack management network action with the MOVE-N-LSE operation is added to the HBH-scoped NAS with MOVE-N = 1 to apply the HBH preservation mechanism. Each node popping the top-of-stack label and processing this action brings one LSE from below the NAS to the top. This prevents the HBH-scoped NAS from being exposed to the top.

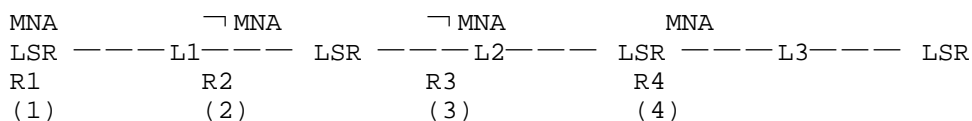
However, this mechanism poses a challenge when there are MNA-incapable nodes on the path. An MNA-incapable node pops the top-of-stack forwarding label and exposes the HBH-scoped NAS to the top, leading to packet drop at the next hop. To fix this, the MOVE-N-LSE operation can be leveraged to bring LSEs at the preceding node of an MNA-incapable node to the top. For that purpose, a select-scoped NAS is used. Forwarding labels for upcoming MNA-incapable nodes are brought to the top and the HBH-scoped NAS is never exposed. The MNA-capabilities are signaled to the ingress LER [I-D.ihle-song-mpls-mna-signaling-00]. Therefore, the ingress LER can place a select-scoped NAS in the stack destined for the preceding node of MNA-incapable nodes. This NAS may bring more than one label to the top to skip processing on MNA-incapable nodes.

No information about MNA capabilities of neighboring nodes is required in a transit node as all node capabilities are signaled to the ingress LER.

4.1.3. Example

Figure 3 shows an example network of an MNA-capable node followed by two MNA-incapable nodes. Further, the MPLS stacks at hops (1) - (4) and the corresponding actions on the LSEs are shown.

For clarity, in this example, a forwarding label is popped on each hop. In practice, however, this is typically not the case. If the top-of-stack label is not popped, no labels have to be moved to the top-of-stack.



MPLS label stacks:

```
(1)
MPLS Label L1                -> pop + forward
HBH-scoped NAS with MOVE-N-LSE=1 -> process
Select-scoped NAS with MOVE-N-LSE=2 -> process + pop
MPLS Label L2                -> move to top
MPLS Label L3                -> move to top
MPLS Label L4                -> move to top
MPLS Label L5

(2)
MPLS Label L2                -> pop + forward
MPLS Label L3
MPLS Label L4
HBH-scoped NAS
MPLS Label L5

(3)
MPLS Label L3                -> pop + forward
MPLS Label L4
HBH-scoped NAS
MPLS Label L5

(4)
MPLS Label L4                -> pop + forward
HBH-scoped NAS with MOVE-N-LSE=1 -> process
MPLS Label L5                -> move to top
```

Figure 3: Example using the MOVE-N-LSE operation.

For backward compatibility, the stack management network action with MOVE-N = 2 for the MOVE-N-LSE operation is pushed by the ingress LER as a select-scoped NAS for the LSR R1. Further, to enable the HBH preservation mechanism, the stack management action with MOVE-N = 1 for the MOVE-N-LSEs operation is added to the HBH-scoped NAS. R1 brings three LSEs to the top-of-stack, two from the MOVE-N-LSE operation in the select-scoped NAS and one from the HBH-scoped NAS. At the MNA-incapable LSRs R2 and R3, the forwarding label is popped without exposing the NAS to the top. Finally, the MNA-capable LSR R4 processes the HBH-scoped NAS and brings one LSE from below the NAS to the top.

4.2. POP-N-LSE

In this section, we give an example for the POP-N-LSE operation. Another application of this operation can be found in [I-D.ihle-mpls-mna-stateless-egress-protection].

4.2.1. Example

Figure 4 shows an MPLS stack containing the stack management network action with POP-N = 2. The next node that pops the top-of-stack label will process the NAS containing the stack management network action. Therefore, two LSEs after the NAS, i.e., label L2 and L3 will be popped. Since the NAS is exposed to the top, it is popped as well. The resulting stack contains only forwarding label L4.

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Figure 4: Example using the POP-N-LSE operation.

5. Implementation Status

[Note to the RFC Editor - remove this section before publication, as well as remove the reference to [rfc7942]]

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [rfc7942]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

5.1. University of Tuebingen Implementation

The stack management network action defined in this document has been implemented using the MOVE-N-LSE operation for HBH preservation with a P4 pipeline [IhMe25-2]. The implementation code can be found at <https://github.com/uni-tue-kn/P4-MNA> (<https://github.com/uni-tue-kn/P4-MNA>).

6. Security Considerations

The security issues discussed in [I-D.ietf-mpls-mna-hdr] apply to this document.

7. IANA Considerations

This document requests that IANA allocates a new codepoint with the name "Stack Management" in the "Network Action Opcodes Registry" introduced in [I-D.ietf-mpls-mna-hdr].

MNA Opcode	Description	Reference
TBA1	Stack Management	This document

Table 2: Stack Management Opcode IANA allocation.

8. References

8.1. Normative References

- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/rfc/rfc2119>>.
- [RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <<https://www.rfc-editor.org/rfc/rfc8174>>.

8.2. Informative References

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Andersson, L., Bryant, S., Bocci, M., and T. Li, "MPLS Network Actions (MNA) Framework", Work in Progress, Internet-Draft, draft-ietf-mppls-mna-fwk-15, 27 December 2024, <<https://datatracker.ietf.org/doc/html/draft-ietf-mppls-mna-fwk-15>>.
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