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**Encapsulations for In-situ OAM Data
draft-brockners-inband-oam-transport-05**

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 fields 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

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1. Introduction

This document discusses transport mechanisms for "in-situ" Operations, Administration, and Maintenance (OAM) data fields. 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:

- o IPv6
- o IPv4
- o VXLAN-GPE
- o NSH
- o 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:

IOAM: In-situ Operations, Administration, and Maintenance

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.

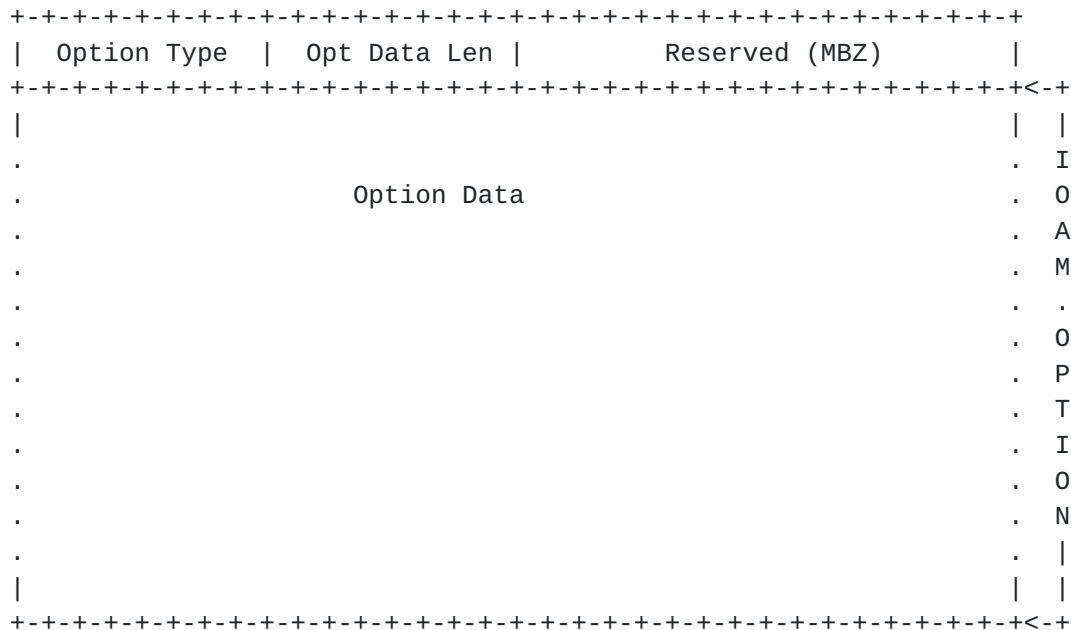
The in-situ OAM options translate into options for an IPv6 hop by hop extension header. The extension header would be inserted by either a host source of the packet, or by a transit/domain-edge node. If the addition of the in-situ OAM Hop-by-Hop Option header would lead to the packet exceeding the MTU 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 Options are transported in IPv6 hop-by-hop extension header.

3.1.1. In-situ OAM Hop by Hop Options

IPv6 hop-by-hop option format for carrying in-situ OAM data fields:



- Option Type 8-bit identifier of the type of option.
- Opt Data Len 8-bit unsigned integer. Length of the Reserved and Option Data field of this option, in octets.
- Reserved (MBZ) 16-bit field MUST be filled with zeroes.
- Option Data Variable-length field. Option-Type-specific data.

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

1. Pre-allocated Tracing Option: The in-situ OAM Preallocated 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: 001xxxxxx 8-bit identifier of the type of option.
xxxxxx=TBD_IANA_PRE_TRACE_OPTION_IPV6.
2. Incremental Tracing Option: The in-situ OAM Incremental 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: 001xxxxxx 8-bit identifier of the type of option.
xxxxxx=TBD_IANA_INCR_TRACE_OPTION_IPV6.

3. 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.

4. 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.

4. In-situ OAM Metadata Transport in IPv4

Transport of in-situ OAM data in IPv4 will use GRE encapsulation.

GRE encapsulation is defined in [\[RFC2784\]](#). IOAM is defined as a "set of Protocol Types" TBD_IANA_ETHERNET_NUMBER_IOAM_* and follows GRE header. These Protocol Types are defined in [\[RFC3232\]](#) as "ETHER TYPES" and in [\[ETYPES\]](#).

The different IOAM data fields defined in [\[I-D.brockners-inband-oam-data\]](#) are added as TLVs following the GRE header. In an administrative domain where IOAM is used, insertion of the IOAM protocol header in GRE is enabled at the GRE tunnel endpoints which also serve as IOAM encapsulating/decapsulating nodes by means of configuration.

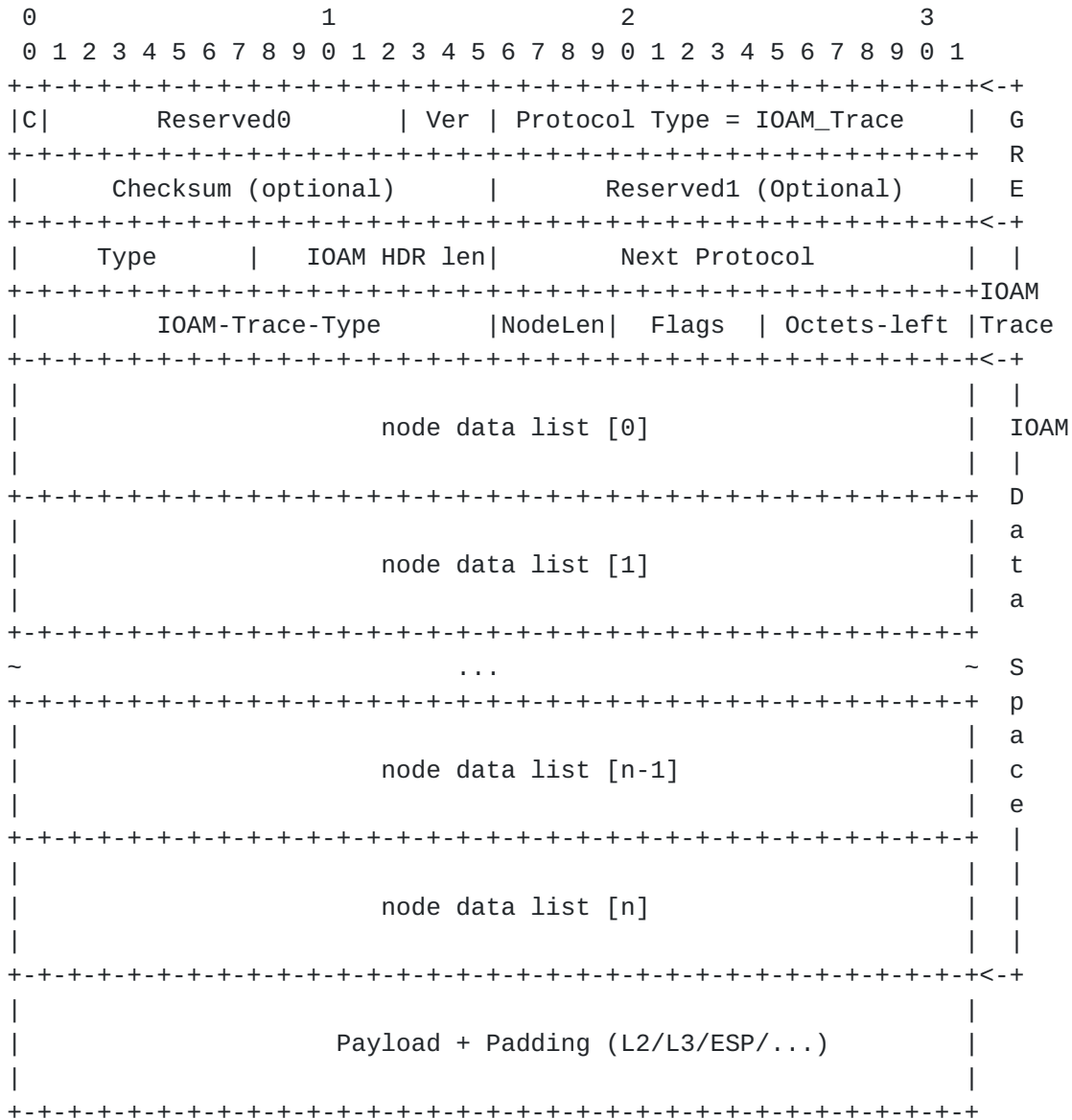
For IOAM the following new GRE protocol types are requested:

1. IOAM_Trace_Preallocated:
TBD_IANA_ETHERNET_NUMBER_IOAM_TRACE_PREALLOCATED
2. IOAM_Trace_Incremental:
TBD_IANA_ETHERNET_NUMBER_IOAM_TRACE_INCREMENTAL
3. IOAM_POT: TBD_IANA_ETHERNET_NUMBER_IOAM_POT
4. IOAM_End-to_End: TBD_IANA_ETHERNET_NUMBER_IOAM_E2E

4.1. In-situ OAM Tracing in GRE

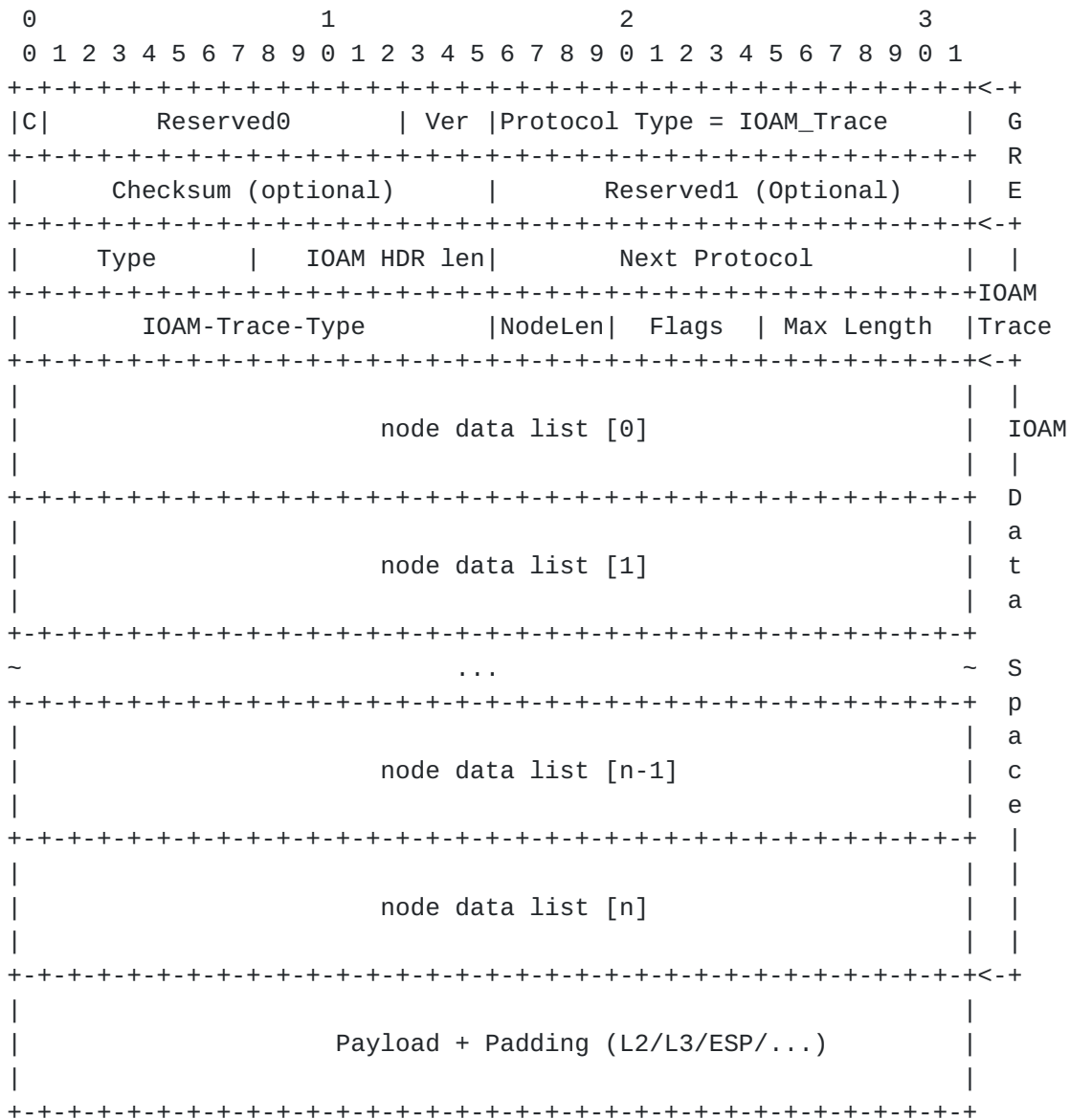
The packet formats of the pre-allocated IOAM trace and incremental IOAM trace when transported using GRE are defined as below. See [\[I-D.brockners-inband-oam-data\]](#) for details about pre-allocated and incremental IOAM trace options.

In-situ OAM Trace header following GRE header(Preallocated IOAM trace):



Pre-allocated Trace Option Data MUST be 4-octet aligned:

In-situ OAM Trace header following GRE header(Incremental IOAM trace):



In-situ OAM Incremental Trace Option Data MUST be 4-octet aligned:

The GRE header and fields are defined in [RFC2784] with Protocol Type set to TBD_IANA_ETHERNET_NUMBER_IOAM_TRACE. IOAM specific fields and header are defined here:

Type: 8-bit unsigned integer defining IOAM header type
IOAM_TRACE_Preallocated or IOAM_Trace_Incremental are defined here.

IOAM HDR Len: 8 bits Length field contains the length of the variable metadata octets.

Next Protocol: 16 bits Next Protocol Type field contains the protocol type of the packet following IOAM protocol header. These Protocol Types are defined in [[RFC3232](#)] as "ETHER TYPES" and in [[ETYPES](#)]. An implementation receiving a packet containing a Protocol Type which is not listed in [[RFC3232](#)] or [[ETYPES](#)] SHOULD discard the packet.

IOAM-Trace-Type: 16-bit identifier of IOAM Trace Type as defined in [[I-D.brockners-inband-oam-data](#)] IOAM-Trace-Types.

Node Data Length: 4-bit unsigned integer as defined in [[I-D.brockners-inband-oam-data](#)].

Flags: 5-bit field as defined in [[I-D.brockners-inband-oam-data](#)].

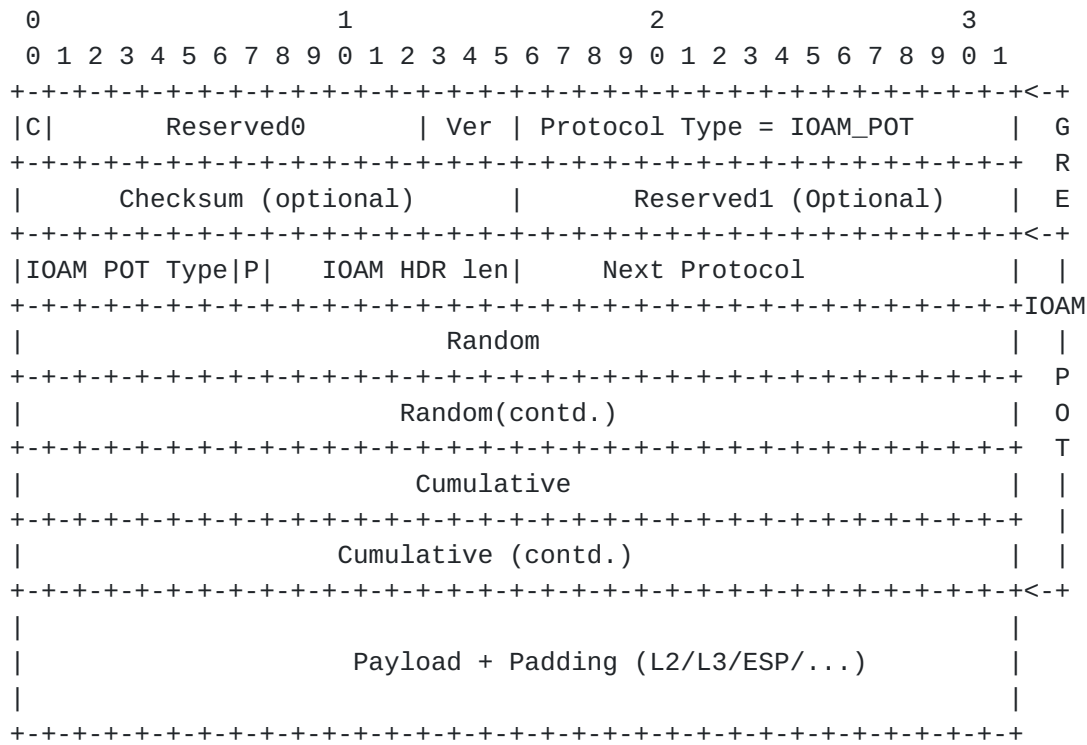
Octets-left: 7-bit unsigned integer as defined in [[I-D.brockners-inband-oam-data](#)].

Maximum-length: 7-bit unsigned integer as defined in [[I-D.brockners-inband-oam-data](#)].

Node data List [n]: Variable-length field as defined in [[I-D.brockners-inband-oam-data](#)].

4.2. In-situ OAM POT in GRE

In-situ OAM POT header following GRE header:



The GRE header and fields are defined in [RFC2784] with Protocol Type set to TBD_IANA_ETHERNET_NUMBER_IOAM_POT. IOAM specific fields and header are defined here:

IOAM POT Type: 7-bit identifier of a particular POT variant that dictates the POT data that is included as defined in [I-D.brockners-inband-oam-data].

Profile to use (P): 1-bit as defined in [I-D.brockners-inband-oam-data] IOAM POT Option.

IOAM HDR Len: 8 bits Length field contains the length of the variable metadata octets.

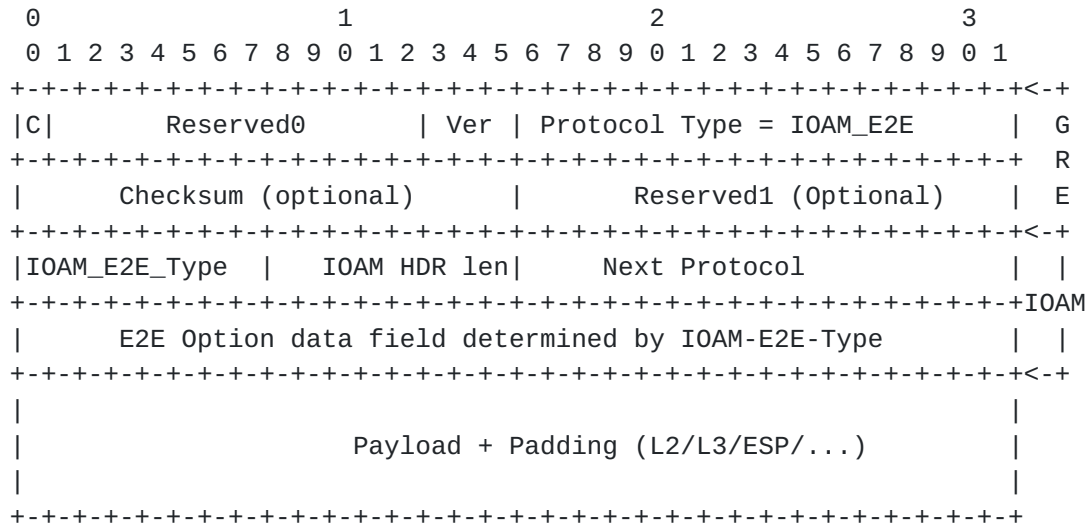
Next Protocol: 16 bits Next Protocol Type field contains the protocol type of the packet following IOAM protocol header. These Protocol Types are defined in [RFC3232] as "ETHER TYPES" and in [ETYPES]. An implementation receiving a packet containing a Protocol Type which is not listed in [RFC3232] or [ETYPES] SHOULD discard the packet.

Random: 64-bit Per-packet random number.

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

4.3. In-situ OAM End-to-End in GRE

In-situ OAM End-to-End header following GRE header:



IOAM E2E Type: 8-bit identifier of a particular E2E variant that dictates the E2E data that is included as defined in [\[I-D.brockners-inband-oam-data\]](#).

IOAM HDR Len: 8 bits Length field contains the length of the variable metadata octets.

Next Protocol: 16 bits Next Protocol Type field contains the protocol type of the packet following IOAM protocol header. These Protocol Types are defined in [\[RFC3232\]](#) as "ETHER TYPES" and in [\[ETYPES\]](#). An implementation receiving a packet containing a Protocol Type which is not listed in [\[RFC3232\]](#) or [\[ETYPES\]](#) SHOULD discard the packet.

E2E Option data field: Variable length field as defined in [\[I-D.brockners-inband-oam-data\]](#) IOAM E2E Option.

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 iIOAM types are added as options within a new IOAM protocol header in VXLAN GPE. In an administrative domain where IOAM is used, insertion of the IOAM

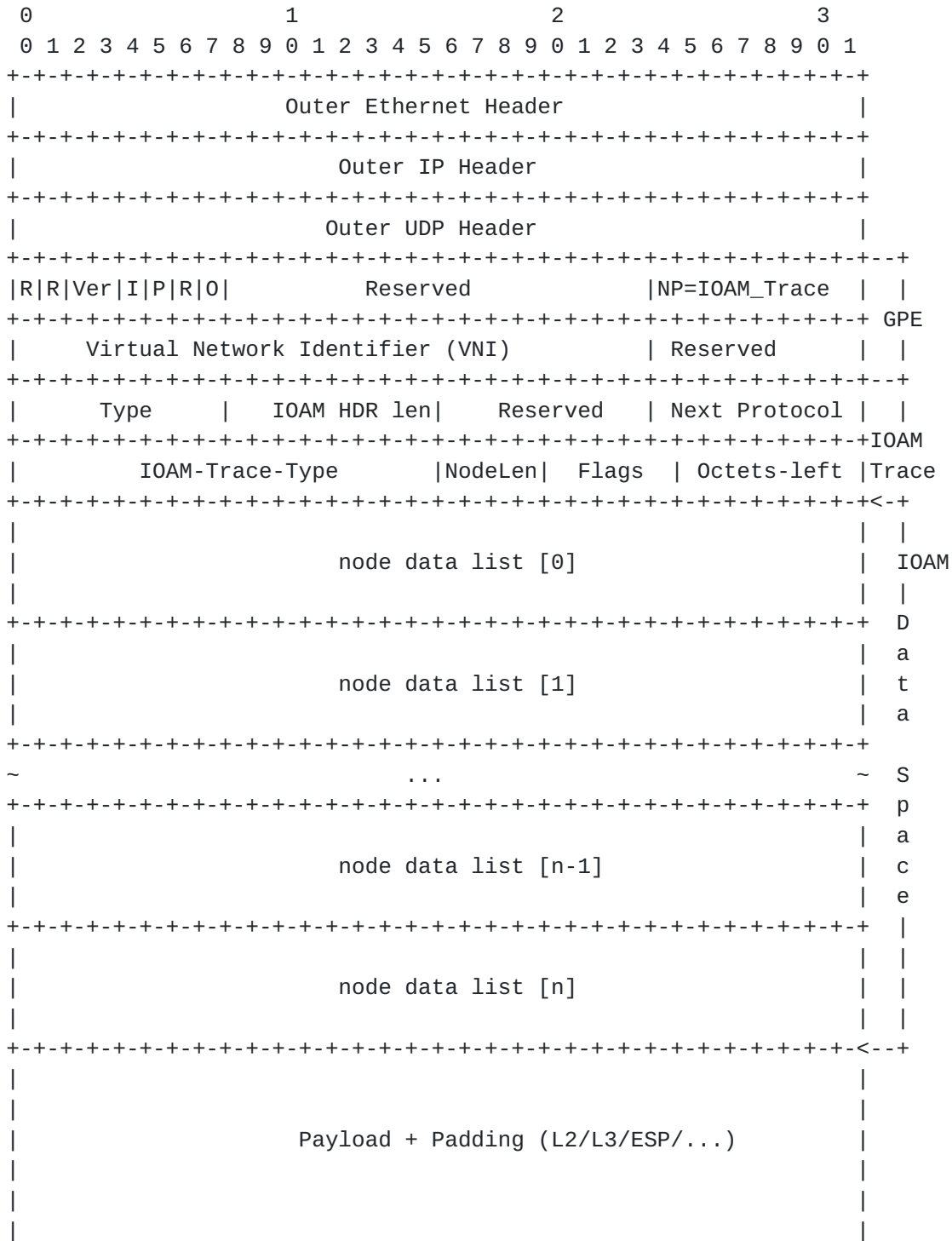
protocol header in VXLAN GPE is enabled at the VXLAN GPE tunnel endpoint which also serve as IOAM encapsulating/decapsulating nodes by means of configuration.

5.1. In-situ OAM Tracing in VXLAN-GPE

The packet formats of the pre-allocated IOAM trace and incremental IOAM trace when transported in VXLAN-GPE are defined as below. See [[I-D.brockners-inband-oam-data](#)] for details about pre-allocated and incremental IOAM trace options.

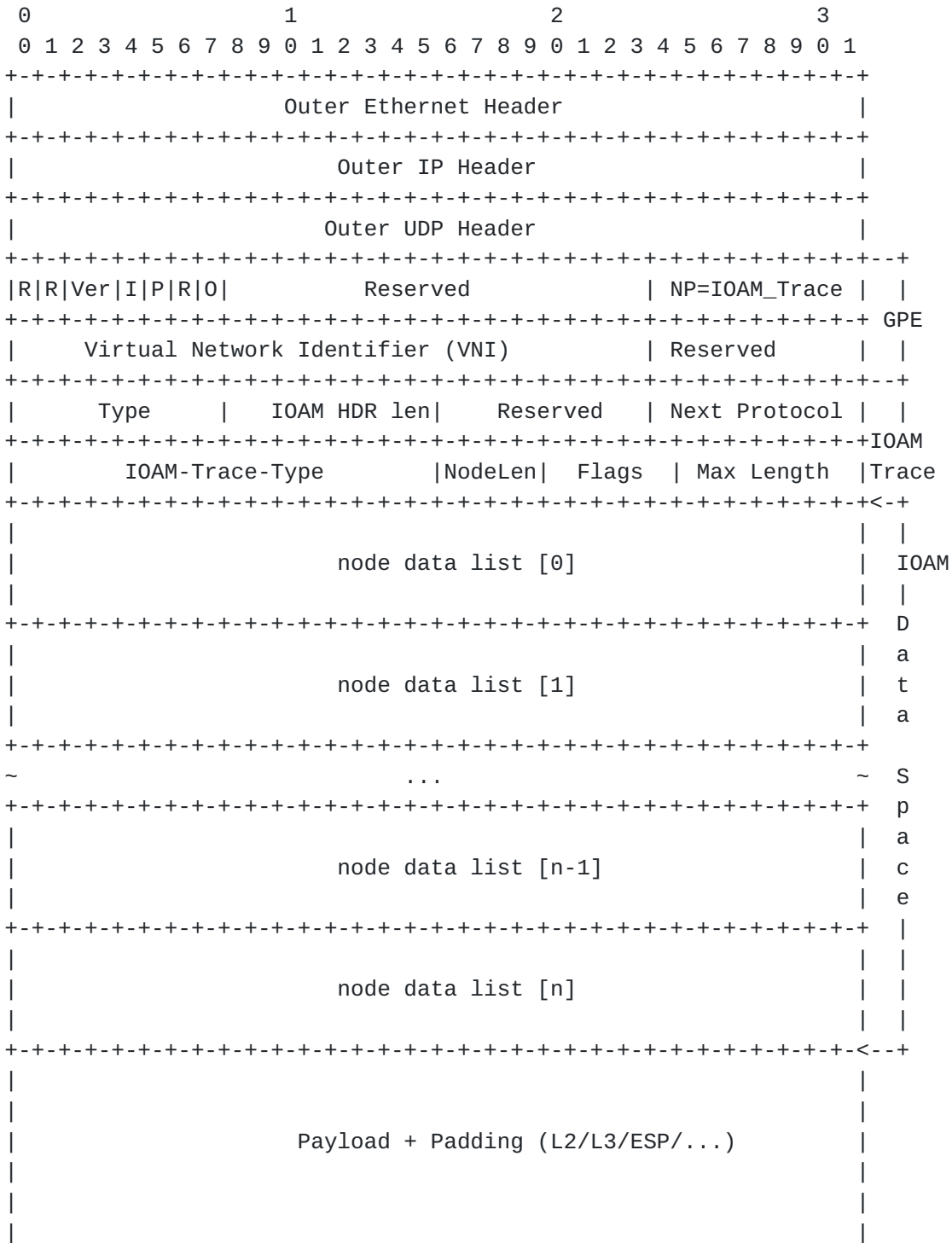
The VXLAN-GPE header and fields are defined in [[I-D.ietf-nvo3-vxlan-gpe](#)]. IOAM specific fields and header are defined here:

In-situ OAM Trace header following VXLAN GPE header (Pre-allocated trace):



Pre-allocated Trace Option Data MUST be 4-octet aligned:

In-situ OAM Trace header following VXLAN GPE header
(Incremental IOAM trace):



In-situ OAM Incremental Trace Option Data MUST be 4-octet aligned:

Type: 8-bit unsigned integer defining IOAM header type
IOAM_TRACE_Preallocated or IOAM_Trace_Incremental are defined here.

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

Reserved: 8-bit reserved field MUST be set to zero.

Next Protocol: 8-bit unsigned integer that determines the type of header following IOAM protocol. The value is from the IANA registry setup for VXLAN GPE Next Protocol defined in [[I-D.ietf-nvo3-vxlan-gpe](#)].

IOAM-Trace-Type: 16-bit identifier of IOAM Trace Type as defined in [[I-D.brockners-inband-oam-data](#)] IOAM-Trace-Types.

Node Data Length: 4-bit unsigned integer as defined in [[I-D.brockners-inband-oam-data](#)].

Flags: 5-bit field as defined in [[I-D.brockners-inband-oam-data](#)].

Octets-left: 7-bit unsigned integer as defined in [[I-D.brockners-inband-oam-data](#)].

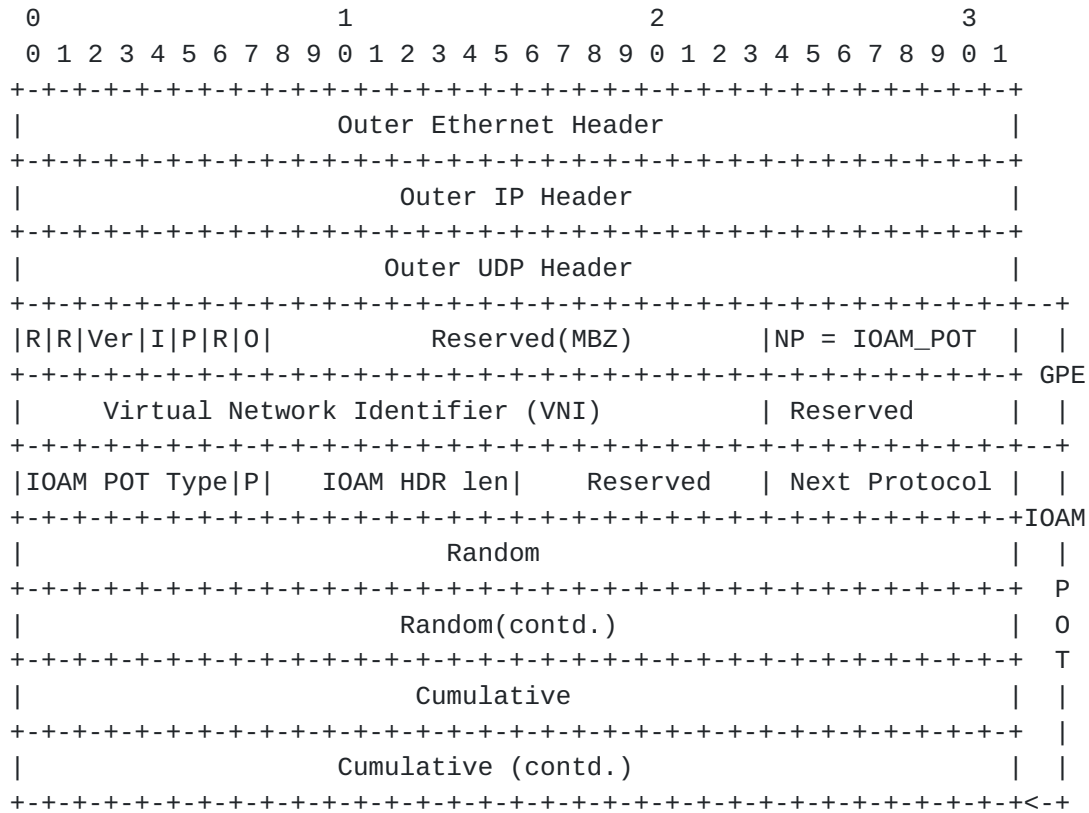
Maximum-length: 7-bit unsigned integer as defined in [[I-D.brockners-inband-oam-data](#)].

Node data List [n]: Variable-length field as defined in [[I-D.brockners-inband-oam-data](#)].

[5.2.](#) In-situ OAM POT in VXLAN-GPE

The VXLAN-GPE header and fields are defined in [[I-D.ietf-nvo3-vxlan-gpe](#)]. IOAM specific fields and header are defined here:

In-situ OAM POT header following VXLAN GPE header:



IOAM POT Type: 7-bit identifier of a particular POT variant that dictates the POT data that is included as defined in [\[I-D.brockners-inband-oam-data\]](#).

Profile to use (P): 1-bit as defined in [\[I-D.brockners-inband-oam-data\]](#) IOAM POT Option.

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

Reserved: 8-bit reserved field MUST be set to zero.

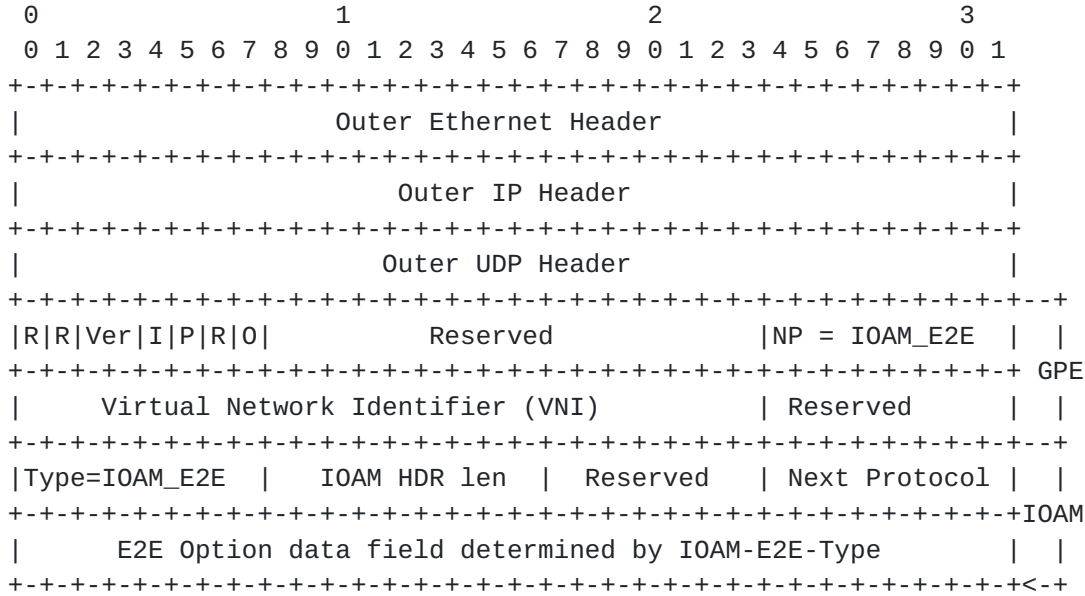
Next Protocol: 8-bit unsigned integer that determines the type of header following IOAM protocol. The value is from the IANA registry setup for VXLAN GPE Next Protocol defined in [\[I-D.ietf-nvo3-vxlan-gpe\]](#).

Random: 64-bit Per-packet random number.

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

5.3. In-situ OAM Edge-to-Edge in VXLAN-GPE

In-situ OAM Edge-to-Edge in VXLAN GPE header:



Type: 8-bit identifier of a particular E2E variant that dictates the E2E data that is included as defined in [I-D.brockners-inband-oam-data].

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

Reserved: 8-bit reserved field MUST be set to zero.

Next Protocol: 8-bit unsigned integer that determines the type of header following IOAM protocol. The value is from the IANA registry setup for VXLAN GPE Next Protocol defined in [I-D.ietf-nvo3-vxlan-gpe].

E2E Option data field: Variable length field as defined in [I-D.brockners-inband-oam-data] IOAM E2E Option.

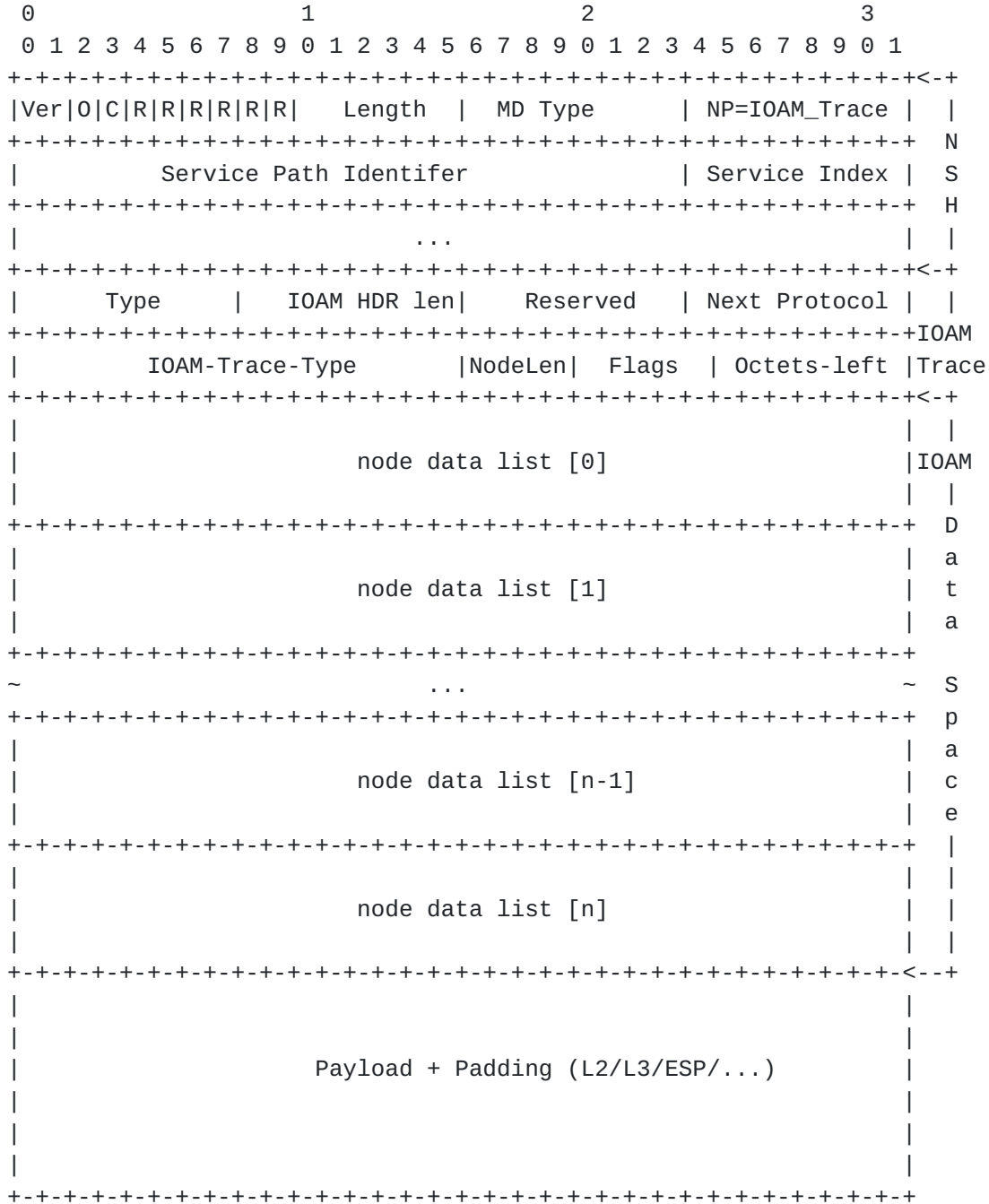
6. In-situ OAM Metadata Transport in NSH

6.1. In-situ OAM Tracing in NSH

The packet formats of the pre-allocated IOAM trace and incremental IOAM trace when transported in NSH are defined as below. See [I-D.brockners-inband-oam-data] for details about pre-allocated and incremental IOAM trace options.

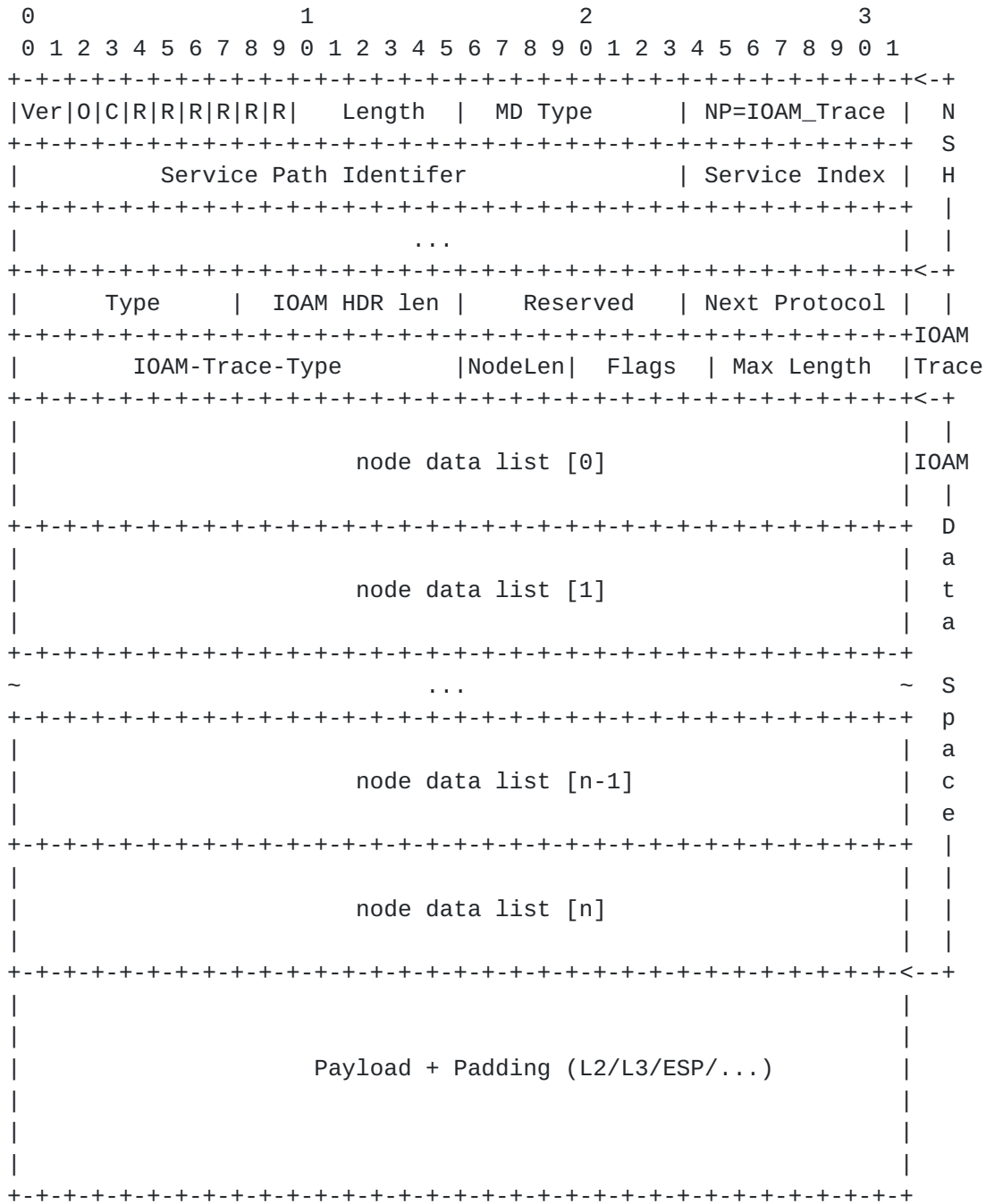
In Service Function Chaining (SFC) [[RFC7665](#)], the Network Service Header (NSH) [[I-D.ietf-sfc-nsh](#)] already includes path tracing capabilities [[I-D.penno-sfc-trace](#)]. Tracing information can be carried in-situ as IOAM data fields following NSH MDx metadata TLVs.

In-situ OAM Trace header following NSH MDx header
(Pre-allocated IOAM trace):



In-situ OAM Pre-allocated Trace Option Data MUST be 4-octet aligned:

In-situ OAM Trace header following NSH MDx header
(Incremental IOAM trace):



In-situ OAM Incremental Trace Option Data MUST be 4-octet aligned:

Next Protocol of NSH: TBD value for IOAM_Trace.

Type: 8-bit unsigned integer defining IOAM header type
IOAM_TRACE_Preallocated or IOAM_Trace_Incremental are defined here.

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

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

Next Protocol: 8-bit unsigned integer that determines the type of header following IOAM protocol.

IOAM-Trace-Type: 16-bit identifier of IOAM Trace Type as defined in [\[I-D.brockners-inband-oam-data\]](#) IOAM-Trace-Types.

Node Data Length: 4-bit unsigned integer as defined in [\[I-D.brockners-inband-oam-data\]](#).

Flags: 5-bit field as defined in [\[I-D.brockners-inband-oam-data\]](#).

Octets-left: 7-bit unsigned integer as defined in [\[I-D.brockners-inband-oam-data\]](#).

Maximum-length: 7-bit unsigned integer as defined in [\[I-D.brockners-inband-oam-data\]](#).

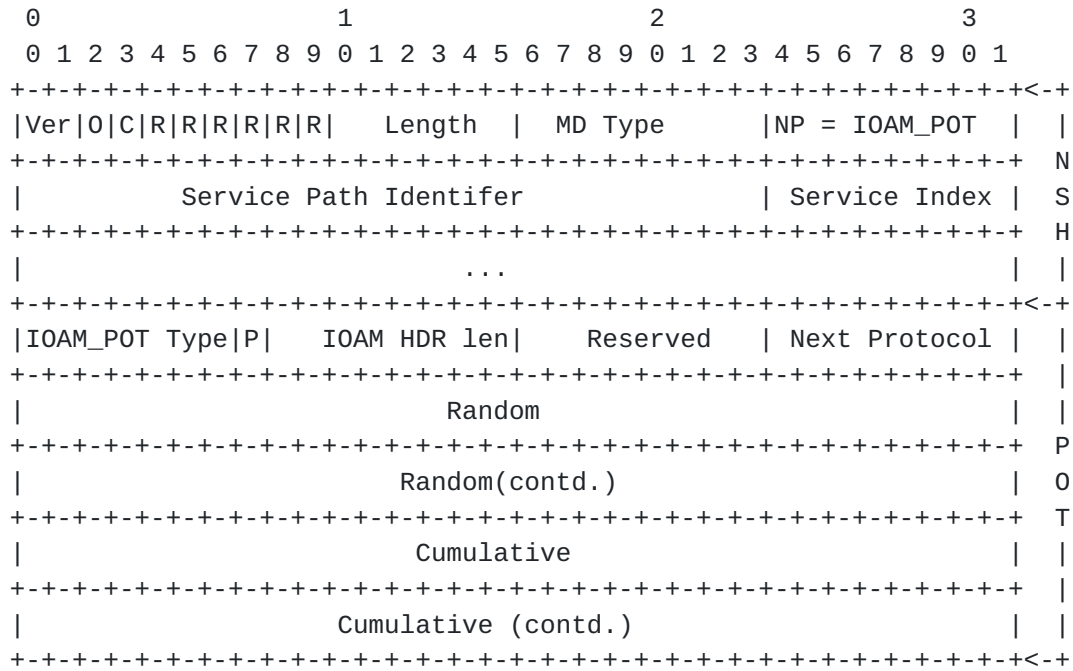
Node data List [n]: Variable-length field as defined in [\[I-D.brockners-inband-oam-data\]](#).

6.2. In-situ OAM POT in NSH

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:

In-situ OAM POT header following NSH MDx header:



Next Protocol of NSH: TBD value for IOAM_POT.

IOAM POT Type: 7-bit identifier of a particular POT variant that dictates the POT data that is included as defined in [\[I-D.brockners-inband-oam-data\]](#).

Profile to use (P): 1-bit as defined in [\[I-D.brockners-inband-oam-data\]](#) IOAM POT Option.

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

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

Next Protocol: 8-bit unsigned integer that determines the type of header following IOAM protocol.

Random: 64-bit Per-packet random number.

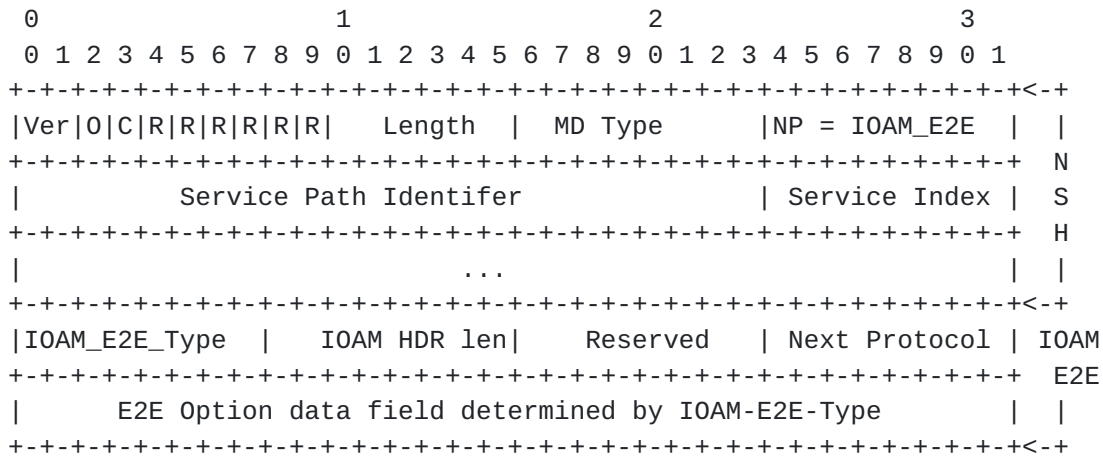
Cumulative: 64-bit Cumulative value that is updated by the Service Functions.

6.3. In-situ OAM Edge-to-Edge in NSH

The "Edge-to-Edge" capabilities (see [\[I-D.brockners-inband-oam-requirements\]](#)) 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.

Edge-to-Edge in-situ OAM data is added as a TLV following NSH MDx metadata:

In-situ OAM E2E header following NSH MDx header:



Next Protocol of NSH: TBD value for IOAM_E2E.

IOAM E2E Type: 8-bit identifier of a particular E2E variant that dictates the IOAM E2E data that is included as defined in [\[I-D.brockners-inband-oam-data\]](#).

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

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

Next Protocol: 8-bit unsigned integer that determines the type of header following IOAM protocol.

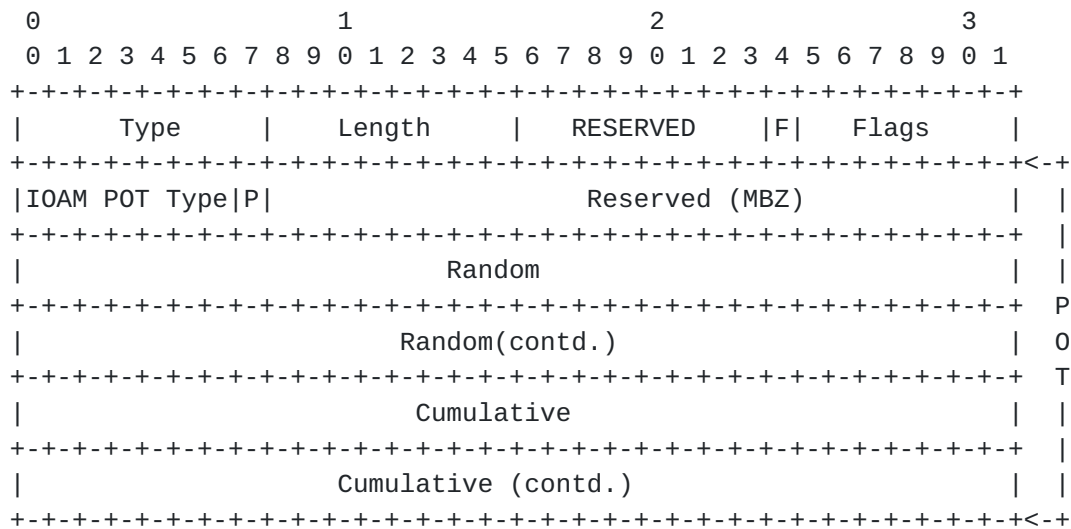
E2E Option data field: Variable length field as defined in [\[I-D.brockners-inband-oam-data\]](#) IOAM E2E Option.

7. In-situ OAM Metadata Transport in Segment Routing

7.1. In-situ OAM in SR with IPv6 Transport

Similar to NSH, a policy 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: 20.

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.

IOAM POT Type: 7-bit identifier of a particular POT variant that dictates the POT data that is included as defined in [I-D.brockners-inband-oam-data].

Profile to use (P): 1-bit as defined in
[[I-D.brockners-inband-oam-data](#)] IOAM POT Option.

Reserved (MBZ): 24-bit field MUST be filled with zeroes.

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](#)].

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