

ippm
Internet-Draft
Intended status: Standards Track
Expires: March 22, 2021

S. Bhandari
F. Brockners
C. Pignataro
Cisco
H. Gredler
RtBrick Inc.
J. Leddy
Comcast
S. Youell
JMPC
T. Mizrahi
Huawei Network.IO Innovation Lab
A. Kfir
B. Gafni
Mellanox Technologies, Inc.
P. Lapukhov
Facebook
M. Spiegel
Barefoot Networks, an Intel company
S. Krishnan
Kaloomb
R. Asati
Cisco
M. Smith
September 18, 2020

In-situ OAM IPv6 Options
[draft-ietf-ippm-ioam-ipv6-options-03](#)

Abstract

In-situ Operations, Administration, and Maintenance (IOAM) records operational and telemetry information in the packet while the packet traverses a path between two points in the network. This document outlines how IOAM data fields are encapsulated in IPv6.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of [BCP 78](#) and [BCP 79](#).

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at <https://datatracker.ietf.org/drafts/current/>.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on March 22, 2021.

Copyright Notice

Copyright (c) 2020 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to [BCP 78](https://trustee.ietf.org/license-info) and the IETF Trust's Legal Provisions Relating to IETF Documents (<https://trustee.ietf.org/license-info>) in effect on the date of publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Simplified BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Simplified BSD License.

Table of Contents

| | | |
|------------------------|---|--------------------|
| 1. | Introduction | 3 |
| 2. | Conventions | 3 |
| 2.1. | Requirements Language | 3 |
| 2.2. | Abbreviations | 3 |
| 3. | In-situ OAM Metadata Transport in IPv6 | 3 |
| 4. | IOAM Deployment In IPv6 Networks | 6 |
| 4.1. | Considerations for IOAM deployment in IPv6 networks . . . | 6 |
| 4.2. | IOAM domains bounded by hosts | 7 |
| 4.3. | IOAM domains bounded by network devices | 7 |
| 4.4. | Deployment options | 7 |
| 4.4.1. | IPv6-in-IPv6 encapsulation | 7 |
| 4.4.2. | IP-in-IPv6 encapsulation with ULA | 8 |
| 4.4.3. | x-in-IPv6 Encapsulation that is used Independently . | 9 |
| 5. | Security Considerations | 9 |
| 6. | IANA Considerations | 9 |
| 7. | Acknowledgements | 9 |
| 8. | References | 10 |
| 8.1. | Normative References | 10 |
| 8.2. | Informative References | 10 |
| | Authors' Addresses | 11 |

1. Introduction

In-situ Operations, Administration, and Maintenance (IOAM) records operational and telemetry information in the packet while the packet traverses a path between two points in the network. This document outlines how IOAM data fields are encapsulated in the IPv6 [[RFC8200](#)] and discusses deployment options for networks which leverage IOAM data fields encapsulated in the IPv6 protocol. Deployment considerations differ, whether the IOAM domain starts and ends on hosts or whether the IOAM encapsulating and decapsulating nodes are network devices that forward traffic, such as routers.

2. Conventions

2.1. Requirements Language

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.

2.2. Abbreviations

Abbreviations used in this document:

| | |
|-------|---|
| E2E: | Edge-to-Edge |
| IOAM: | In-situ Operations, Administration, and Maintenance |
| ION: | IOAM Overlay Network |
| OAM: | Operations, Administration, and Maintenance |
| POT: | Proof of Transit |

3. In-situ OAM Metadata Transport in IPv6

In-situ OAM in IPv6 is used to enhance diagnostics of IPv6 networks. It complements other mechanisms proposed to enhance diagnostics of IPv6 networks, such as the IPv6 Performance and Diagnostic Metrics Destination Option described in [[RFC8250](#)].

IOAM data fields are encapsulated in "option data" fields of two types of extension headers in IPv6 packets - either Hop-by-Hop Options header or Destination options header. The selection of a particular extension header type depends on IOAM usage, as described in section 4 of [[I-D.ietf-ippm-ioam-data](#)]. Multiple options with the

same Option Type MAY appear in the same Hop-by-Hop Options or Destination Options header, with varying content.

In order for IOAM to work in IPv6 networks, IOAM MUST be explicitly enabled per interface on every node within the IOAM domain. Unless a particular interface is explicitly enabled (i.e. explicitly configured) for IOAM, a router MUST drop packets which contain extension headers carrying IOAM data-fields. This is the default behavior and is independent of whether the Hop-by-Hop options or Destination options are used to encode the IOAM data. This ensures that IOAM data does not unintentionally get forwarded outside the IOAM domain.

An IPv6 packet carrying IOAM data in an Extension header can have other extension headers, compliant with [\[RFC8200\]](#).

IPv6 Hop-by-Hop and Destination Option format for carrying in-situ OAM data fields:

```

+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Option Type | Opt Data Len |   Reserved   |   IOAM Type   |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                                                     | |
.                                                     . I
.                                                     . O
.                                                     . A
.                                                     . M
.                                                     . .
.                   Option Data                       . O
.                                                     . P
.                                                     . T
.                                                     . I
.                                                     . O
.                                                     . N
|                                                     | |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Option Type: 8-bit option type identifier as defined in [Section 6](#).

Opt Data Len: 8-bit unsigned integer. Length of this option, in octets, not including the first 2 octets.

Reserved: 8-bit field MUST be set to zero upon transmission and ignored upon reception.

IOAM Type: 8-bit field as defined in section 7.2 in [\[I-D.ietf-ippm-ioam-data\]](#).

Option Data: Variable-length field. Option-Type-specific data.

In-situ OAM Options are inserted as Option data as follows:

1. Pre-allocated Trace Option: The in-situ OAM Preallocated Trace option defined in [\[I-D.ietf-ippm-ioam-data\]](#) is represented as an IPv6 option in Hop-by-Hop extension header:

Option Type: 001xxxxx 8-bit identifier of the IOAM type of option. xxxxx=TBD.

IOAM Type: IOAM Pre-allocated Trace Option Type.

2. Incremental Trace Option: The in-situ OAM Incremental Trace option defined in [\[I-D.ietf-ippm-ioam-data\]](#) is represented as an IPv6 option in Hop-by-Hop extension header:

Option Type: 001xxxxx 8-bit identifier of the IOAM type of option. xxxxx=TBD.

IOAM Type: IOAM Incremental Trace Option Type.

3. Proof of Transit Option: The in-situ OAM POT option defined in [\[I-D.ietf-ippm-ioam-data\]](#) is represented as an IPv6 option in Hop-by-Hop extension header:

Option Type: 001xxxxx 8-bit identifier of the IOAM type of option. xxxxx=TBD.

IOAM Type: IOAM POT Option Type.

4. Edge to Edge Option: The in-situ OAM E2E option defined in [\[I-D.ietf-ippm-ioam-data\]](#) is represented as an IPv6 option in Destination extension header:

Option Type: 000xxxxx 8-bit identifier of the IOAM type of option. xxxxx=TBD.

IOAM Type: IOAM E2E Option Type.

All the in-situ OAM IPv6 options defined here have alignment requirements. Specifically, they all require 4n alignment. This ensures that fields specified in [\[I-D.ietf-ippm-ioam-data\]](#) are aligned at a multiple-of-4 offset from the start of the Hop-by-Hop and Destination Options header. In addition, to maintain IPv6

extension header 8-octet alignment and avoid the need to add or remove padding at every hop, the Trace-Type for Incremental Trace Option in IPv6 MUST be selected such that the IOAM node data length is a multiple of 8-octets.

4. IOAM Deployment In IPv6 Networks

4.1. Considerations for IOAM deployment in IPv6 networks

IOAM deployment in an IPv6 network should take the following considerations and requirements into account:

- C1 It is desirable that the addition of IOAM data fields neither changes the way routers forward the packets, nor the forwarding decision the routers takes. The packet with the added OAM information should follow the same path within the domain that the same packet without the OAM information would follow within the domain even in the presence of ECMP. Such a behavior is particularly interesting for deployments where IOAM data fields are only added "on-demand", e.g. to provide further insights in case of undesired network behavior for certain flows. Implementations of IOAM should ensure that ECMP behavior for packets with and without IOAM data fields is the same.
- C2 Given that IOAM data fields increase the total size of the packet, the size of the packet including the IOAM data could exceed the PMTU. In particular, the incremental trace IOAM HbH Option, which is proposed to support hardware implementations of IOAM, changes Option Data Length en-route. Operators of an IOAM domain are to ensure that the addition of OAM information does not lead to fragmentation of the packet, e.g. by configuring the MTU of transit routers and switches to a sufficiently high value. Careful control of the MTU in a network is one of the reasons why IOAM is considered a domain specific feature, see also [[I-D.ietf-ippm-ioam-data](#)]. In addition, the PMTU tolerance range in the IOAM domain should be identified (e.g. through configuration) and IOAM encapsulation operations and/or IOAM data field insertion (in case of incremental tracing) should not be performed if it exceeds the packet size beyond PMTU.
- C3 Packets with IOAM data or associated ICMP errors, should not arrive at destinations which have no knowledge of IOAM. Consider using IOAM in transit devices; misleading ICMP errors due to addition and/or presence of OAM data in the packet can confuse a source of the packet that did not insert the OAM information.
- C4 OAM data leaks may affect the forwarding behavior and state of network elements outside an IOAM domain. IOAM domains SHOULD

provide a mechanism to prevent data leaks or be able to assure that upon leak network elements outside the domain are not affected i.e they continue to process other valid packets.

C5 The source of that inserted and leaked the IOAM data must be easy to identify for the purpose of troubleshooting, due to the high complexity of troubleshooting a source that inserted the IOAM data and did not remove it when the packet traversed across an AS. Such a troubleshooting process may require coordination between multiple operators, complicated configuration verification, packet capture analysis, etc.

C6 Compliance with [\[RFC8200\]](#) would require OAM data to be encapsulated instead of header/option insertion directly into in-flight packets using the original IPv6 header.

4.2. IOAM domains bounded by hosts

For deployments where the IOAM domain is bounded by hosts, hosts will perform the operation of IOAM data field encapsulation and decapsulation. IOAM data is carried in IPv6 packets as Hop-by-Hop or Destination options as specified in this document.

4.3. IOAM domains bounded by network devices

For deployments where the IOAM domain is bounded by network devices, network devices such as routers form the edge of an IOAM domain. Network devices will perform the operation of IOAM data field encapsulation and decapsulation.

4.4. Deployment options

This section lists out possible deployment options that can be employed to meet the requirements listed in [Section 4.1](#).

4.4.1. IPv6-in-IPv6 encapsulation

Leverage an IPv6-in-IPv6 approach: Preserve the original IP packet and add an IPv6 header including IOAM data fields in an extension header in front of it, to forward traffic within and across the IOAM domain. The overlay network formed by the additional IPv6 header with the IOAM data fields included in an extension header is referred to as IOAM Overlay Network (ION) in this document.

1. Perform an IPv6-in-IPv6 approach. The source address of the outer IPv6 header is that of the IOAM encapsulating node. The destination address of the outer IPv6 header is the same as the

inner IPv6 destination address, i.e. the destination address of the packet does not change.

2. To simplify debugging in case of leaked IOAM data fields in packets, consider a new IOAM E2E destination option to identify the Source IOAM domain (AS, v6 prefix). Insert this option into the IOAM destination options EH attached to the outer IPv6 header. This additional information would allow for easy identification of an AS operator that is the source of packets with leaked IOAM information. Note that leaked packets with IOAM data fields would only occur in case a router would be misconfigured.
3. All the IOAM options are defined with type "00" - skip over this option and continue processing the header. So presence of the options must not cause packet drop in the network elements that do not understand the option. In addition [\[I-D.ietf-6man-hbh-header-handling\]](#) should be considered.

4.4.2. IP-in-IPv6 encapsulation with ULA

The "IP-in-IPv6 encapsulation with ULA" [\[RFC4193\]](#) approach can be used to apply IOAM to an IPv6 as well as an IPv4 network. In addition, it fulfills requirement C4 (avoid leaks) by using ULA for the ION. Similar to the IPv6-in-IPv6 encapsulation approach above, the original IP packet is preserved. An IPv6 header including IOAM data fields in an extension header is added in front of it, to forward traffic within and across the IOAM domain. IPv6 addresses for the ION, i.e. the outer IPv6 addresses are assigned from the ULA space. Addressing and routing in the ION are to be configured so that the IP-in-IPv6 encapsulated packets follow the same path as the original, non-encapsulated packet would have taken. This would create an internal IPv6 forwarding topology using the IOAM domain's interior ULA address space which is parallel with the forwarding topology that exists with the non-IOAM address space (the topology and address space that would be followed by packets that do not have supplemental IOAM information). Establishment and maintenance of the parallel IOAM ULA forwarding topology could be automated, e.g. similar to how LDP [\[RFC5036\]](#) is used in MPLS to establish and maintain an LSP forwarding topology that is parallel to the network's IGP forwarding topology.

Transit across the ION could leverage the transit approach for traffic between BGP border routers, as described in [\[RFC1772\]](#), "A.2.3 Encapsulation". Assuming that the operational guidelines specified in [Section 4 of \[RFC4193\]](#) are properly followed, the probability of leaks in this approach will be almost close to zero. If the packets do leak through IOAM egress device misconfiguration or partial IOAM

egress device failure, the packets' ULA destination address is invalid outside of the IOAM domain. There is no exterior destination to be reached, and the packets will be dropped when they encounter either a router external to the IOAM domain that has a packet filter that drops packets with ULA destinations, or a router that does not have a default route.

4.4.3. x-in-IPv6 Encapsulation that is used Independently

In some cases it is desirable to monitor a domain that uses an overlay network that is deployed independently of the need for IOAM, e.g., an overlay network that runs Geneve-in-IPv6, or VXLAN-in-IPv6. In this case IOAM can be encapsulated in as an extension header in the tunnel (outer) IPv6 header. Thus, the tunnel encapsulating node is also the IOAM encapsulating node, and the tunnel end point is also the IOAM decapsulating node.

5. Security Considerations

This document describes the encapsulation of IOAM data fields in IPv6. Security considerations of the specific IOAM data fields for each case (i.e., Trace, Proof of Transit, and E2E) are described and defined in [[I-D.ietf-ippm-ioam-data](#)].

As this document describes new options for IPv6, these are similar to the security considerations of [[RFC8200](#)] and the new weakness documented in [[RFC8250](#)].

6. IANA Considerations

This draft requests the following IPv6 Option Type assignments from the Destination Options and Hop-by-Hop Options sub-registry of Internet Protocol Version 6 (IPv6) Parameters.

<http://www.iana.org/assignments/ipv6-parameters/ipv6-parameters.xhtml#ipv6-parameters-2>

| Hex Value | Binary Value | | | Description | Reference |
|-----------|--------------|-----|-------|-------------|--------------|
| | act | chg | rest | | |
| ----- | | | | | |
| TBD_1_0 | 00 | 0 | TBD_1 | IOAM | [This draft] |
| TBD_1_1 | 00 | 1 | TBD_1 | IOAM | [This draft] |

7. Acknowledgements

The authors would like to thank Tom Herbert, Eric Vyncke, Nalini Elkins, Srihari Raghavan, Ranganathan T S, Karthik Babu Harichandra Babu, Akshaya Nadahalli, Stefano Previdi, Hemant Singh, Erik

Nordmark, LJ Wobker, Mark Smith, Andrew Yourtchenko and Justin Iurman for the comments and advice. For the IPv6 encapsulation, this document leverages concepts described in [\[I-D.kitamura-ipv6-record-route\]](#). The authors would like to acknowledge the work done by the author Hiroshi Kitamura and people involved in writing it.

8. References

8.1. Normative References

- [I-D.ietf-ippm-ioam-data]
Brockners, F., Bhandari, S., Pignataro, C., Gredler, H., Leddy, J., Youell, S., Mizrahi, T., Mozes, D., Lapukhov, P., Chang, R., and d. daniel.bernier@bell.ca, "Data Fields for In-situ OAM", [draft-ietf-ippm-ioam-data-01](#) (work in progress), October 2017.
- [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/info/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/info/rfc8174>>.

8.2. Informative References

- [I-D.ietf-6man-hbh-header-handling]
Baker, F. and R. Bonica, "IPv6 Hop-by-Hop Options Extension Header", March 2016.
- [I-D.kitamura-ipv6-record-route]
Kitamura, H., "Record Route for IPv6 (PR6) Hop-by-Hop Option Extension", [draft-kitamura-ipv6-record-route-00](#) (work in progress), November 2000.
- [RFC1772] Rekhter, Y. and P. Gross, "Application of the Border Gateway Protocol in the Internet", [RFC 1772](#), DOI 10.17487/RFC1772, March 1995, <<https://www.rfc-editor.org/info/rfc1772>>.
- [RFC4193] Hinden, R. and B. Haberman, "Unique Local IPv6 Unicast Addresses", [RFC 4193](#), DOI 10.17487/RFC4193, October 2005, <<https://www.rfc-editor.org/info/rfc4193>>.

- [RFC5036] Andersson, L., Ed., Minei, I., Ed., and B. Thomas, Ed., "LDP Specification", [RFC 5036](#), DOI 10.17487/RFC5036, October 2007, <<https://www.rfc-editor.org/info/rfc5036>>.
- [RFC8200] Deering, S. and R. Hinden, "Internet Protocol, Version 6 (IPv6) Specification", STD 86, [RFC 8200](#), DOI 10.17487/RFC8200, July 2017, <<https://www.rfc-editor.org/info/rfc8200>>.
- [RFC8250] Elkins, N., Hamilton, R., and M. Ackermann, "IPv6 Performance and Diagnostic Metrics (PDM) Destination Option", [RFC 8250](#), DOI 10.17487/RFC8250, September 2017, <<https://www.rfc-editor.org/info/rfc8250>>.

Authors' Addresses

Shwetha Bhandari
Cisco Systems, Inc.
Cessna Business Park, Sarjapura Marathalli Outer Ring Road
Bangalore, KARNATAKA 560 087
India

Email: shwethab@cisco.com

Frank Brockners
Cisco Systems, Inc.
Kaiserswerther Str. 115,
RATINGEN, NORDRHEIN-WESTFALEN 40880
Germany

Email: fbrockne@cisco.com

Carlos Pignataro
Cisco Systems, Inc.
7200-11 Kit Creek Road
Research Triangle Park, NC 27709
United States

Email: cpignata@cisco.com

Hannes Gredler
RtBrick Inc.

Email: hannes@rtbrick.com

John Leddy
Comcast

Email: John_Leddy@cable.comcast.com

Stephen Youell
JP Morgan Chase
25 Bank Street
London E14 5JP
United Kingdom

Email: stephen.youell@jpmorgan.com

Tal Mizrahi
Huawei Network.IO Innovation Lab
Israel

Email: tal.mizrahi.phd@gmail.com

Aviv Kfir
Mellanox Technologies, Inc.
350 Oakmead Parkway, Suite 100
Sunnyvale, CA 94085
U.S.A.

Email: avivk@mellanox.com

Barak Gafni
Mellanox Technologies, Inc.
350 Oakmead Parkway, Suite 100
Sunnyvale, CA 94085
U.S.A.

Email: gbarak@mellanox.com

Petr Lapukhov
Facebook
1 Hacker Way
Menlo Park, CA 94025
US

Email: petr@fb.com

Mickey Spiegel
Barefoot Networks, an Intel company
4750 Patrick Henry Drive
Santa Clara, CA 95054
US

Email: mickey.spiegel@intel.com

Suresh Krishnan
Kaloom

Email: suresh@kaloom.com

Rajiv Asati
Cisco Systems, Inc.
7200 Kit Creek Road
Research Triangle Park, NC 27709
US

Email: rajiva@cisco.com

Mark Smith
PO BOX 521
HEIDELBERG, VIC 3084
AU

Email: markzzzsmith+id@gmail.com

