

6man
Internet-Draft
Intended status: Standards Track
Expires: March 5, 2020

R. Bonica
Juniper Networks
Y. Kamite
NTT Communications Corporation
T. Niwa
KDDI
A. Alston
D. Henriques
Liquid Telecom
N. So
F. Xu
Reliance Jio
G. Chen
Baidu
Y. Zhu
G. Yang
China Telecom
Y. Zhou
ByteDance
September 2, 2019

**The IPv6 Compressed Routing Header (CRH)
draft-bonica-6man-comp-rtg-hdr-07**

Abstract

This document defines two new IPv6 Routing header types. Generically, they are called the Compressed Routing Header (CRH). More specifically, the 16-bit version of the CRH is called the CRH-16, while the 32-bit version of the CRH is called the CRH-32. SRv6+ nodes use the CRH to steer packets from segment to segment along SRv6+ paths.

Status of This Memo

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

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

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

This Internet-Draft will expire on March 5, 2020.

Copyright Notice

Copyright (c) 2019 IETF Trust and the persons identified as the document authors. All rights reserved.

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

Table of Contents

1.	Introduction	3
2.	Requirements Language	3
3.	The Compressed Routing Header (CRH)	3
4.	The Segment Forwarding Information Base (SFIB)	4
5.	Processing Rules	5
5.1.	General	5
5.2.	CRH Specific	6
5.2.1.	Computing Minimum CRH Length	7
5.2.2.	Topological Instructions That Control Adjacency Segments	8
5.2.3.	Topological Instructions That Control Node Segments .	8
6.	Mutability	9
7.	Compliance	9
8.	Management Considerations	9
9.	Security Considerations	9
10.	IANA Considerations	9
11.	Acknowledgements	10
12.	References	10
12.1.	Normative References	10
12.2.	Informative References	10
Appendix A.	CRH Processing Examples	11
A.1.	SR Path Contains Node Segments Only	12
A.2.	SR Path Contains Node Segments Only And Preserves The First SID	13
A.3.	SR Path Contains Adjacency Segments Only	13
Authors' Addresses	14

1. Introduction

This document defines two new IPv6 [\[RFC8200\]](#) Routing header types. Generically, they are called the Compressed Routing Header (CRH). More specifically, the 16-bit version of the CRH is called the CRH-16, while the 32-bit version of the CRH is called the CRH-32. SRv6+ [\[I-D.bonica-spring-srv6-plus\]](#) nodes use the CRH to steer packets from segment to segment along SRv6+ paths.

For details regarding SRv6+ paths, segments, Segment Identifiers (SIDs) and instructions, see [\[I-D.bonica-spring-srv6-plus\]](#).

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [BCP 14](#) [\[RFC2119\]](#) [\[RFC8174\]](#) when, and only when, they appear in all capitals, as shown here.

3. The Compressed Routing Header (CRH)

Both CRH versions (i.e., CRH-16 and CRH-32) contain the following fields:

- o Next Header - Defined in [\[RFC8200\]](#). Identifies the type of header immediately following the CRH.
- o Hdr Ext Len - Defined in [\[RFC8200\]](#). Length of the CRH in 8-octet units, not including the first 8 octets.
- o Routing Type - Defined in [\[RFC8200\]](#). Value TBD by IANA. (For CRH-16, the suggested value is 5. For CRH-32, the suggested value is 6.)
- o Segments Left - Defined in [\[RFC8200\]](#). Number of route segments remaining, i.e., number of explicitly listed intermediate nodes still to be visited before reaching the final destination.
- o SID List - Represents the SRv6+ path as an ordered list of SIDs. SIDs are listed in reverse order, with SID[0] representing the final segment, SID[1] representing the penultimate segment, and so forth. SIDs are listed in reverse order so that Segments Left can be used as an index to the SID List. The SID indexed by Segments Left is called the current SID.

In the CRH-16 (Figure 1), each SID list entry is encoded in 16-bits. In the CRH-32 (Figure 2), each SID list entry is encoded in 32-bits.

In networks where the smallest feasible Maximum SID Value (MSV) [[I-D.bonica-spring-srv6-plus](#)] is greater than 65,635, CRH-32 is required. Otherwise, CRH-16 is preferred.

In all cases, the CRH MUST end on a 64-bit boundary. Therefore, the CRH MAY be padded with zeros.

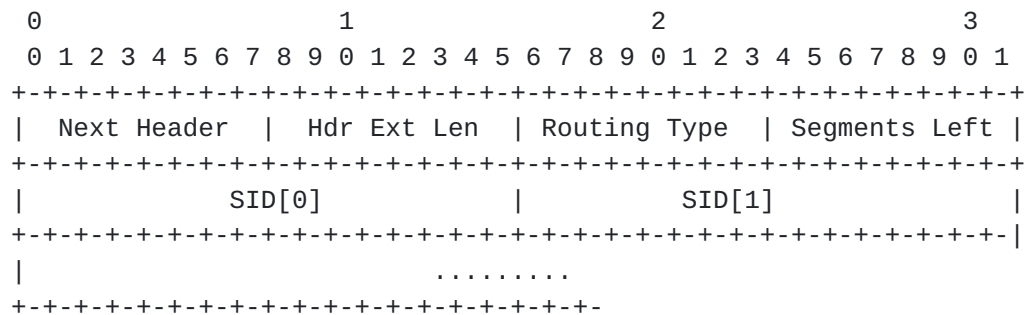


Figure 1: CRH-16

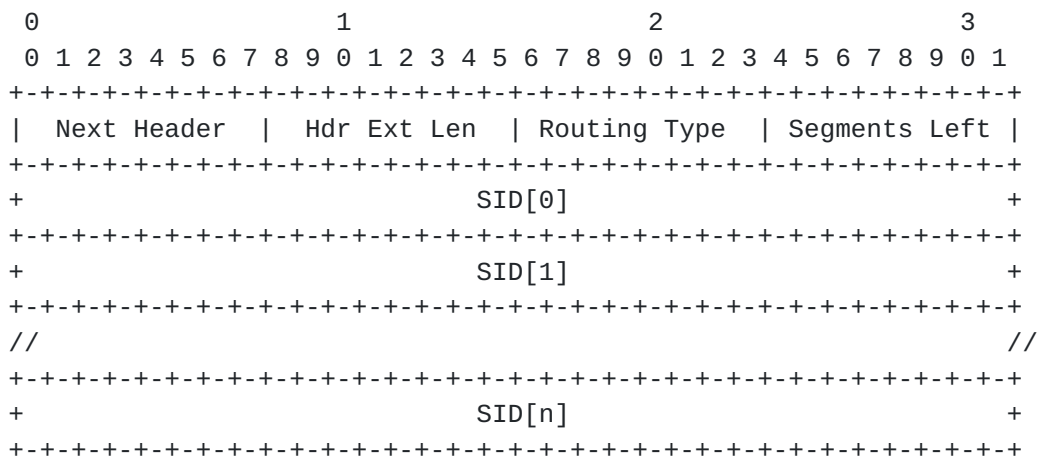


Figure 2: CRH-32

4. The Segment Forwarding Information Base (SFIB)

A segment ingress node MUST maintain one Segment Forwarding Information Base (SFIB) entry for each segment that it originates. Each SFIB entry contains the following information:

- o A SID.
- o A segment type.

- o Topological instruction parameters.

The following are valid segment types:

- o Adjacency.
- o Node.

The following parameters are associated with topological instructions that control adjacency segments:

- o An IPv6 address that identifies an interface on the segment egress node.
- o An interface identifier.

Node segments are associated with a single topological instruction parameter. This parameter is an IPv6 address that identifies an interface on the segment egress node.

5. Processing Rules

5.1. General

[RFC8200] defines rules that apply to IPv6 extension headers, in general, and IPv6 Routing headers, in particular. All of these rules apply to the CRH.

For example:

- o Extension headers (except for the Hop-by-Hop Options header) are not processed, inserted, or deleted by any node along a packet's delivery path, until the packet reaches the node (or each of the set of nodes, in the case of multicast) identified in the Destination Address field of the IPv6 header.
- o If, while processing a received packet, a node encounters a Routing header with an unrecognized Routing Type value, the required behavior of the node depends on the value of the Segments Left field. If Segments Left is zero, the node must ignore the Routing header and proceed to process the next header in the packet, whose type is identified by the Next Header field in the Routing header. If Segments Left is non-zero, the node must discard the packet and send an ICMPv6 [\[RFC4443\]](#) Parameter Problem, Code 0, message to the packet's Source Address, pointing to the unrecognized Routing Type.

- o If, after processing a Routing header of a received packet, an intermediate node determines that the packet is to be forwarded onto a link whose link MTU is less than the size of the packet, the node must discard the packet and send an ICMPv6 Packet Too Big message to the packet's Source Address.

5.2. CRH Specific

When a node recognizes and processes a CRH, it executes the following procedure:

- o If the IPv6 Source Address is a link-local address, discard the packet.
- o If the IPv6 Source Address is a multicast address, discard the packet.
- o If Segments Left equals 0, skip over the CRH and process the next header in the packet.
- o If Hdr Ext Len indicates that the CRH is larger than the implementation can process, discard the packet and send an ICMPv6 Parameter Problem, Code 0, message to the Source Address, pointing to the Hdr Ext Len field.
- o Compute L, the minimum CRH length (See [Section 5.2.1](#)).
- o If L is greater than Hdr Ext Len, discard the packet and send an ICMPv6 Parameter Problem, Code 0, message to the Source Address, pointing to the Segments Left field.
- o Decrement the packet's Hop Count.
- o If the Hop Count has expired, discard the packet and send an ICMPv6 Time Expired message to the packet's source node.
- o Decrement Segments Left
- o Search for the current SID in the SFIB.
- o If the above-mentioned search does not return an SFIB entry, discard the packet and send an ICMPv6 Parameter Problem, Code 0, message to the Source Address, pointing to the current SID.
- o If the above-mentioned search returns an SFIB entry that represents an adjacency segment, execute the topological instruction described in [Section 5.2.2](#).

- o If the above-mentioned search returns an SFIB entry that represents a node segment, execute the topological instruction described in [Section 5.2.3](#).

The above stated rules are demonstrated in [Appendix A](#).

[5.2.1](#). Computing Minimum CRH Length

The algorithm described in this section accepts the following CRH fields as its input parameters:

- o Routing Type (i.e., CRH-16 or CRH-32).
- o Segments Left.

It yields L, the minimum CRH length. The minimum CRH length is measured in 8-octet units, not including the first 8 octets.

<CODE BEGINS>

```
switch(Routing Type) {  
    case CRH-16:  
        sidsBeyondFirstWord = Segments Left - 2;  
        sidsPerWord = 4;  
    case CRH-32:  
        sidsBeyondFirstWord = Segments Left - 1;  
        sidsPerWord = 2;  
    case default:  
        return(0xFF);  
}
```

```
if (sidsBeyondFirstWord <= 0)  
    return(0)
```

```
words = sidsBeyondFirstWord div sidsPerWord;  
if (sidsBeyondFirstWord mod sidsPerWord)  
    words++;
```

```
return(words)
```

<CODE ENDS>

5.2.2. Topological Instructions That Control Adjacency Segments

A topological instruction that controls an adjacency segment accepts the following parameters:

- o An IPv6 address that identifies an interface on the segment egress node.
- o An interface identifier.

The instruction behaves as follows:

- o If the interface that was received as a parameter is not operational, discard the packet and send an ICMPv6 Destination Unreachable message (Code: 5, Source Route Failed) to the packet's source node.
- o Overwrite the packet's Destination Address with the IPv6 address that was received as a parameter.
- o Forward the packet through the above-mentioned interface.

5.2.3. Topological Instructions That Control Node Segments

A topological instruction that controls a node segment accepts a single parameter. This parameter is an IPv6 address that identifies an interface on the segment egress node.

The instruction behaves as follows:

- o If the segment ingress node does not have a viable route to the IPv6 address included as a parameter, discard the packet and send an ICMPv6 Destination Unreachable message (Code:1 Net Unreachable) to the packet's source node.
- o Overwrite the packet's Destination Address with the destination address that was included as a parameter.
- o Forward the packet to the next hop along the least cost path to the segment egress node. If there are multiple least cost paths to the segment egress node (i.e., Equal Cost Multipath), execute procedures so that all packets belonging to a flow are forwarded through the same next hop.

6. Mutability

In the CRH, the Segments Left field is mutable. All remaining fields are immutable.

7. Compliance

In order to be compliant with this specification, an SRv6+ implementation MUST:

- o Be able to process IPv6 options as described in [Section 4.2 of \[RFC8200\]](#).
- o Be able to process the Routing header as described in [Section 4.4 of \[RFC8200\]](#).
- o Support the CRH-16 and the CRH-32.

8. Management Considerations

PING and TRACEROUTE [[RFC2151](#)] both operate correctly in the presence of the CRH.

9. Security Considerations

SRv6+ domains MUST NOT span security domains. In order to enforce this requirement, security domain edge routers MUST do one of the following:

- o Discard all inbound SRv6+ packets whose IPv6 destination address represents domain infrastructure.
- o Authenticate [[RFC4302](#)] [[RFC4303](#)] all inbound SRv6+ packets whose IPv6 destination address represents domain infrastructure.

10. IANA Considerations

IANA is requested to make the following entries in the Internet Protocol Version 6 (IPv6) Parameters "Routing Type" registry:

Suggested Value	Description	Reference
5	Compressed Routing Header (16-bit) (CRH-16)	This document
6	Compressed Routing Header (32-bit) (CRH-32)	This document

11. Acknowledgements

Thanks to Naveen Kottapalli, Joel Halpern, Tony Li, Gerald Schmidt, Nancy Shaw, and Chandra Venkatraman for their comments.

12. References

12.1. Normative References

- [I-D.bonica-spring-srv6-plus]
Bonica, R., Hegde, S., Kamite, Y., Alston, A., Henriques, D., Halpern, J., Linkova, J., and G. Chen, "IPv6 Support for Segment Routing: SRv6+", [draft-bonica-spring-srv6-plus-04](#) (work in progress), July 2019.
- [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>>.
- [RFC4302] Kent, S., "IP Authentication Header", [RFC 4302](#), DOI 10.17487/RFC4302, December 2005, <<https://www.rfc-editor.org/info/rfc4302>>.
- [RFC4303] Kent, S., "IP Encapsulating Security Payload (ESP)", [RFC 4303](#), DOI 10.17487/RFC4303, December 2005, <<https://www.rfc-editor.org/info/rfc4303>>.
- [RFC4443] Conta, A., Deering, S., and M. Gupta, Ed., "Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification", STD 89, [RFC 4443](#), DOI 10.17487/RFC4443, March 2006, <<https://www.rfc-editor.org/info/rfc4443>>.
- [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>>.

12.2. Informative References

[RFC2151] Kessler, G. and S. Shepard, "A Primer On Internet and TCP/IP Tools and Utilities", FYI 30, [RFC 2151](https://www.rfc-editor.org/info/rfc2151), DOI 10.17487/RFC2151, June 1997, <<https://www.rfc-editor.org/info/rfc2151>>.

Appendix A. CRH Processing Examples

This appendix demonstrates CRH processing in the following scenarios:

- o SR path contains node segments only (Appendix A.1).
- o SR path contains node segments only and preserves the first SID (Appendix A.2).
- o SR path contains adjacency segments only (Appendix A.3).

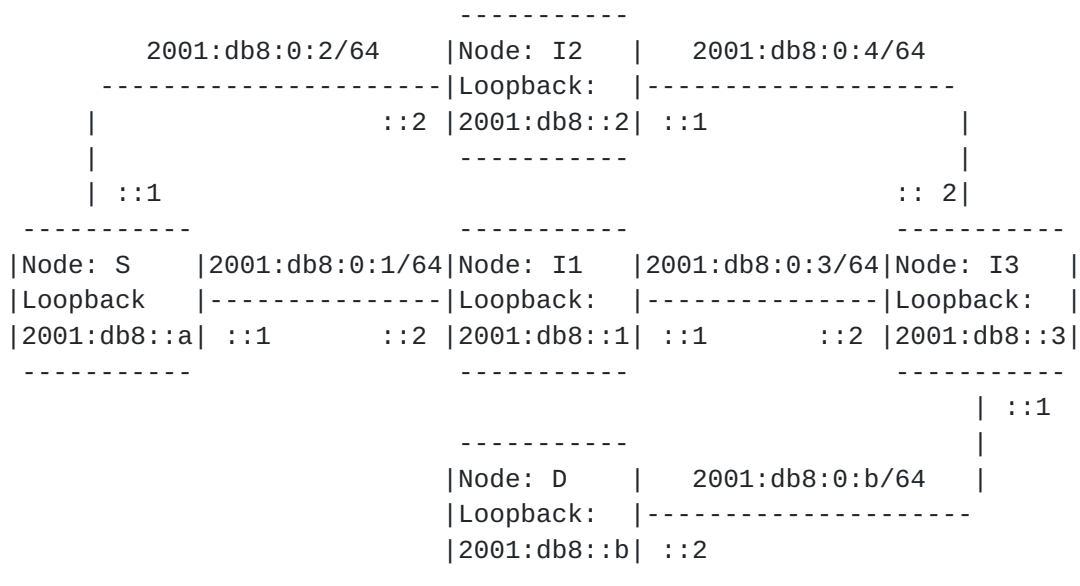


Figure 3: Reference Topology

Figure 3 provides a reference topology that is used in all examples.

Instantiating Node	SID	Segment Type	IPv6 Address
All	1	Node	2001:db8::1
All	2	Node	2001:db8::2
All	3	Node	2001:db8::3
All	10	Node	2001:db8::a
All	11	Node	2001:db8::b

Table 1: Node SIDs

Table 1 describes SFIB entries that are instantiated on all nodes. All of these SFIB entries represent node segments.

Instantiating Node	SID	IPv6 Address	Interface
S	129	2001:db8:0:1::2	S -> I1
S	130	2001:db8:0:2::2	S -> I2
I1	129	2001:db8:0:3::2	I1 -> I3
I2	129	2001:db8:0:4::2	I2 -> I3
I3	129	2001:db8:0:b::2	I3 -> D

Table 2: Adjacency SIDs

Table 2 describes SFIB entries that are instantiated on specific nodes. All of these SFIB entries represent adjacency segments.

[A.1.](#) SR Path Contains Node Segments Only

In this example, Node S sends a packet to Node D, though a node segment that terminates on I3. In this example, I3 does not appear in the CRH segment list. Therefore, the destination node may not be able to send return traffic through the same path.

As the packet travels from S to I3:	
Source Address = 2001:db8::a	Segments Left = 1
Destination Address = 2001:db8::3	SID[0] = 11

As the packet travels from S to I1:	
Source Address = 2001:db8::a	Segments Left = 2
Destination Address = 2001:db8:0:1::2	SID[0] = 129
	SID[1] = 129


```

+-----+-----+
| As the packet travels from I1 to I3: |
+-----+-----+
| Source Address = 2001:db8::a          | Segments Left = 1 |
| Destination Address = 2001:db8:0:3::2 | SID[0] = 129      |
|                                     | SID[1] = 129      |
+-----+-----+

+-----+-----+
| As the packet travels from I3 to D:   |
+-----+-----+
| Source Address = 2001:db8::a          | Segments Left = 0 |
| Destination Address = 2001:db8:0:b::2 | SID[0] = 129      |
|                                     | SID[1] = 129      |
+-----+-----+

```

Authors' Addresses

Ron Bonica
 Juniper Networks
 2251 Corporate Park Drive
 Herndon, Virginia 20171
 USA

Email: rbonica@juniper.net

Yuji Kamite
 NTT Communications Corporation
 3-4-1 Shibaura, Minato-ku
 Tokyo 108-8118
 Japan

Email: : y.kamite@ntt.com

Tomonobu Niwa
 KDDI
 3-22-7, Yoyogi, Shibuya-ku
 Tokyo 151-0053
 Japan

Email: to-niwa@kddi.com

Andrew Alston
Liquid Telecom
Nairobi
Kenya

Email: Andrew.Alston@liquidtelecom.com

Daniam Henriques
Liquid Telecom
Johannesburg
South Africa

Email: daniam.henriques@liquidtelecom.com

Ning So
Reliance Jio
3010 Gaylord PKWY, Suite 150
Frisco, Texas 75034
USA

Email: Ning.So@ril.com

Fengman Xu
Reliance Jio
3010 Gaylord PKWY, Suite 150
Frisco, Texas 75034
USA

Email: Fengman.Xu@ril.com

Gang Chen
Baidu
No.10 Xibeiwang East Road Haidian District
Beijing 100193
P.R. China

Email: phdgang@gmail.com

Yongqing Zhu
China Telecom
109 West Zhongshan Ave, Tianhe District
Guangzhou
P.R. China

Email: zhuyq.gd@chinatelecom.cn

Guangming Yang
China Telecom
109 West Zhongshan Ave, Tianhe District
Guangzhou
P.R. China

Email: yanggm.gd@chinatelecom.cn

Yifeng Zhou
ByteDance
Building 1, AVIC Plaza, 43 N 3rd Ring W Rd Haidian District
Beijing 100000
P.R. China

Email: yifeng.zhou@bytedance.com

