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# Encapsulations for In-situ OAM Data
# draft-brockners-inband-oam-transport-02

## Abstract

In-situ Operations, Administration, and Maintenance (OAM) records operational and telemetry information in the packet while the packet traverses a path between two points in the network. In-situ OAM is to complement current out-of-band OAM mechanisms based on ICMP or other types of probe packets. This document outlines how in-situ OAM data records can be transported in protocols such as NSH, Segment Routing, VXLAN-GPE, native IPv6 (via extension headers), and IPv4. Transport options are currently investigated as part of an implementation study. This document is intended to only serve informational purposes.

## 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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## Table of Contents

## 1. Introduction

This document discusses transport mechanisms for "in-situ" Operations, Administration, and Maintenance (OAM) data records. In-situ OAM records OAM information within the packet while the packet traverses a particular network domain. The term "in-situ" refers to the fact that the OAM data is added to the data packets rather than is being sent within packets specifically dedicated to OAM. A discussion of the motivation and requirements for in-situ OAM can be found in [I-D.brockners-inband-oam-requirements]. Data types and data formats for in-situ OAM are defined in [I-D.brockners-inband-oam-data].

This document outlines transport encapsulations for the in-situ OAM data defined in [I-D.brockners-inband-oam-data]. This document is to serve informational purposes only. As part of an in-situ OAM implementation study different protocol encapsulations for in-situ OAM data are being explored. Once data formats and encapsulation approaches are settled, protocol specific specifications for in-situ OAM data transport will address the standardization aspect.

The data for in-situ OAM defined in [I-D.brockners-inband-oam-data] can be carried in a variety of protocols based on the deployment needs. This document discusses transport of in-situ OAM data for the following protocols:

- IPv6
- IPv4
- VXLAN-GPE
- NSH
- Segment Routing (IPv6 and MPLS)

This list is non-exhaustive, as it is possible to carry the in-situ OAM data in several other protocols and transports.

A feasibility study of in-situ OAM is currently underway as part of the FD.io project [FD.io]. The in-situ OAM implementation study should be considered as a "tool box" to showcase how "in-situ" OAM can complement probe-packet based OAM mechanisms for different deployments and packet transport formats. For details, see the open source code in the FD.io [FD.io].

## 2. Conventions

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].

Abbreviations used in this document:

MTU: Maximum Transmit Unit

NSH: Network Service Header

OAM: Operations, Administration, and Maintenance

POT: Proof of Transit

SFC: Service Function Chain

SID: Segment Identifier

SR: Segment Routing

VXLAN-GPE: Virtual eXtensible Local Area Network, Generic Protocol Extension

## 3. In-Situ OAM Metadata Transport in IPv6

This mechanisms of in-situ OAM in IPv6 complement others proposed to enhance diagnostics of IPv6 networks, such as the IPv6 Performance and Diagnostic Metrics Destination Option described in [I-D.ietf-ippm-6man-pdm-option]. The IP Performance and Diagnostic Metrics Destination Option is destination focused and specific to IPv6, whereas in-situ OAM is performed between end-points of the network or a network domain where it is enabled and used.

A historical note: The idea of IPv6 route recording was originally introduced by [I-D.kitamura-ipv6-record-route] back in year 2000. With IPv6 now being generally deployed and new concepts such as Segment Routing [I-D.ietf-spring-segment-routing] being introduced, it is imperative to further mature the Operations, Administration, and Maintenance mechanisms available to IPv6 networks.

The in-situ OAM options translate into options for an IPv6 extension header. The extension header would be inserted by either a host source of the packet, or by a transit/domain-edge node. If the addition of the in-situ OAM Hop-by-Hop Option header would lead to the packet exceeding the MTU of the domain an error should be reported. The methods and procedures of how the error is reported

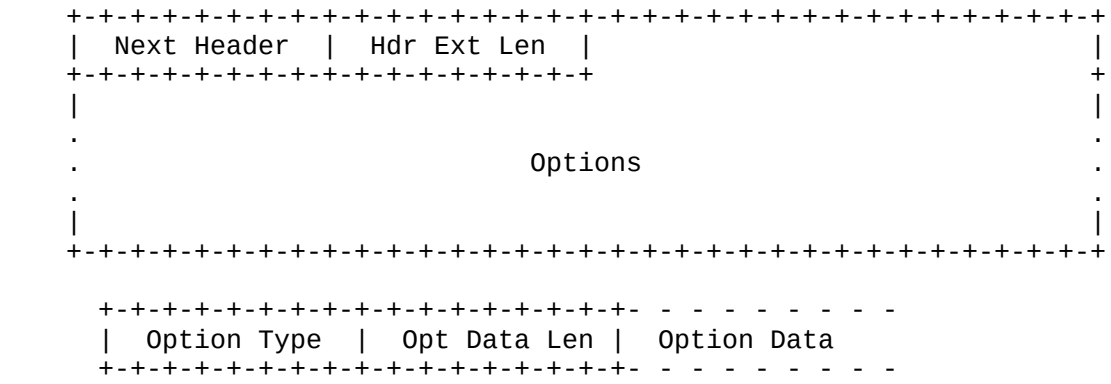
are outside the scope of this document. Likewise if an ICMPv6 forwarding error occurs between encapsulating and decapsulating nodes, the node generating the ICMPv6 error should strip the in-situ OAM Hop-by-Hop Option header before sending the ICMPv6 message to the source.

### 3.1. In-situ OAM in IPv6 Hop by Hop Extension Header

This section defines in-situ OAM for IPv6 transport. In-situ OAM data is transported as an IPv6 hop-by-hop extension header.

#### 3.1.1. In-situ OAM Hop by Hop Options

Brief recap of the IPv6 hop-by-hop header as well as the options used for carrying in-situ OAM data:




With 2 highest order bits of Option Type indicating the following:

00 - skip over this option and continue processing the header.

01 - discard the packet.

10 - discard the packet and, regardless of whether or not the packet's Destination Address was a multicast address, send an ICMP Parameter Problem, Code 2, message to the packet's Source Address, pointing to the unrecognized Option Type.

11 - discard the packet and, only if the packet's Destination Address was not a multicast address, send an ICMP Parameter Problem, Code 2, message to the packet's Source Address, pointing to the unrecognized Option Type.

3rd highest bit:

0 - Option Data does not change en-route

1 - Option Data may change en-route

In-situ OAM data records are inserted as options in an IPv6 hop-by-hop extension header:

1. Tracing Option: The in-situ OAM Tracing option defined in [I-D.brockners-inband-oam-data] is represented as a IPv6 option in hop by hop extension header by allocating following type:

   Option Type: 001xxxxx 8-bit identifier of the type of option. xxxxxx=TBD_IANA_TRACE_OPTION_IPV6.

2. Proof of Transit Option: The in-situ OAM POT option defined in [I-D.brockners-inband-oam-data] is represented as a IPv6 option in hop by hop extension header by allocating following type:

   Option Type: 001xxxxxx 8-bit identifier of the type of option. xxxxxx=TBD_IANA_POT_OPTION_IPV6.

3. Edge to Edge Option: The in-situ OAM E2E option defined in [I-D.brockners-inband-oam-data] is represented as a IPv6 option in hop by hop extension header by allocating following type:

   Option Type: 000xxxxxx 8-bit identifier of the type of option. xxxxxx=TBD_IANA_E2E_OPTION_IPV6.

#### 3.1.2. Procedure at the Ingress Edge to Insert the In-situ OAM Header

In an administrative domain where in-situ OAM is used, insertion of the in-situ OAM header is enabled at the required edge nodes (i.e. at the encapsulating/decapsulating nodes) by means of configuration.

Such a configuration SHOULD allow selective enablement of in-situ OAM header insertion for a subset of traffic (e.g., one or several "pipes").

Further the ingress edge node should be aware of maximum size of the header that can be inserted. Details on how the maximum size/size of the in-situ OAM domain are retrieved are outside the scope of this document.

```
   Let n = max number of nodes updating in-situ OAM data;
   (calculated based on the packet size and the minimal MTU on all
   links within the OAM domain)

   Let k = number of node data records that can be allocated
   by this node.

   Let node_data_size = size of each node_data based on
   in-situ OAM type.

   if (packet matches traffic for which in-situ OAM is enabled) {
       Create in-situ OAM hbyh ext-header with k node data records
       preallocated.
       Increment payload length in IPv6 header:
                         with size of in-situ OAM hbyh ext-header
       Populate node data at:
          (size of in-situ OAM hbyh ext-header = 8) + k * node_data_size
       from the beginning of the header
       Set Elements-left to: k - 1

       Update "Next Header" field in main IPv6 header and
       set "Next Header" field of OAM hbyh extension header
       appropriately.
    }
```

### 3.1.3. Procedure at Transit Nodes

```
   If a network node receives a packet with an in-situ OAM header and it
   is enabled to process in-situ OAM data it performs the following:

   k = number of node data that this node can allocate

   if (in-situ OAM ext hbyh ext-header is present) {
       if (Elements-left > 0)) {
         populate node data at :
            node_data_start[Elements-left]
         Elements-left = Elements-left - 1
       }
   }
```

### 3.1.4. Procedure at the Egress Edge to Remove the In-situ OAM Header

```
egress_edge = list of interfaces where in-situ OAM hbyh ext
               header is to be stripped

Before forwarding packet out of interfaces in egress_edge list:

if (in-situ OAM hbyh ext-header is present) {
   remove the in-situ OAM hbyh ext-header,
   possibly store the record along with additional
   fields for analysis and export
   Decrement Payload Length in IPv6 header
   by size of in-situ OAM ext header

   Update "Next Header" field in main IPv6 header and
   set "Next Header" field of OAM hbyh extension header
   appropriately.
}
```

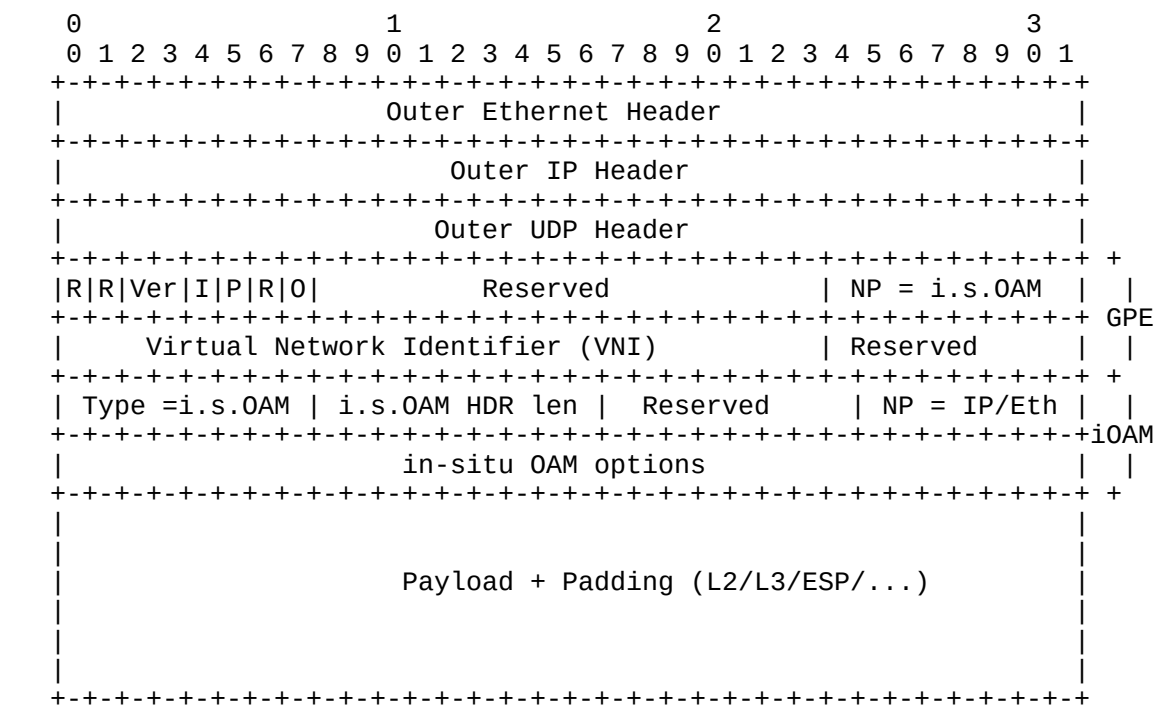
## 4. In-situ OAM Metadata Transport in IPv4

Transport of in-situ OAM data in IPv4 will be detailed in a future version of this document.

## 5. In-situ OAM Metadata Transport in VXLAN-GPE

VXLAN-GPE [I-D.ietf-nvo3-vxlan-gpe] encapsulation is somewhat similar to IPv6 extension headers in that a series of headers can be contained in the header as a linked list. The different in-situ OAM types are added as options within a new in-situ OAM protocol header in VXLAN GPE. In an administrative domain where in-situ OAM is used, insertion of the in-situ OAM protocol header in VXLAN GPE is enabled at the VXLAN GPE tunnel endpoint which also serve as in-situ OAM encapsulating/decapsulating nodes by means of configuration.

In-situ OAM header in VXLAN GPE header:

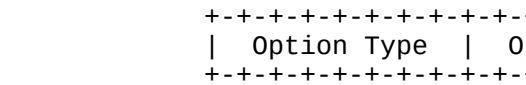



The VXLAN-GPE header and fields are defined in [I-D.ietf-nvo3-vxlan-gpe]. in-situ OAM specific fields and header are defined here:

Type:  8-bit unsigned integer defining in-situ OAM header type

in-situ OAM HDR len:  8-bit unsigned integer.  Length of the in-situ OAM HDR in 8-octet units

in-situ OAM options:  Variable-length field, of length such that the complete in-situ OAM header is an integer multiple of 8 octets long.  Contains one or more TLV-encoded options of the format:



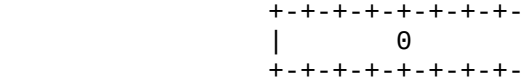
Option Type 8-bit identifier of the type of option.

Opt Data Len 8-bit unsigned integer. Length of the Option Data field of this option, in octets.

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

The in-situ OAM options defined in [I-D.brockners-inband-oam-data] are encoded with an option type allocated in the new in-situ OAM IANA registry - in-situ OAM_PROTOCOL_OPTION_REGISTRY_IANA_TBD. In addition the following padding options are defined to be used when necessary to align subsequent options and to pad out the containing header to a multiple of 8 octets in length.

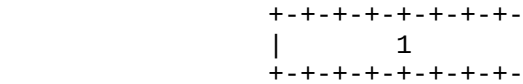
Pad1 option (alignment requirement: none)



NOTE: The format of the Pad1 option is a special case -- it does not have length and value fields.

The Pad1 option is used to insert one octet of padding into the Options area of a header. If more than one octet of padding is required, the PadN option, described next, should be used, rather than multiple Pad1 options.

PadN option (alignment requirement: none)



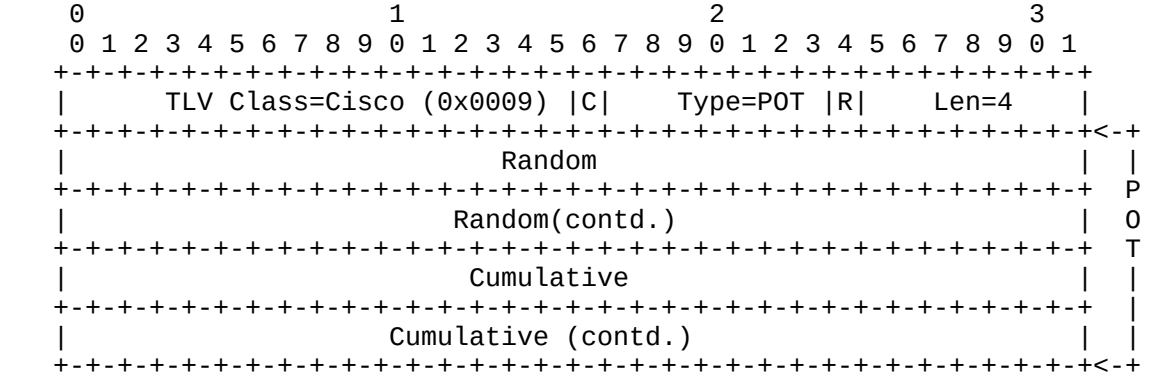
The PadN option is used to insert two or more octets of padding into the Options area of a header. For N octets of padding, the Opt Data Len field contains the value N-2, and the Option Data consists of N-2 zero-valued octets.

## 6. In-situ OAM Metadata Transport in NSH

In Service Function Chaining (SFC) [RFC7665], the Network Service Header (NSH) [I-D.ietf-sfc-nsh] already includes path tracing capabilities [I-D.penno-sfc-trace], but currently does not offer a solution to securely prove that packets really traversed the service

chain. The "Proof of Transit" capabilities (see [I-D.brockners-inband-oam-requirements] and [I-D.brockners-proof-of-transit]) of in-situ OAM can be leveraged within NSH. In an administrative domain where in-situ OAM is used, insertion of the in-situ OAM data into the NSH header is enabled at the required nodes (i.e. at the in-situ OAM encapsulating/ decapsulating nodes) by means of configuration.

Proof of transit in-situ OAM data is added as NSH Type 2 metadata:




TLV Class: Describes the scope of the "Type" field. In some cases, the TLV Class will identify a specific vendor, in others, the TLV Class will identify specific standards body allocated types. POT is currently defined using the Cisco (0x0009) TLV class.

Type: The specific type of information being carried, within the scope of a given TLV Class. Value allocation is the responsibility of the TLV Class owner. Currently a type value of 0x94 is used for proof of transit

Reserved bits: Two reserved bit are present for future use. The reserved bits MUST be set to 0x0.

F: One bit. Indicates which POT-profile is active. 0 means the even POT-profile is active, 1 means the odd POT-profile is active.

Length: Length of the variable metadata, in 4-octet words. Here the length is 4.

Random: 64-bit Per-packet Random number.

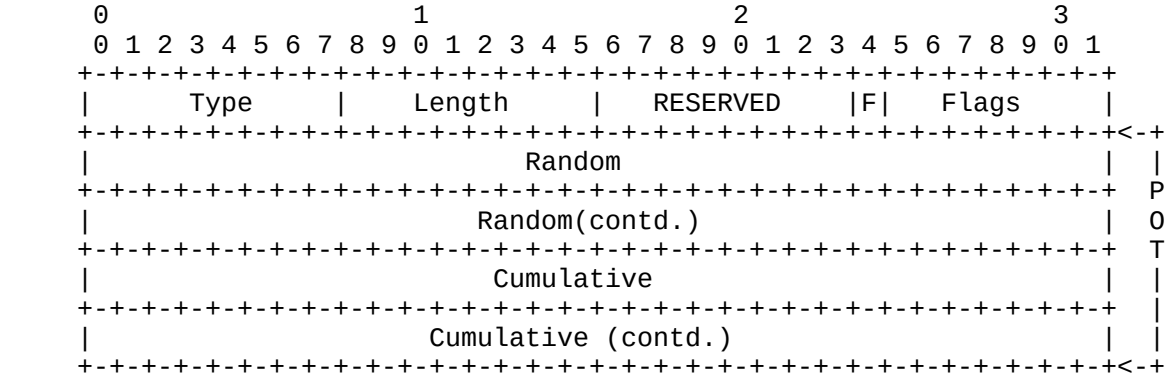
Cumulative: 64-bit Cumulative that is updated by the Service Functions.

## 7. In-situ OAM Metadata Transport in Segment Routing

### 7.1. In-situ OAM in SR with IPv6 Transport

Similar to NSH, a service chain or path defined using Segment Routing for IPv6 can be verified using the in-situ OAM "Proof of Transit" approach. The Segment Routing Header (SRH) for IPv6 offers the ability to transport TLV structured data, similar to what NSH does (see [I-D.ietf-6man-segment-routing-header]). In an domain where in-situ OAM is used, insertion of the in-situ OAM data is enabled at the required edge nodes (i.e. at the in-situ OAM encapsulating/ decapsulating nodes) by means of configuration.

A new "POT TLV" is defined for the SRH which is to carry proof of transit in situ OAM data.




Type: To be assigned by IANA.

Length: 18.

RESERVED: 8 bits. SHOULD be unset on transmission and MUST be ignored on receipt.

F: 1 bit. Indicates which POT-profile is active. 0 means the even POT-profile is active, 1 means the odd POT-profile is active.

Flags: 8 bits. No flags are defined in this document.

Random: 64-bit per-packet random number.

Cumulative: 64-bit cumulative value that is updated at specific nodes that form the service path to be verified.

### 7.2. In-situ OAM in SR with MPLS Transport

In-situ OAM "Proof of Transit" data can also be carried as part of the MPLS label stack. Details will be addressed in a future version of this document.

## 8. IANA Considerations

IANA considerations will be added in a future version of this document.

## 9. Manageability Considerations

Manageability considerations will be addressed in a later version of this document..

## 10. Security Considerations

Security considerations will be addressed in a later version of this document. For a discussion of security requirements of in-situ OAM, please refer to [I-D.brockners-inband-oam-requirements].

## 11. Acknowledgements

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