

Internet Engineering Task Force (IETF)  
Request for Comments: 9487  
Category: Standards Track  
ISSN: 2070-1721

T. Graf  
Swisscom  
B. Claise  
Huawei  
P. Francois  
INSA-Lyon  
November 2023

## 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>.

### Copyright Notice

Copyright (c) 2023 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 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 Revised BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Revised BSD License.

### Table of Contents

1. Introduction
2. Terminology
3. New IPFIX IPv6 SRH Information Elements
4. Sample Use Cases
5. IANA Considerations
  - 5.1. IPFIX Information Elements Registry
    - 5.1.1. srhFlagsIPv6
    - 5.1.2. srhTagIPv6
    - 5.1.3. srhSegmentIPv6
    - 5.1.4. srhActiveSegmentIPv6
    - 5.1.5. srhSegmentIPv6BasicList

- 5.1.6. srhSegmentIPv6ListSection
- 5.1.7. srhSegmentsIPv6Left
- 5.1.8. srhIPv6Section
- 5.1.9. srhIPv6ActiveSegmentType
- 5.1.10. srhSegmentIPv6LocatorLength
- 5.1.11. srhSegmentIPv6EndpointBehavior
- 5.2. New IPFIX IPv6 SRH Segment Type (Value 500) Subregistry
- 6. Operational Considerations
  - 6.1. SRv6 Segment List
  - 6.2. Compressed SRv6 Segment List Decomposition
- 7. Security Considerations
- 8. References
  - 8.1. Normative References
  - 8.2. Informative References
- Appendix A. IPFIX Encoding Examples
  - A.1. Three Observed SRH Headers and Their Routing Protocols
    - A.1.1. Template Record and Data Set with Segment Basic List
    - A.1.2. Template Record and Data Set with Segment List Section
    - A.1.3. Template Record and Data Set with SRH Section
  - A.2. Options Template Record and Data Set for SRv6 Segment
    - Endpoint Behavior and Locator Length

Acknowledgements

Authors' Addresses

## 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

#### 5.1.1.1. 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

#### 5.1.1.2. 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

#### 5.1.1.3. 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

- [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>>.
- [RFC6313] Claise, B., Dhandapani, G., Aitken, P., and S. Yates, "Export of Structured Data in IP Flow Information Export (IPFIX)", RFC 6313, DOI 10.17487/RFC6313, July 2011, <<https://www.rfc-editor.org/info/rfc6313>>.
- [RFC7011] Claise, B., Ed., Trammell, B., Ed., and P. Aitken, "Specification of the IP Flow Information Export (IPFIX) Protocol for the Exchange of Flow Information", STD 77, RFC 7011, DOI 10.17487/RFC7011, September 2013, <<https://www.rfc-editor.org/info/rfc7011>>.
- [RFC7012] Claise, B., Ed. and B. Trammell, Ed., "Information Model for IP Flow Information Export (IPFIX)", RFC 7012, DOI 10.17487/RFC7012, September 2013, <<https://www.rfc-editor.org/info/rfc7012>>.
- [RFC8126] Cotton, M., Leiba, B., and T. Narten, "Guidelines for Writing an IANA Considerations Section in RFCs", BCP 26, RFC 8126, DOI 10.17487/RFC8126, June 2017, <<https://www.rfc-editor.org/info/rfc8126>>.
- [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>>.
- [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>>.
- [RFC8754] Filsfils, C., Ed., Dukes, D., Ed., Previdi, S., Leddy, J., Matsushima, S., and D. Voyer, "IPv6 Segment Routing Header (SRH)", RFC 8754, DOI 10.17487/RFC8754, March 2020, <<https://www.rfc-editor.org/info/rfc8754>>.

### 8.2. Informative References

- [IANA-IPFIX] IANA, "IP Flow Information Export (IPFIX) Entities", <<https://www.iana.org/assignments/ipfix>>.
- [OSPFV3-SRV6-EXT] Li, Z., Hu, Z., Talaulikar, K., Ed., and P. Psenak, "OSPFv3 Extensions for SRv6", Work in Progress, Internet-Draft, draft-ietf-lsr-ospfv3-srv6-extensions-15, 21 June 2023, <<https://datatracker.ietf.org/doc/html/draft-ietf->

```
lsr-ospfv3-srv6-extensions-15>.
```

## [ PCEP-SRV6-EXT ]

Li, C., Kaladharan, P., Sivabalan, S., Koldychev, M., and Y. Zhu, "Path Computation Element Communication Protocol (PCEP) Extensions for Segment Routing leveraging the IPv6 dataplane", Work in Progress, Internet-Draft, draft-ietf-pce-segment-routing-ipv6-20, 8 September 2023, <<https://datatracker.ietf.org/doc/html/draft-ietf-pce-segment-routing-ipv6-20>>.

[RFC7270] Yourtchenko, A., Aitken, P., and B. Claise, "Cisco-Specific Information Elements Reused in IP Flow Information Export (IPFIX)", RFC 7270, DOI 10.17487/RFC7270, June 2014, <<https://www.rfc-editor.org/info/rfc7270>>.

[RFC8402] Filssils, C., Ed., Previdi, S., Ed., Ginsberg, L., Decraene, B., Litkowski, S., and R. Shakir, "Segment Routing Architecture", RFC 8402, DOI 10.17487/RFC8402, July 2018, <<https://www.rfc-editor.org/info/rfc8402>>.

[RFC8669] Previdi, S., Filsfils, C., Lindem, A., Ed., Sreekantiah, A., and H. Gredler, "Segment Routing Prefix Segment Identifier Extensions for BGP", RFC 8669, DOI 10.17487/RFC8669, December 2019, <<https://www.rfc-editor.org/info/rfc8669>>.

[RFC8986] Filsfils, C., Ed., Camarillo, P., Ed., Leddy, J., Voyer, D., Matsushima, S., and Z. Li, "Segment Routing over IPv6 (SRv6) Network Programming", RFC 8986, DOI 10.17487/RFC8986, February 2021, <<https://www.rfc-editor.org/info/rfc8986>>.

[RFC9256] Filssils, C., Talaulikar, K., Ed., Voyer, D., Bogdanov, A., and P. Mattes, "Segment Routing Policy Architecture", RFC 9256, DOI 10.17487/RFC9256, July 2022, <<https://www.rfc-editor.org/info/rfc9256>>.

[RFC9352] Psenak, P., Ed., Filsfils, C., Bashandy, A., Decraene, B., and Z. Hu, "IS-IS Extensions to Support Segment Routing over the IPv6 Data Plane", RFC 9352, DOI 10.17487/RFC9352, February 2023, <<https://www.rfc-editor.org/info/rfc9352>>.

## [ SRV6-SRH-COM ]

Cheng, W., Ed., Filsfils, C., Li, Z., Decraene, B., and F. Clad, Ed., "Compressed SRv6 Segment List Encoding", Work in Progress, Internet-Draft, draft-ietf-spring-srv6-srh-compression-09, 23 October 2023, <<https://datatracker.ietf.org/doc/html/draft-ietf-spring-srv6-srh-compression-09>>.

## 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)

0	1	2	3
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			
SET ID = 2	Length = 24		
Template ID = 256	Field Count = 4		
0  srhFlagsIPv6 = 492	Field Length = 1		
0  srhTagIPv6 = 493	Field Length = 2		
0 srhIPv6ActiveSegmentType= 500	Field Length = 1		
0 srhSegmentIPv6BasicList = 496	Field Length = 0xFFFF		

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:

0	1	2	3
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			
SET ID = 256	Length = 136		
srhFlagsIPv6 = 0	srhTagIPv6 = 123	srhIPv6ActiveSegmentType= 4	
255	List Length = 53	semantic= ordered	
srhSegmentIPv6 = 494	Field Length = 16		
Segment List[0] = 2001:db8::1			

```

|                                     ...                                     |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
|                                     Segment List[1] = 2001:db8::2          |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
|                                     Segment List[2] = 2001:db8::3          |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| srhFlagsIPv6 = 0 | srhTagIPv6 = 456 | srhIPv6Active | srhIPv6Active |
|                   |                   | SegmentType= 4 | SegmentType= 4 |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                   255 | List Length = 37 | semantic= | semantic= |
|                   |                   | ordered  | 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 | srhIPv6Active |
|                   |                   | SegmentType= 4 | SegmentType= 4 |
|-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                   255 | List Length = 21 | semantic= | semantic= |
|                   |                   | ordered  | 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:

0										1										2										3									
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	2	3	4	5	6	7	8	9
SET ID = 2										Length = 24																													
Template ID = 257										Field Count = 4																													
0  srhFlagsIPv6 = 492										Field Length = 1																													
0  srhTagIPv6 = 493										Field Length = 2																													
0 srhIPv6ActiveSegmentType= 500										Field Length = 1																													
0 srhSegmentIPv6ListSection=497										Field Length = 0xFFFF																													

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]).

[illegible]

...		
...		
...		
...	srhFlagsIPv6 = 0	srhTagIPv6 = 456
srhIPv6Active SegmentType= 4	Length = 32	2001:db8::4
...		
...		
...		
...	2001:db8::5	
...		
...		
...		
...	srhFlagsIPv6=0	srhTagIPv6 =
789	srhIPv6ActiveSegmentType = 4	Length = 16
2001:db8::6 ...		
...		
...		
...		

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)

0	1	2	3
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
SET ID = 2	Length = 16		
Template ID = 258	Field Count = 2		
0 srhIPv6ActiveSegmentType= 500	Field Length = 1		
0 srhIPv6Section = 499	Field Length = 0xFFFF		

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:

```

      0          1          2          3
    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
+-----+-----+-----+-----+-----+-----+-----+-----+
|          SET ID = 258          |          Length = (*)          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          srhIPv6ActiveSegmentType = 4          |          Length = (*)          |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Next Header | Hdr Ext Len | Routing Type | Segments Left |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Last Entry  | Flags      |          Tag          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          2001:db8::1          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          2001:db8::2          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          2001:db8::3          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
~          Optional Type Length Value objects (variable)          ~
+-----+-----+-----+-----+-----+-----+-----+-----+
|          srhIPv6ActiveSegmentType = 4          |          0xFFFF          |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Next Header | Hdr Ext Len | Routing Type | Segments Left |
+-----+-----+-----+-----+-----+-----+-----+-----+
| Last Entry  | Flags      |          Tag          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          2001:db8::4          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          2001:db8::5          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|          ...          |
+-----+-----+-----+-----+-----+-----+-----+-----+

```

```

|                                     ...                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
~      Optional Type Length Value objects (variable)      ~
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|      srhIPv6ActiveSegmentType = 4      |      0xFFFF      |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Next Header      | Hdr Ext Len      | Routing Type      | Segments Left      |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
| Last Entry      | Flags      | Tag      |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     2001:db8::6                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
|                                     ...                                     |
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
~      Optional Type Length Value objects (variable)      ~
+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+

```

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

0	1	2	3
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			
Set ID = 3		Length = 24	
Template ID 259		Field Count = 3	
Scope Field Count = 1	0	srhActiveSegmentIPv6 = 495	
Scope 1 Field Length = 4	0	srhSegmentIPv6End.Behav = 502	
Field Length = 1	0	srhSegmentIPv6Lo.Length = 501	
Field Length = 4		Padding	

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:

0										1										2										3									
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								
SET ID = 259										Length = 28																													
srhActiveSegmentIPv6 = 2001:db8::1																																							
srhSegmentIPv6EndpointBehavior										srhSegmentIPv6LocatorLength= 48																													
= End [1]																																							
srhActiveSegmentIPv6 = 2001:db8::4																																							
srhSegmentIPv6EndpointBehavior										srhSegmentIPv6LocatorLength= 48																													
= End with NEXT-CSID [43]																																							
srhActiveSegmentIPv6 = 2001:db8::6																																							
srhSegmentIPv6EndpointBehavior										srhSegmentIPv6LocatorLength= 48																													
= End.DX6 [16]																																							

Figure 8: Data Set Encoding Format for Segment Endpoint Behaviors

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

#### Acknowledgements

The authors would like to thank Yao Liu, Eduard Vasilenko, Bruno Decraene, Mohamed Boucadair, Kamran Raza, Qin Wu, Jim Guichard, Tero Kivinen, Paul Aitken, Roman Danyliw, John Scudder, ric Vyncke, Erik Kline, Lars Eggert, and Andrew Alston for their reviews and valuable comments. And thank you to Paolo Lucente and Alex Huang Feng for the implementation and validation.

#### Authors' Addresses

Thomas Graf  
Swisscom  
Binzring 17  
CH-8045 Zurich  
Switzerland  
Email: thomas.graf@swisscom.com

Benoit Claise  
Huawei  
Email: benoit.claise@huawei.com

Pierre Francois  
INSA-Lyon  
Lyon  
France  
Email: pierre.francois@insa-lyon.fr