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J. Xie
Huawei Technologies
L. Geng
L. Wang
China Mobile
G. Yan
M. McBride
Y. Xia
Huawei

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Encapsulation for BIER in Non-MPLS IPv6 Networks
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Abstract

Bit Index Explicit Replication (BIER) introduces a new multicast-specific BIER Header. Currently BIER has two types of encapsulation formats: one is MPLS encapsulation, the other is Ethernet encapsulation. This document proposes a BIER IPv6 encapsulation for Non-MPLS IPv6 Networks using an IPv6 Destination Option extension header.

Requirements Language

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].

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1. Introduction

Bit Index Explicit Replication (BIER) [RFC8279] is an architecture that provides optimal multicast forwarding without requiring intermediate routers to maintain any per-flow state by using a multicast-specific BIER header. [RFC8296] defines two types of BIER encapsulation to run on physical links: one is BIER MPLS encapsulation to run on various physical links that support MPLS, the other is BIER Ethernet encapsulation to run on ethernet links, with an ethertype 0xAB37. This document proposes a BIER IPv6 encapsulation for Non-MPLS IPv6 Networks using an IPv6 Destination Option extension header.

2. Terminology

Readers of this document are assumed to be familiar with the terminology and concepts of the documents listed as Normative References.

3. Problem Statement and Requirements

3.1. Problem Statement

MPLS is a very popular and successful encapsulation. With MPLS encapsulation, packets forwarding can not only run on various physical links hop-by-hop, but also leverage the MPLS bypass tunnel to gain the "fast reroute" capability.

This same label benefit is also available for BIER by using an MPLS encapsulation. For example, an MPLS-encapsulated BIER packet can be forwarding on various physical links hop-by-hop, as well as on any MPLS bypass tunnels to support "fast reroute".

With a BIER Ethernet encapsulation, however, a packet can not be forwarded on any other type of links except for ethernet links in hop-by-hop case. It can not run on an MPLS bypass tunnel to support "fast reroute" either.

In an IPv6 network, there are considerations of using a non-MPLS encapsulation for unicast as the data-plane, such as SRH defined in [I-D.ietf-6man-segment-routing-header], where the function of a bypass tunnel uses an SRH header, with one or many Segments (or SIDs), instead of MPLS Labels. In such case, it is expected to have a BIER IPv6 encapsulation, which can run on IPv6 to be compliant with various kind of physical link in hop-by-hop case, as well as on SRH tunnel to have the significant benefit of "fast reroute" and so on.

3.2. Requirements

This chapter lists the BIER IPv6 encapsulation requirements needed to make the deployment of BIER on IPv6 network with SRH data-plane the same as on IPv4/IPv6 network with MPLS data-plane. These BIER IPv6 encapsulation requirements should provide similar benefits to MPLS encapsulation such as "fast reroute" or "run on any link or interface".

1. The listed requirements MUST be supported with any L1/L2 over which BIER layer can be realized.

2. It SHOULD support a hop-by-hop replication to multiple destinations in a BIER Domain.

3. It SHOULD support BIER on an "SRH tunnel".

4. It SHOULD align with the recommendations of the 6MAN working group.

4. IPv6 BIER Encapsulation

4.1. Considerations

BIER is generally a hop-by-hop and one-to-many architecture, and thus the IPv6 Destination Address (DA) being a Multicast Address is a proper approach for both the two diagrams in BIER IPv6 encapsulation. It is also required for a BIER IPv6 encapsulation to include the BIER Header ([RFC8296]) as an IPv6 Extension Header, to pilot the hop-by-hop BIER replication.

According to [RFC8200], [RFC6564], and [RFC7045], a new defined IPv6 extention header is not recommended, and an IPv6 Destination Option extension header is suitable and recommended for such a well-known BIER header as its Option.

4.2. IPv6 BIER Destination Option

The IPv6 BIER Destination Option is carried by the IPv6 Destination Option Header (indicated by a Next Header value 60). It is initialized in a packet sent by an IPv6 BFIR router to inform the following BFR routers in an IPv6 BIER domain to replicate to destination BFER routers hop-by-hop.

The IPv6 BIER Destination Option is encoded in type-length-value (TLV) format as follows:

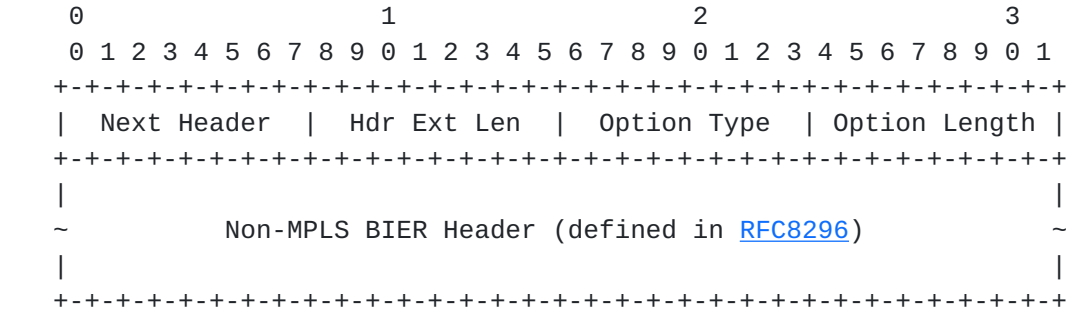


Figure 1: IPv6 BIER Destination Option

Next Header 8-bit selector. Identifies the type of header immediately following the Destination Options header.

Hdr Ext Len 8-bit unsigned integer. Length of the Destination Options header in 8-octet units, not including the first 8 octets.

Option Type TBD. Need to be allocated by IANA.

Option Length 8-bit unsigned integer. Length of the option, in octets, excluding the Option Type and Option Length fields.

Non-MPLS BIER Header The Non-MPLS BIER Header defined in RFC8296, including the BIFT-id. The function of TTL field is replaced by the Hop Limit field in IPv6 header and MUST be set to a non-zero value. The function of Entropy field is replaced by the Flow Label field in IPv6 header and MUST be set to zero value.

4.3. The whole IPv6 header for BIER packets

[RFC8200] specifies that the Destination Option Header can be located either before the Routing Header or after the Routing Header. However, this document requires that the Destination Option Header with a BIER Destination Option TLV is always located after the Routing Header if the Routing Header is present.

This is because the BIER header is always handled after the tunnels (or bypass tunnels) have been handled. BIER MPLS encapsulation has the same behavior. To quote [RFC8296]:

- It is crucial to understand that in an MPLS network the first four octets of the BIER encapsulation header are also the last four octets of the MPLS header. Therefore, any prior MPLS label stack entries MUST have the S bit (see [RFC3032]) clear (i.e., the S bit must be 0).

Other IPv6 extension headers are not commonly used in the current Internet. For Example, [RFC6744] says that "IPv6 Destination Options headers, and the options carried by such headers, are extremely uncommon in the deployed Internet". [RFC6564] says that "Extension headers, with the exception of the Hop-by-Hop Options header, are not usually processed on intermediate nodes", and that "Reports from the field indicate that some IP routers deployed within the global Internet are configured either to ignore the presence of headers with hop-by-hop behavior or to drop packets containing headers with hop-by-hop behavior."

Such IPv6 extension headers will even be more uncommon when a BIER encapsulation is used in data-plane forwarding. The entire IPv6 header, with BIER encapsulation and Routing Header, is expected to look like this:

IPv6 header [Multicast Address in DA]

Hop-by-Hop Options header [No use]

Destination Options header [No use]

Routing header [SRH Header may be used, Appendix A]

Fragment header [No use]

Authentication header [No use]

Encapsulating Security Payload header [No use]

Destination Options header [BIER header in BIER Option TLV]

Upper-layer header [BIER payload]

In a hop-by-hop BIER IPv6 replication scenario, there is only an IPv6 header with DA being a "BIER specific" Multicast address, and an IPv6 Destination Option header with a BIER destination option TLV.

BIER header has a 'proto' field to identify the type of BIER packet payload, and the IANA has created a registry called "BIER Next Protocol Identifiers" to assign the value. That means the 'Upper-layer header' of a BIER packet have already been identified by the 'proto' field of the BIER header in the Destination Option Header. Thus the 'Next Header' in the Destination Option Header is not need to identify the 'Upper-layer header' any more, and is recommended to be set to 'No Next Header (value 59)'.

Procedures for encapsulating a BIER IPv6 packet in SRH tunnel are outside the scope of this document.

Procedures for encapsulating a BIER IPv6 packet in other types of tunnels are outside the scope of this document.

5. IPv6 BIER Forwarding

In an IPv6 BIER domain, the Multicast Address of the IPv6 DA in an incoming BIER IPv6 packet indicates the BIER information of this 'host', and the packet will be forwarded according to the BIER Header in the BIER Destination Option TLV in the IPv6 Destination Option extension header. A router is required to ignore the IPv6 BIER Destination Option if the IPv6 Destination Address of a packet is not a multicast address, or is a multicast adddress without indicating the BIER information of this 'host'.

Below is the procedure that a BFR uses for forwarding a BIER IPv6 encapsulated packet.

1. Read the IPv6 header, get the the IPv6 DA, and get the indication of the multicast address if the IPv6 DA is a multicast address. The case when IPv6 DA not being a multicast address is outside the scope of this document.

2. If the multicast address is interested by this router, and the 'Next Header' of the IPv6 header indicates a IPv6 Destination Option Header, then read the IPv6 Destination Option Header, and get the BIER Option (BIER Header). The case when the multicast address not being interested by this router is outside the scope of this document.

3. The following steps are the same as step 1 to 9 described in chapter 6.5 in [RFC8279]. One difference need to point out is that, the copied packet includes a IPv6 header, a IPv6 Destination Header and its BIER Destination Option Type and Option Length before the BIER Header. If the copied packet is forwarded to a BFR-NBR, the 'Hop Limit' field of the IPv6 header MUST be decremented, whereas the TTL in the BIER header MUST be unchanged.

Procedures for forwarding a BIER IPv6 packet in SRH tunnel, and hand-off to a hop-by-hop replication, can refer to Appendix A.

Procedures for forwarding a BIER IPv6 packet in other types of tunnels, and hand-off to a hop-by-hop replication, are outside the scope of this document.

6. Security Considerations

An IPv6 BIER Destination Option with Multicast Address Destination would be used only when an IPv6 BIER state with the specific Multicast Address Destination has been built by the control-plane. Otherwise the packet with an IPv6 BIER Destination Option will be discarded.

7. IANA Considerations

Allocation is expected from IANA for a BIER Destination Option Type codepoint from the "Destination Options and Hop-by-Hop Options" sub-registry of the "Internet Protocol Version 6 (IPv6) Parameters" registry [RFC2780] at <https://www.iana.org/assignments/ipv6-parameters/>.

Allocation is expected from IANA for a BIER Multicast Address from the "Variable Scope Multicast Addresses" sub-registry of the "IPv6 Multicast Address Space Registry" registry at <https://www.iana.org/assignments/ipv6-multicast-addresses/>.

8. Acknowledgements

TBD.

9. Appendix A - BIER over IPv6 SRH Tunnel

In a Non-MPLS IPv6 Network, BIER may be deployed in a hop-by-hop manner, or possibly be deployed through an SRH tunnel either for "bypassing Non-capable BIER routers" or "fast rerouting". Here is an example where a packet is firstly forwarded through an SRH tunnel and then through a hop-by-hop BIER domain.

When a router along the Segment Routing path receives an IPv6 BIER packet with an SRH header, and if the IPv6 destination address is not one of the router's address, then the packet is forwarded by an IPv6 FIB lookup of the destination address and none of the IPv6 extension headers will be checked. If the IPv6 Destination Address is one of the router's address, and also one of the router's Segment (or SID) of some type, then the router will do a specific function indicated by the Segment, as defined in [I-D.filsfils-spring-srv6-network-programming]. If the IPv6 Destination Address is a specific type of Segment, called BIER Segment or BIER SID, then the according function is called Endpoint BIER function or 'End.BF' function for short.

When router receives a packet destined to X and X is a local End.BF SID, the router does:

```
1.    IF SL > 0
2.      decrement SL
3.      update IPv6 DA with SRH[SL]
4.      IF SL = 0 & STATE(SRH[0]) = BIER
5.        update IPv6 header NH with SRH NH
6.        pop the SRH
7.        forward the updated packet
8.      ELSE
9.        drop the packet
10.   ELSE
11.     drop the packet
```

Figure 2: End.BF Function

The End.BF function is used for the SRH tunnel destination router to terminate the source-routing SRH forwarding and begin the hop-by-hop BIER IPv6 forwarding. After the SRH header is popped, the multicast address in the updated IPv6 Destination Address indicates the BIER information of this 'host', and the packet will be forwarded according to the BIER Header in the BIER Destination Option TLV in the IPv6 Destination Option extension header of this 'host'.

In the following hop-by-hop forwarding procedure, the IPv6 Destination Address in an incoming packet indicates the BIER information of this 'host', and the packet will be forwarded according to the BIER Header in the BIER Destination Option TLV in the IPv6 Destination Option extension header. A router is required to ignore the IPv6 BIER Destination Option if the IPv6 Destination Address of a packet is not a multicast address, or is a multicast adddress without indicating the BIER information of this 'host'.

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Authors' Addresses

Jingrong Xie
Huawei Technologies

Email: xiejingrong@huawei.com

Liang Geng
China Mobile
Beijing 10053

Email: gengliang@chinamobile.com

Lei Wang
China Mobile
Beijing 10053

Email: wangleiyjy@chinamobile.com

Gang Yan
Huawei

Email: yangang@huawei.com

Mike McBride
Huawei

Email: mmcbride7@gmail.com

Yang Xia
Huawei

Email: yolanda.xia@huawei.com