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Export of Segment Routing over IPv6 Information in IP Flow Information Export (IPFIX)

Abstract

This document introduces new IP Flow Information Export (IPFIX) Information Elements (IEs) to identify a set of information related to Segment Routing over IPv6 (SRv6) such as data contained in a Segment Routing Header (SRH), the SRv6 control plane, and the SRv6 Endpoint behavior that traffic is being forwarded with.

Status of This Memo

This is an Internet Standards Track document.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Further information on Internet Standards is available in Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc9487.

Table of Contents

1. Introduction

A dedicated Routing Extension Header, called "Segment Routing Header (SRH)", is defined in [RFC8754] for use of Segment Routing over IPv6 (SRv6) data plane.

Also, three routing protocol extensions, OSPFv3 [OSPFV3-SRV6-EXT], IS-IS [RFC9352], and BGP Prefix Segment Identifiers (Prefix-SIDs) [RFC8669]; the Path Computation Element Communication Protocol (PCEP) Extension [PCEP-SRV6-EXT]; and the Segment Routing Policy [RFC9256] are defined to propagate Segment Identifiers (SIDs).

SRv6 Segment Endpoint behaviors describe how packets should be processed by SRv6 Segment Endpoint Nodes. Such behaviors are defined in [RFC8986].

This document specifies eleven new IPFIX Information Elements (IEs) and one new subregistry within the "IPFIX Information Elements" registry [RFC7012], for SRv6 purposes.

These IEs are used to export the SRv6 active segment and its control plane protocol, the SRv6 Segment List, the next SRv6 node and its type, and the numbers of SRv6 segments left.

Some examples are provided in Appendix A.

2. Terminology

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.

This document makes use of the terms defined in [RFC7011], [RFC8402], and [RFC8754].

The following terms are used as defined in [RFC7011]:

* IPFIX
* IPFIX Information Elements
* Template
* Template Record
* Options Template
* Options Template Record
* Data Record
* Data Set

The following terms are used as defined in [RFC8402]:

* Segment Routing (SR)
* Segment
* Segment List
* Active Segment
* Segment Identifier (SID)
* SRv6
* SRv6 SID

The following terms are used as defined in [RFC8754]:

* Segment Routing Header (SRH)
* SR Source Node
* Transit Node
* SR Segment Endpoint Node
* Reduced SRH

* Segments Left

* Last Entry

3. New IPFIX IPv6 SRH Information Elements

This section specifies the new IPFIX IPv6 SRH IEs.

srhFlagsIPv6
: The 8-bit Flags field defined in the SRH (Section 2 of [RFC8754]).

srhTagIPv6
: The 16-bit Tag field defined in the SRH (Section 2 of [RFC8754]). A tag is used to mark a packet as part of a class or group of packets sharing the same set of properties.

srhSegmentIPv6
: The 128-bit IPv6 address that represents an SRv6 segment.

srhActiveSegmentIPv6
: The 128-bit IPv6 address that represents the active SRv6 segment.

srhSegmentIPv6BasicList
: The ordered basicList [RFC6313] of zero or more 128-bit IPv6 addresses in the SRH that represents the SRv6 Segment List. As specified in Section 2 of [RFC8754], the Segment List is encoded starting from the last segment of the SR Policy. That is, the first element of the Segment List (Segment List[0]) contains the last segment of the SR Policy, the second element contains the penultimate segment of the SR Policy, and so on.

srhSegmentIPv6ListSection
: The SRH Segment List as defined in Section 2 of [RFC8754] as a series of octets in IPFIX.

srhSegmentsIPv6Left
: The 8-bit unsigned integer that defines the number of segments remaining to reach the end of the Segment List from the SRH, as specified by the "Segments Left" field in Section 4.4 of [RFC8200] and as mentioned in the SRH part of Section 2 of [RFC8754].

srhIPv6Section
: The SRH and its TLVs as specified in Section 2 of [RFC8754] as a series of octets in IPFIX.

srhIPv6ActiveSegmentType
: The designator of the routing protocol or PCEP extension where the active SRv6 segment has been learned from.

srhSegmentIPv6LocatorLength
: The length of the SRH segment IPv6 locator specified as the number of significant bits. Together with srhSegmentIPv6, it enables the calculation of the SRv6 Locator.

srhSegmentIPv6EndpointBehavior

The 16-bit unsigned integer that represents an SRv6 Endpoint behavior as per Section 4 of [RFC8986].

Note that the srhSegmentIPv6, srhSegmentIPv6LocatorLength, and srhSegmentIPv6EndpointBehavior IPFIX IEs are generic fields to be used in the context of IPFIX Options Templates or IPFIX Structured Data [RFC6313].

4. Sample Use Cases

The IPFIX IEs srhSegmentIPv6BasicList (496) or alternatively srhSegmentIPv6ListSection (497), srhActiveSegmentIPv6 (495), srhSegmentsIPv6Left (498), srhIPv6ActiveSegmentType (500), and forwardingStatus (89) [RFC7270] [IANA-IPFIX] as well as some existing counter information [IANA-IPFIX] provide answers to the following questions (amongst others):

* How many packets steered with an SR policy are forwarded or dropped using SRv6 in a network?
* If dropped, for which reasons?
* What is the current active segment and its associated control plane protocol?
* What is the SRv6 Segment List?
* What is the next SRv6 node and its type?
* How many SRv6 segments are left?

5. IANA Considerations

5.1. IPFIX Information Elements Registry

IANA has added the following new IEs to the "IPFIX Information Elements" registry [RFC7012] at [IANA-IPFIX]:

ElementID	Name
492	srhFlagsIPv6
493	srhTagIPv6
494	srhSegmentIPv6
495	srhActiveSegmentIPv6
496	srhSegmentIPv6BasicList
497	srhSegmentIPv6ListSection
498	srhSegmentsIPv6Left
499	srhIPv6Section

500	srhIPv6ActiveSegmentType
501	srhSegmentIPv6LocatorLength
502	srhSegmentIPv6EndpointBehavior

Table 1: IPFIX Information Elements Registry

5.1.1. srhFlagsIPv6

ElementID: 492
Name: srhFlagsIPv6
Abstract Data Type: unsigned8
Data Type Semantics: flags
Description: The 8-bit Flags field defined in the SRH (Section 2 of [RFC8754]). Assigned flags and their meanings are provided in the "Segment Routing Header Flags" IANA registry.
Additional Information: See the assignments in the "Segment Routing Header Flags" registry at <https://www.iana.org/assignments/ipv6-parameters>. See also [RFC8754] for the SRH specification.
Reference: RFC 9487

5.1.2. srhTagIPv6

ElementID: 493
Name: srhTagIPv6
Abstract Data Type: unsigned16
Data Type Semantics: identifier
Description: The 16-bit Tag field defined in the SRH (Section 2 of [RFC8754]). A tag is used to mark a packet as part of a class or group of packets sharing the same set of properties.
Additional Information: See Section 2 of [RFC8754] for more details about the Tag.
Reference: RFC 9487

5.1.3. srhSegmentIPv6

ElementID: 494
Name: srhSegmentIPv6
Abstract Data Type: ipv6Address
Data Type Semantics: default
Description: The 128-bit IPv6 address that represents an SRv6 segment.
Additional Information: Specified in Section 1 of [RFC8402] and mentioned in "Segment List" in Section 2 of [RFC8754].
Reference: RFC 9487

5.1.4. srhActiveSegmentIPv6

ElementID: 495
Name: srhActiveSegmentIPv6
Abstract Data Type: ipv6Address
Data Type Semantics: default
Description: The 128-bit IPv6 address that represents the active

SRv6 segment.
Additional Information: See Section 2 of [RFC8402] for the definition of "active segment".
Reference: RFC 9487

5.1.5. srhSegmentIPv6BasicList

ElementID: 496
Name: srhSegmentIPv6BasicList
Abstract Data Type: basicList
Data Type Semantics: list
Description: The ordered basicList [RFC6313] of zero or more 128-bit IPv6 addresses in the SRH that represents the SRv6 Segment List. As specified in Section 2 of [RFC8754], the Segment List is encoded starting from the last segment of the SR Policy. That is, the first element of the Segment List (Segment List[0]) contains the last segment of the SR Policy, the second element contains the penultimate segment of the SR Policy, and so on.
Additional Information: See Section 2 of [RFC8754] for more details about the SRv6 Segment List.
Reference: RFC 9487

5.1.6. srhSegmentIPv6ListSection

ElementID: 497
Name: srhSegmentIPv6ListSection
Abstract Data Type: octetArray
Data Type Semantics: default
Description: The SRv6 Segment List as defined in Section 2 of [RFC8754] as a series of octets in IPFIX.
Additional Information: See Section 2 of [RFC8754] for more details about the SRv6 Segment List.
Reference: RFC 9487

5.1.7. srhSegmentsIPv6Left

ElementID: 498
Name: srhSegmentsIPv6Left
Abstract Data Type: unsigned8
Data Type Semantics: quantity
Description: The 8-bit unsigned integer defining the number of segments remaining to reach the end of the Segment List from the SRH.
Additional Information: Specified by the "Segments Left" field in Section 4.4 of [RFC8200] and mentioned in Section 2 of [RFC8754].
Reference: RFC 9487

5.1.8. srhIPv6Section

ElementID: 499
Name: srhIPv6Section
Abstract Data Type: octetArray
Data Type Semantics: default
Description: The SRH and its TLVs as defined in Section 2 of [RFC8754] as a series of octets in IPFIX.
Additional Information: See Section 2 of [RFC8754] for more details

about the structure of an SRH.
Reference: RFC 9487

5.1.9. srhIPv6ActiveSegmentType

ElementID: 500
Name: srhIPv6ActiveSegmentType
Abstract Data Type: unsigned8
Data Type Semantics: identifier
Description: The designator of the routing protocol or PCEP extension where the active SRv6 segment has been learned from. Values for this Information Element are listed in the "IPFIX IPv6 SRH Segment Type (Value 500)" subregistry.
Additional Information: See the assigned types in the "IPFIX IPv6 SRH Segment (Value 500)" registry at <https://www.iana.org/assignments/ipfix>.
Reference: RFC 9487

5.1.10. srhSegmentIPv6LocatorLength

ElementID: 501
Name: srhSegmentIPv6LocatorLength
Data Type Semantics: default
Description: The length of the SRH segment IPv6 locator specified as the number of significant bits. Together with srhSegmentIPv6, it enables the calculation of the SRv6 Locator.
Additional Information: See Section 3.1 of [RFC8986] for more details about the SID format.
Reference: RFC 9487

5.1.11. srhSegmentIPv6EndpointBehavior

ElementID: 502
Name: srhSegmentIPv6EndpointBehavior
Abstract Data Type: unsigned16
Data Type Semantics: identifier
Description: The 16-bit unsigned integer that represents an SRv6 Endpoint behavior as per Section 4 of [RFC8986]. Assigned values and their meanings are provided in the "SRv6 Endpoint Behaviors" registry.
Additional Information: See the assigned behaviors in the "SRv6 Endpoint Behaviors" registry at <https://www.iana.org/assignments/segment-routing>. See Section 4 of [RFC8986] for more details about the processing of endpoint behaviors.
Reference: RFC 9487

5.2. New IPFIX IPv6 SRH Segment Type (Value 500) Subregistry

IANA has created a new subregistry called "IPFIX IPv6 SRH Segment Type (Value 500)" under the "IPFIX Information Elements" registry [RFC7012] at [IANA-IPFIX].

The allocation policy of this new subregistry is Expert Review (Section 4.5 of [RFC8126]).

The designated experts for this registry should be familiar with SRH.

The guidelines that are being followed by the designated experts for the "IPFIX Information Elements" registry should be followed for this subregistry. In particular, criteria that should be applied by the designated experts include determining whether the proposed registration duplicates existing entries and whether the registration description is clear and fits the purpose of this registry. Within the review period, the designated experts will either approve or deny the registration request, communicating this decision to IANA. Denials should include an explanation and, if applicable, suggestions as to how to make the request successful.

Initial values in the registry are defined in Table 2.

Value	Description	Reference
0	Unknown	RFC 9487
1	Segment Routing Policy	RFC 9487, [RFC9256]
2	Path Computation Element	RFC 9487, [PCEP-SRV6-EXT]
3	OSPFv3 Segment Routing	RFC 9487, [OSPFV3-SRV6-EXT]
4	IS-IS Segment Routing	RFC 9487, [RFC9352]
5	BGP Segment Routing Prefix-SID	RFC 9487, [RFC8669]

Table 2: IPFIX IPv6 SRH Segment Type (Value 500) Subregistry

6. Operational Considerations

6.1. SRv6 Segment List

The zero or more 128-bit IPv6 addresses in the SRH [RFC8754] can be exported in two different ways, with two different IPFIX IEs:

* srhSegmentIPv6BasicList

* srhSegmentIPv6ListSection

The srhSegmentIPv6BasicList encodes the SRv6 Segment List with a basicList, specified in the IPFIX Structured Data [RFC6313]. This encoding is an advantage for data collection since the different IPv6 addresses are already structured as a list, without the need of post-processing. However, this method requires some extra processing on the exporter to realize the basicList data mapping.

The srhSegmentIPv6ListSection, on the other hand, encodes the list of IPv6 addresses as an octetArray. This doesn't impose any data flow manipulation on the exporter, facilitating the immediate export. However, the data collection MUST be able to decode the IPv6 addresses according to the SR specifications. Compared to the srhSegmentIPv6BasicList, the srhSegmentIPv6ListSection flow records

length is slightly reduced.

It is not expected that an exporter would support both srhSegmentIPv6BasicList and srhSegmentIPv6ListSection at the same time.

6.2. Compressed SRv6 Segment List Decomposition

The SRv6 Segment List in the IPFIX IEs srhSegmentIPv6BasicList, srhSegmentIPv6ListSection, and destinationIPv6Address could contain compressed-SID containers as described in [SRV6-SRH-COM]. The SR Endpoint Flavors, as described in Section 4 of [SRV6-SRH-COM], define new flavors for SID Endpoint behaviors and determine wherever the Segment List encoding is compressed, along with the flavor. The SID Locator, as described in Section 3.1 of [RFC8986], determines the common most significant bits. By using described information from srhSegmentIPv6EndpointBehavior and srhSegmentIPv6LocatorLength, the compressed-SID containers can be decoded at the data collection.

7. Security Considerations

There are no additional security considerations regarding allocation of these new IPFIX IEs compared to [RFC7012].

The IEs described in this document export provider plane data metrics on how packets are being forwarded within an SRv6 network. Applications and operators using the IEs described in this document must evaluate the sensitivity of this information in their implementation context and apply the data-at-rest storage guidance in Section 11.8 of [RFC7011] as appropriate.

8. References

8.1. Normative References

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Appendix A. IPFIX Encoding Examples

This appendix represents three different encodings for the newly introduced IEs, for the example values in Table 3. The three different encodings use the following IEs, respectively: srhSegmentIPv6BasicList, srhSegmentIPv6ListSection, and srhIPv6Section.

SRH Nr	SRH Flags	SRH Tag	Active Segment Type	Segment List
1	0	123	IS-IS [4]	2001:db8::1, 2001:db8::2, 2001:db8::3
2	0	456	IS-IS [4]	2001:db8::4, 2001:db8::5
3	0	789	IS-IS [4]	2001:db8::6

Table 3: Three Observed SRH Headers and Their Associated Routing Protocols

A.1. Three Observed SRH Headers and Their Routing Protocols

A.1.1. Template Record and Data Set with Segment Basic List

With encoding in Figure 1, the examples in Table 3 are represented with the following IEs, where "=>" is used to indicate which IE is mapped to given information:

* SRH Flags => srhFlagsIPv6 (492)

* SRH Tag => srhTagIPv6 (493)

* Active Segment Type => srhIPv6ActiveSegmentType (500)

* Segment List => srhSegmentIPv6BasicList (496)

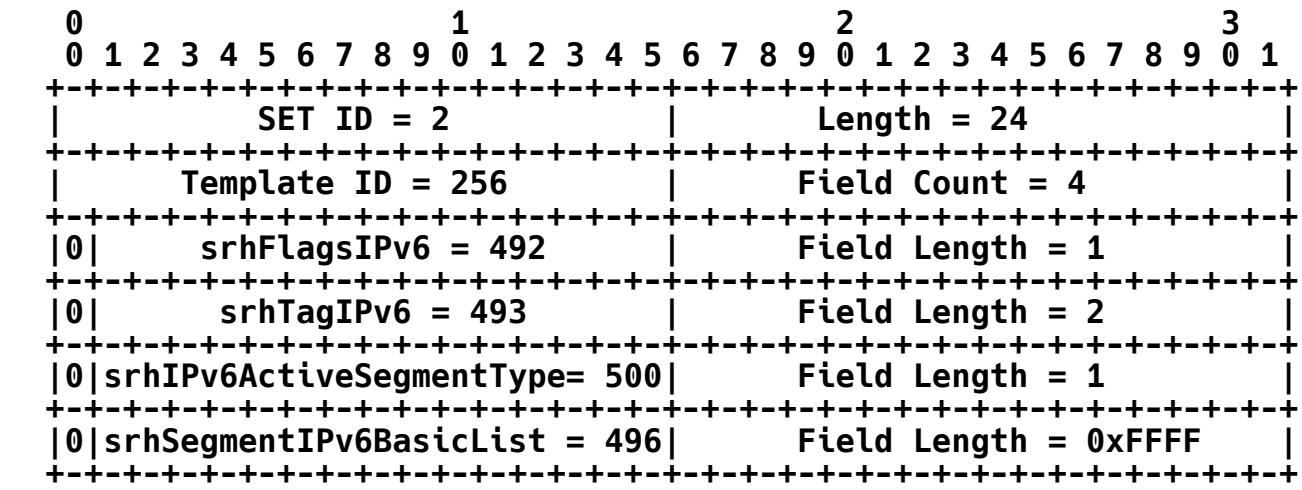
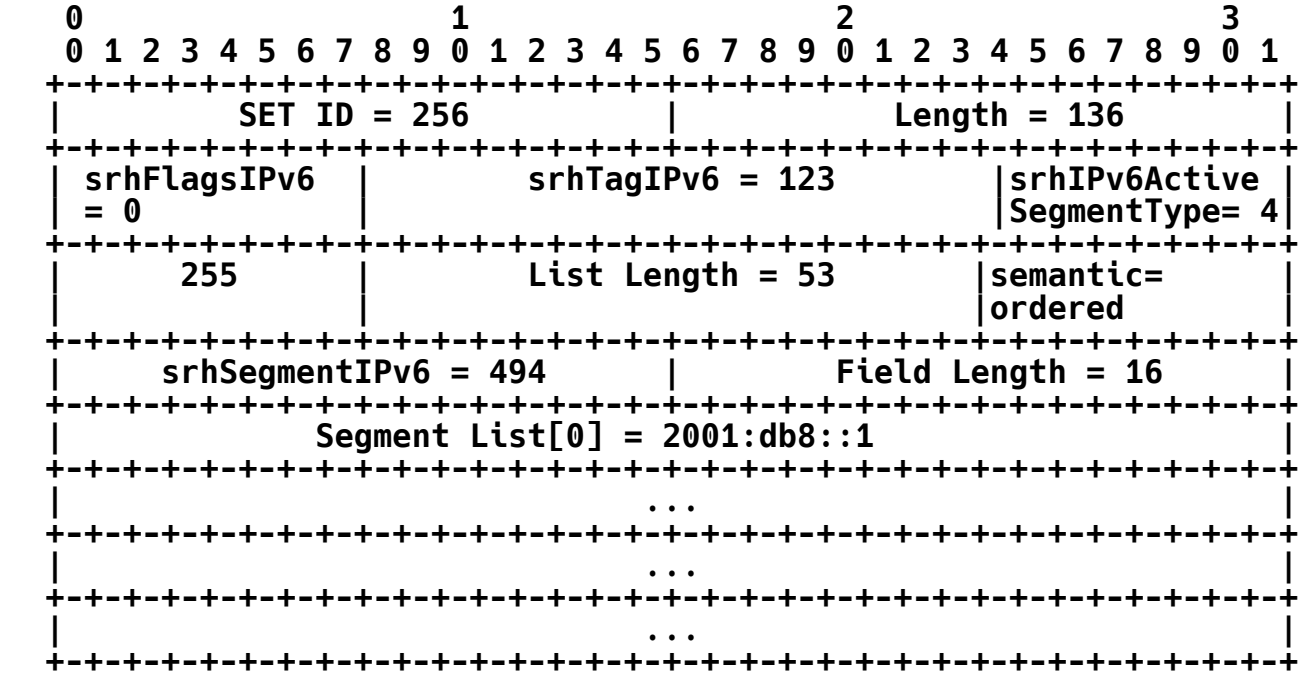


Figure 1: Template Record with Basic List Encoding Format

In this example, the Template ID is 256, which will be used in the Data Record. The field length for srhSegmentIPv6BasicList is 0xFFFF, which means the length of this IE is variable, and the actual length of this IE is indicated by the List Length field in the basicList format as per [RFC6313].

The data set is represented as follows:



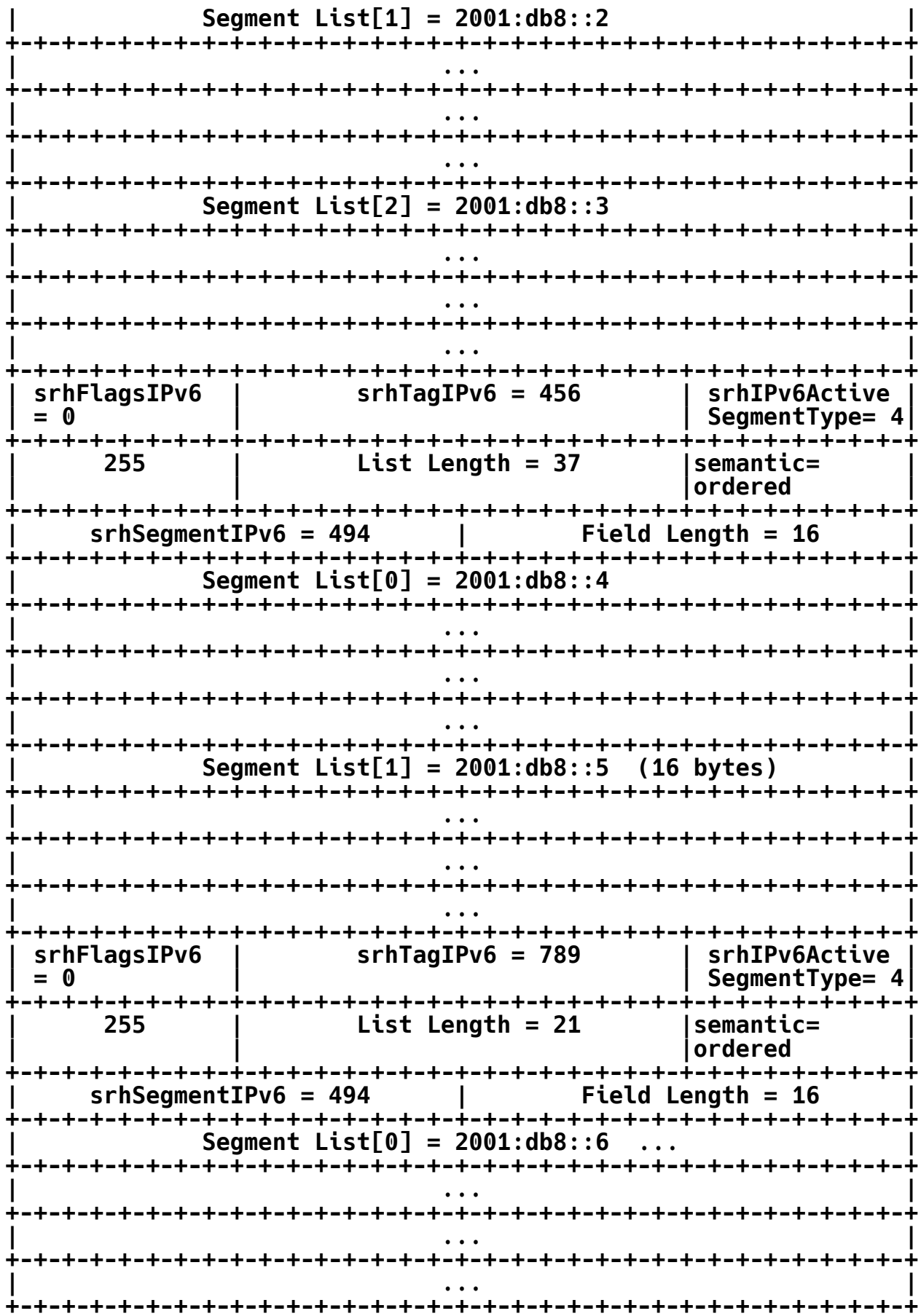

Segment List[1] = 2001:db8::2
...
...
...
Segment List[2] = 2001:db8::3
...
...
...
srhFlagsIPv6 = 0
srhTagIPv6 = 456
srhIPv6Active SegmentType= 4
255
List Length = 37
semantic= ordered
srhSegmentIPv6 = 494
Field Length = 16
Segment List[0] = 2001:db8::4
...
...
...
Segment List[1] = 2001:db8::5 (16 bytes)
...
...
...
srhFlagsIPv6 = 0
srhTagIPv6 = 789
srhIPv6Active SegmentType= 4
255
List Length = 21
semantic= ordered
srhSegmentIPv6 = 494
Field Length = 16
Segment List[0] = 2001:db8::6 ...
...
...
...

Figure 2: Data Set Encoding Format for Basic List

A.1.2. Template Record and Data Set with Segment List Section

With encoding in Figure 3, the examples in Table 3 are represented with the following IEs, where "=>" is used to indicate which IE is mapped to given information:

* SRH Flags => srhFlagsIPv6 (492)

* SRH Tag => srhTagIPv6 (493)

* Active Segment Type => srhIPv6ActiveSegmentType (500)

* Segment List => srhSegmentIPv6ListSection (497)

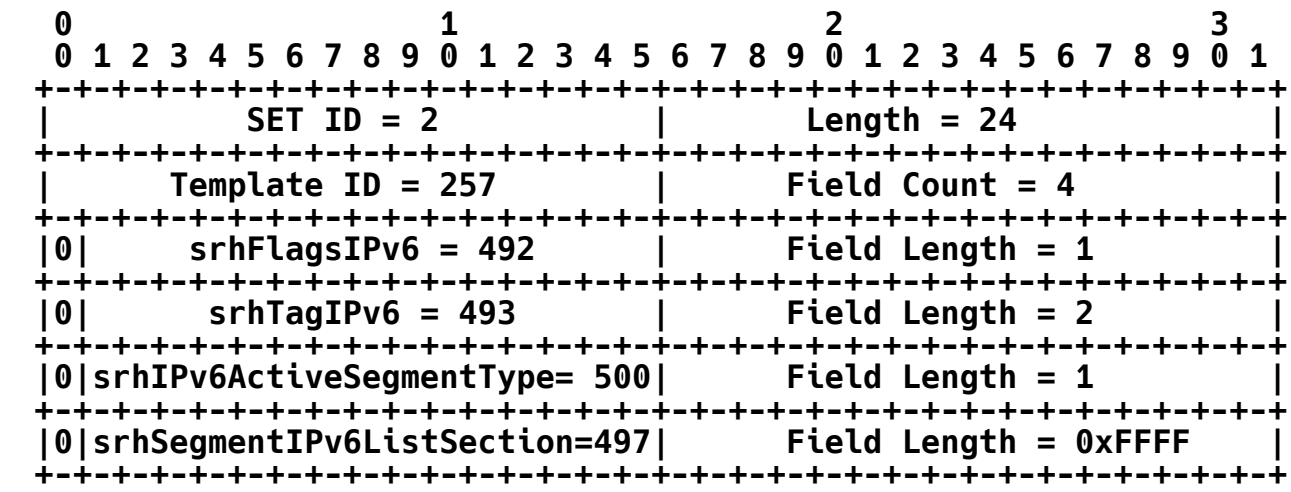
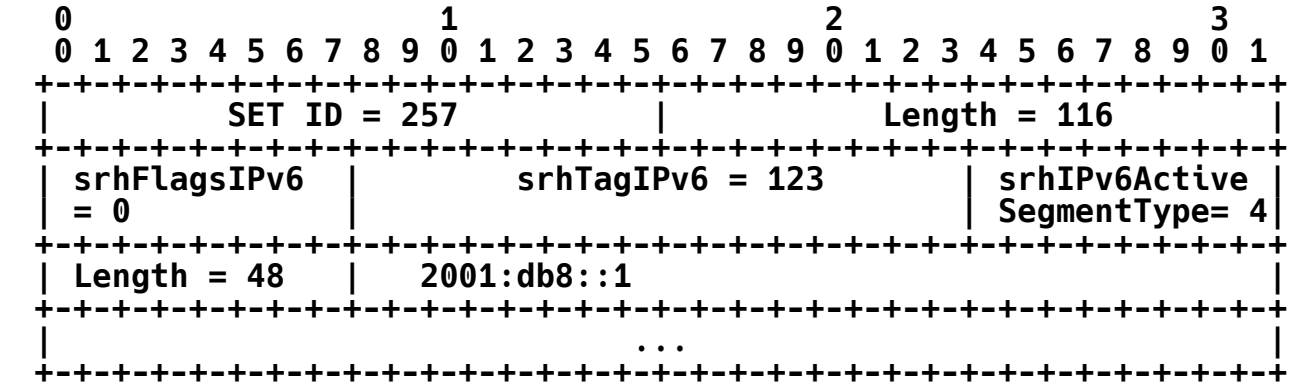


Figure 3: Template Record with Segment List Section Encoding Format

In this example, the Template ID is 257, which will be used in the Data Record. The field length for srhSegmentIPv6ListSection in the Template Record is 0xFFFF, which means that the length of this IE is variable: its actual length is encoded in the Data Set. Note that, with an actual length inferior to 255 in the Data Record example, the length field is encoded in 8 bits (Section 7 of [RFC7011]).

The data can be represented as follows:



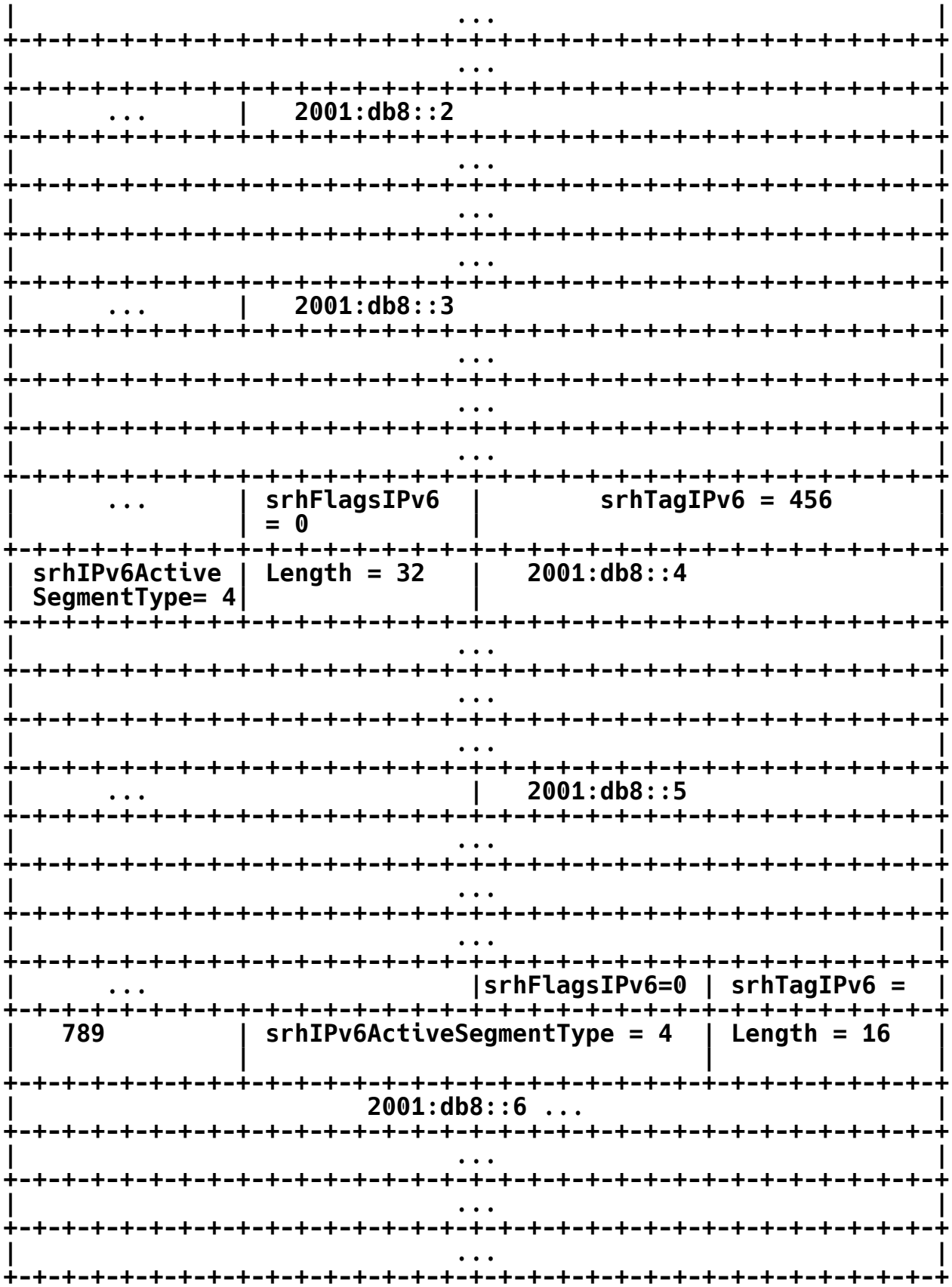


Figure 4: Data Set Encoding Format for Segment List Section

A.1.3. Template Record and Data Set with SRH Section

With encoding in Figure 5, the examples in Table 3 are represented with the following IEs, where "=>" is used to indicate which IE is mapped to given information:

* SRH Flags + SRH Tag + Segment List => srhIPv6Section (499)

* Active Segment Type => srhIPv6ActiveSegmentType (500)

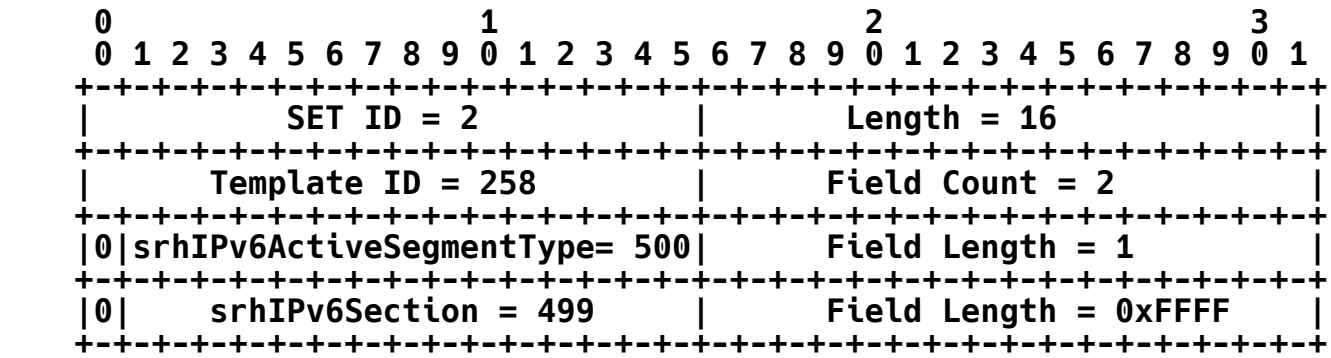
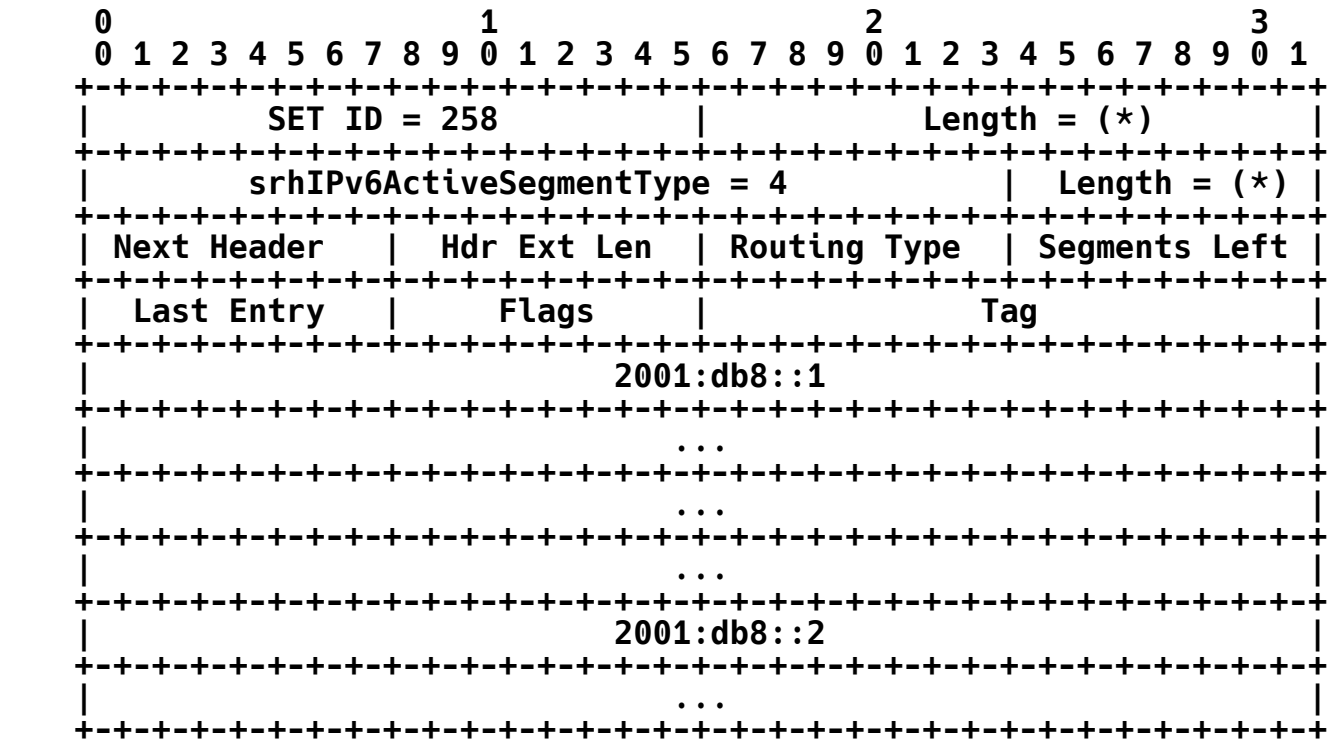


Figure 5: Template Record with SRH Section Encoding Format

In this example, the Template ID is 258, which will be used in the Data Record. The field length for srhIPv6Section in the Template Record is 0xFFFF, which means that the length of this IE is variable: its actual length is encoded in the Data Set. Note that, with an actual length inferior to 255 in the Data Record example, the length field is encoded in 8 bits (Section 7 of [RFC7011]).

The data can be represented as follows:



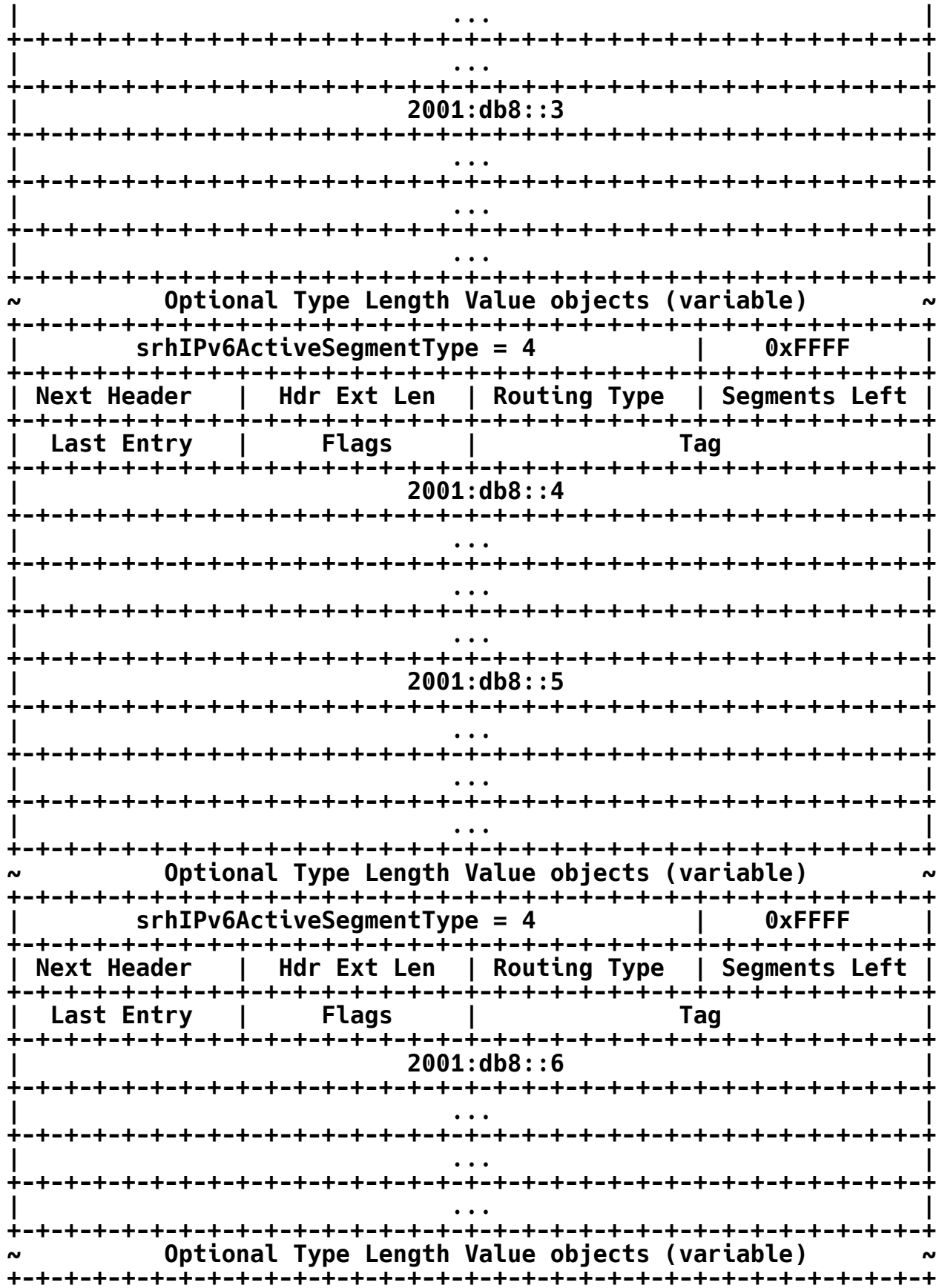


Figure 6: Data Set Encoding Format for SRH Section

(*) The Length must be calculated to include the optional Type Length Value objects.

A.2. Options Template Record and Data Set for SRv6 Segment Endpoint Behavior and Locator Length

This appendix provides an SRv6 Endpoint Behavior Options Template example, for the values presented in Table 4. In the Options Template case, the srhActiveSegmentIPv6 IE is a Scope field.

Entry Nr	SRH Endpoint IPv6	SRH Endpoint Behavior	SRH Segment Locator Length
1	2001:db8::1	End [1]	48
2	2001:db8::4	End with NEXT-CSID [43]	48
3	2001:db8::6	End.DX6 [16]	48

Table 4: Three Observed SRv6 Segment Endpoint Behaviors

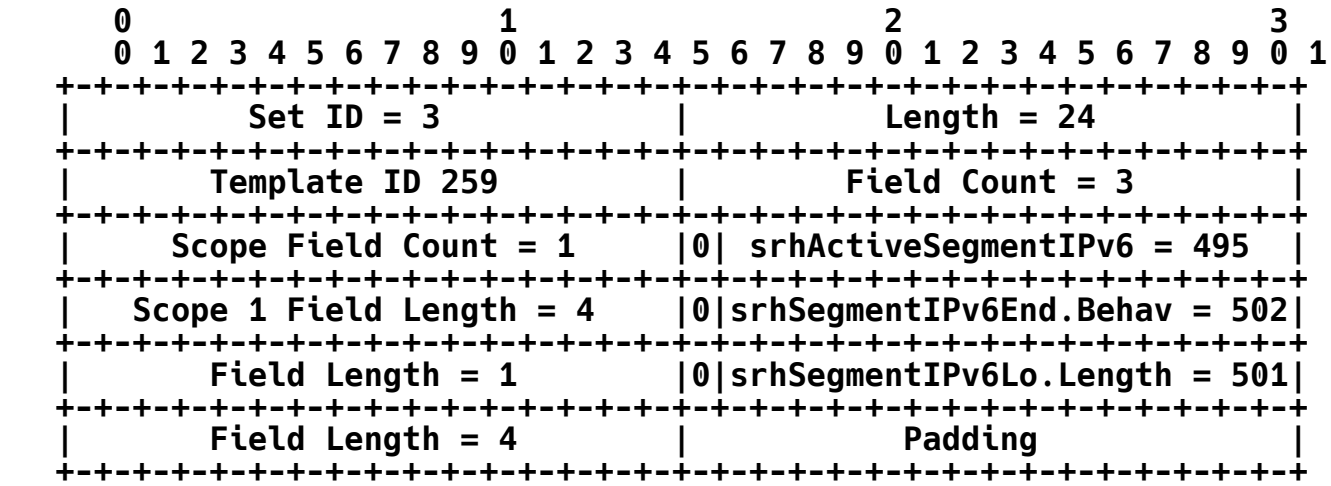
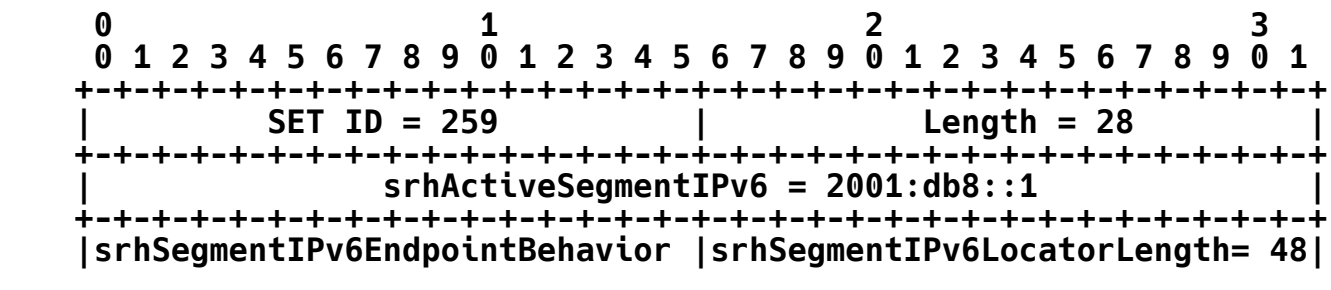


Figure 7: Segment Endpoint Behavior Options Template Record

In this example, the Template ID is 259, which will be used in the Data Record.

The data set is represented as follows:



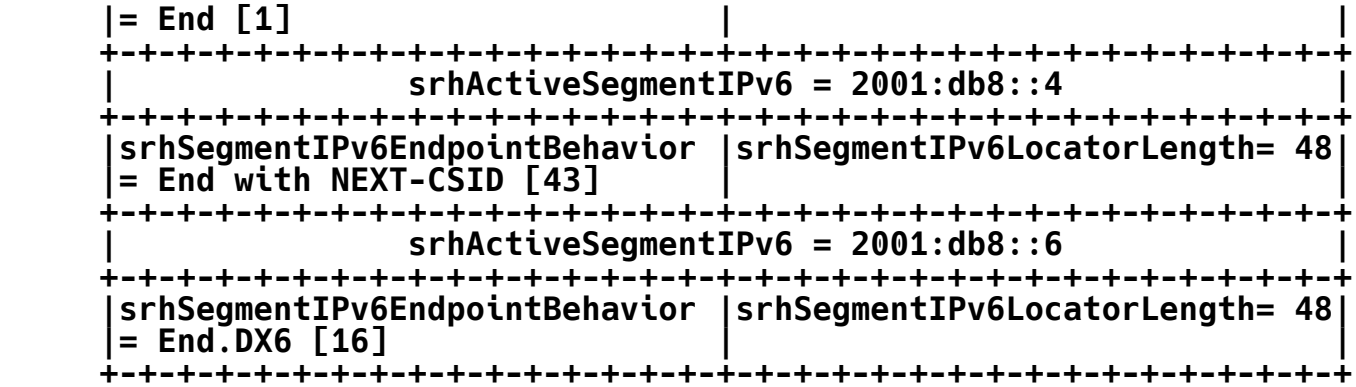


Figure 8: Data Set Encoding Format for Segment Endpoint Behaviors

(*) The Length must be calculated to include the optional Type Length Value objects.

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