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Encapsulation for BIER in Non-MPLS IPv6 Networks
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Abstract

This document proposes a BIER IPv6 (BIERv6) encapsulation for Non-MPLS IPv6 Networks using the 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](#)] and [[RFC8174](#)].

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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 a common BIER Header format for MPLS and Non-MPLS networks. It has defined two types of encapsulation methods using the common BIER Header, (1) BIER encapsulation in MPLS networks, here-in after referred as MPLS BIER Header in this document and (2) BIER encapsulation in Non-MPLS networks, here-in after referred as Non-MPLS BIER Header in this document. [[RFC8296](#)] also assigned

Ethertype=0xAB37 for Non-MPLS BIER Header packets to be directly carried over the Ethernet links.

This document proposes a BIER IPv6 encapsulation for Non-MPLS IPv6 Networks, defining a method to carry the standard Non-MPLS BIER header (as defined in [\[RFC8296\]](#)) in the native IPv6 header. A new IPv6 Option type - BIER Option is defined to encode the standard Non-MPLS BIER header and this newly defined BIER Option is carried under the Destination Options header of the native IPv6 Header [\[RFC8200\]](#).

This document details one of the proposed solutions for transporting BIER packets in an IPv6 network. To better understand the overall BIER IPv6 problem space, use cases and proposed solutions, refer to [\[I-D.ietf-bier-ipv6-requirements\]](#).

2. Terminology

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

The following new terms are used throughout this document:

- o BIERv6 - BIER IPv6.
- o BIER Option - An Option type carried in IPv6 Destination Options Header which includes the standard Non-MPLS BIER Header.
- o BIERv6 Header - An IPv6 Header with BIER Option.
- o BIERv6 Packet - An IPv6 packet with BIERv6 Header. Such an IPv6 packet typically carries the user multicast payload and is forwarded by BFRs in the BIERv6 network towards the multicast receivers.

3. BIER IPv6 Encapsulation

3.1. BIER Option in IPv6 Destination Options Header

Destination Options Header and the Options that can be carried under this extension header is defined in [\[RFC8200\]](#). This document defines a new Option type - BIER Option, to encode the Non-MPLS BIER header. As specified in [Section 4.2 \[RFC8200\]](#), the BIER Option follows type-length-value (TLV) encoding format and the standard Non-MPLS BIER header [\[RFC8296\]](#) is encoded in the value portion of the BIER Option TLV.

This BIER Option MUST be carried only inside the IPv6 Destination Options header and MUST NOT be carried under the Hop-by-Hop Options header.

Co-existence of Destination Options Header with BIER option TLV and other IPv6 extension headers MUST confirm to the general requirements defined in [RFC8200]. In addition to the requirements defined in [RFC8200], this document requires that the Destination Options Header with a BIER Option TLV MUST appear only after the Routing Header if the Routing Header is present in the IPv6 Header.

The BIER Option is encoded in type-length-value (TLV) format 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
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Next Header | Hdr Ext Len | Option Type | Option Length |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|
|           Non-MPLS BIER Header (defined in RFC8296)
|
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

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 To be allocated by IANA. See [section 6](#).

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](#). Fields in the Non-MPLS BIER Header MUST be encoded as below.

BIFT-id: The BIFT-id is a domain-wide unique value in Non-MPLS IPv6 encapsulation. See [Section 2.2 of RFC 8296](#).

TC: SHOULD be set to binary value 000 upon transmission and MUST be ignored upon. See [Section 2.2 of RFC 8296](#).

S bit: SHOULD be set to 1 upon transmission, and MUST be ignored upon reception. See [Section 2.2 of RFC 8296](#).

TTL: MUST be set to 0 upon transmission, and MUST be ignored upon reception. The function of TTL is replaced by the Hop Limit field in IPv6 header.

Nibble: SHOULD be set to 0000 upon transmission, and MUST be ignored upon reception. See [Section 2.2 of RFC 8296](#).

Ver: MUST be set to 0 upon transmission, and MUST be discarded when it is not 0 upon reception. See [Section 2.2 of RFC 8296](#).

BSL: See [Section 2.1.2 of RFC 8296](#).

Entropy: See [Section 2.1.2 of RFC 8296](#).

OAM: See [Section 2.1.2 of RFC 8296](#).

Rsv: See [Section 2.1.2 of RFC 8296](#).

DSCP: SHOULD be set to binary value 000000 upon transmission and MUST be ignored upon reception. In IPv6 BIER encapsulation, uses highest 6-bit of Traffic Class field of IPv6 header to hold a Differentiated Services Codepoint [[RFC2474](#)].

Proto: SHOULD be set to 0 upon transmission and MUST be ignored upon reception. In IPv6 BIER encapsulation, the functionality of this 6-bit Proto field is replaced by the Next Header field in Destination Options header, which is the last IPv6 extension header, to indicate the BIER payload, which is also IPv6 payload.

For BIER Proto 1, indicating a Downstream-assigned MPLS payload, use Next Header value 137.

For BIER Proto 2, indicating an Upstream-assigned MPLS payload, there is no Next Header code currently. An upstream-assigned MPLS label within the context of special BFIR router, which in turn is represented by the BFIR-id and the Sub-domain indirectly indicated by the BIFT-id in a BIER-MPLS or BIER-ETH packet, can be replaced by an IPv6 source address in a BIER IPv6 encapsulation packet in a direct manner. In this case, use Next Header value 4 for IPv4 payload, or value 41 for IPv6 payload.

For BIER Proto 3, indicating an Ethernet payload, use Next Header value 97.

For BIER Proto 4, indicating an IPv4 payload, use Next Header value 4.

For BIER Proto 5, indicating a BIER-OAM payload, use Next Header value 58. How the BIER-PING is supported with BIER IPv6 encapsulation is outside the scope of this document.

For BIER Proto 6, indicating an IPv6 payload, use Next Header value 41.

BFIR-id: See [Section 2.1.2 of RFC 8296](#).

BitString: See [Section 2.1.2 of RFC 8296](#).

3.2. Multicast and Unicast Destination Address

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 way one may think of as an approach for both the two paradigms in BIERv6 encapsulation.

However using a unicast address has the following benefits:

1. Tunneling a BIERv6 packet over a non-BIER capable router.
2. Fast rerouting a BIERv6 packet using a unicast by-pass tunnel.
3. Forwarding a BIERv6 packet to one of the many BFR neighbors connected on a LAN.
4. Connecting BIER domains, for example Data Center domains, in an overlay manner.

Some of the above functions are assumed very basic requirements and part of BIER architecture as described in [[RFC8279](#)]. This document uses unicast address for both one-hop replication and multi-hop replication.

The unicast address used in BIERv6 packet targeting a BFR SHOULD be the IPv6 BFR-Prefix advertised from this BFR. When a BFR advertises the BIER information with BIERv6 encapsulation capability, the IPv6 BFR-prefix of this BFR MUST be selected specifically for BIERv6 packet forwarding. Locally this "BIER Specific" IPv6 address is initialized in FIB with a flag of "BIER specific handling", represented as End.BIER function. For convenience, the indication in FIB share the same space as SRv6 Endpoints Behaviors defined in [[I-D.ietf-spring-srv6-network-programming](#)]. Apart from this sharing

of code space, there is nothing dependent on SRv6. The co-existence of BIERv6 and SRv6 is outside the scope of this document.

BFR Prefix is used only in control plane in BIER MPLS encapsulation but not used in data plane. While in BIERv6, BFR prefix is used in both control plane and data plane. For the convenience of migration to BIERv6, it is RECOMMENDED to use an "exclusive" IPv6 address as BFR prefix when deploying BIER-MPLS in IPv6 networks. The "exclusive" IPv6 address should not be used for general purpose like BGP session establishment, but for "BIER specific" function. For Non-BIER IPv6 routers, the IPv6 address is a regular IPv6 prefix reachable through IPv6 unicast routing.

The following is an example of configuring a BIER specific IPv6 address and using this address as BFR prefix:

```
# Config a BIER specific IPv6 address with 128-bit mask on loopback0.
interface loopback0
    ipv6 address 2001:DB8::AB37 128 End.BIER

# Config the BIER-specific IPv6 address on loopback0 as BFR Prefix.
bier sub-domain 6 ipv6-underlay
bfr-prefix interface loopback0
```

The address used as "BIER specific" IPv6 address can be from inside the scope of an SRv6 Locator or outside the scope of the SRv6 Locator(s) since it is a host prefix (128-bit prefix-length prefix).

Each "BIER specific" address can be used in one or many sub-domains as BFR-prefix, such that it can be associated with one or many Multi-Topologies (MTs) or algorithms.

More than one "BIER specific" address are also allowed as different BFR-prefix of more than one sub-domain, as described in [section 2 of \[RFC8279\]](#).

The following is an example pseudo-code of the End.BIER function:

```
1. IF NH = 60 and HopLimit > 0 ;;Ref1
2.   IF (OptType1 = BIER) and (OptLength1 = HdrExtLen*8 + 4) ;;Ref2
3.     Lookup the BIER Header inside the BIER option TLV.
4.     Forward via the matched entry.
5.   ELSE ;;Ref3
6.     Drop the packet and end the process.
7. ELSE IF NH=ICMPv6 or (NH=60 and Dest_NH=ICMPv6) ;;Ref4
8.   Send to CPU.
9. ELSE ;;Ref5
10.  Drop the packet.
```


Ref1: Destination options header follows the IPv6 header directly and HopLimit is bigger than zero.

Ref2: The first TLV is BIER type and is the only TLV present in Destination options header.

Ref3/Ref5: Undesired packet is dropped because the destination address is the BIER specific IPv6 address (End.BIER function).

Ref4: An ICMPv6 packet using End.BIER as destination address.

3.3. BIERv6 Packet Format

As a multicast packet enters the BIER domain in a Non-MPLS IPv6 network, the multicast packet will be encapsulated with BIERv6 Header.

Typically a BIERv6 header would contain the Destination Options Header as the only Extensions Header besides IPv6 Header. However, it is allowed and possible for other extension headers to appear along with the Destination Options Header as long as the requirements listed in [section 3.1](#) of this document is met.

Format of the multicast packet with BIERv6 encapsulation carrying only the Destination Options header is depicted in the below figure.

```

+-----+-----+-----+
| IPv6 header | Dest Options | X type of
|             | Header with  | multicast
|             | BIER Option  | packet
|             |             |
| Next Hdr = 60 | Nxt Hdr = X |
+-----+-----+-----+

```

Format of the multicast packet with BIERv6 encapsulation carrying other extension headers along with Destination Options extension header is required to follow general recommendations of [\[RFC8200\]](#) and examples in other RFCs. [\[RFC6275\]](#) introduces how the order should be when other extension headers carries along with Home address option in a destination options header. Similar to this example, this document requires the Destination Options Header carrying the BIER option MUST be placed as follows:

- o After the routing header, if that header is present
- o Before the Fragment Header, if that header is present

- o Before the AH Header or ESP Header, if either one of those headers is present

Source Address field in the IPv6 header MUST be a routable IPv6 unicast address of the BFIR in any case.

BFIR encodes the Non-MPLS BIER header in the above mentioned encapsulation format and forwards the BIERv6 packet to the nexthop BFR following the local BIFT table.

BFRs in the IPv6 network, processes and replicates the packets towards the BFRs using the local BIFT table. The bit-string field in the Non-MPLS BIER header may be changed by the BFRs as they replicate the packet. BFRs MUST follow the procedures defined in [section 3.1](#) as they modify the other fields in the Non-MPLS BIER header. The source address in the IPv6 header MUST NOT be modified by the BFRs.

4. BIERv6 Packet Processing

There is no BIER-specific processing, and all the 8 steps in [section 6.5 of RFC8279](#) apply to BIERv6 packet processing. However, there are some IPv6-specific processing procedures due to the base and general procedures of IPv6.

On the overlay layer, when a multicast packet enters the BIER domain in a Non-MPLS IPv6 network, the Ingress BFR (BFIR) encapsulates the multicast packet with a BIERv6 Header, transforming it to a BIERv6 packet. The BIERv6 header includes an IPv6 header and IPv6 Destination Options Header within a standard Non-MPLS BIER header. Source Address field in the IPv6 header MUST be set to a routable IPv6 unicast address of the BFIR. Destination Address field in the IPv6 header is set to the BFR prefix of the next-hop BFR the BIERv6 packet replicating to, no matter next-hop BFR is directly connected (one-hop) or not directly connected (multi-hop).

On the BIER layer, upon receiving an BIERv6 packet, the BFR processes the IPv6 header first. This is the general procedure of IPv6.

If the IPv6 Destination address is an IPv6 BFR-Prefix unicast address of this BFR, a 'BIER Specific Handling' indication will be obtained by the preceding Unicast DA lookup (FIB lookup). The BIER option, if exists, will be checked to decide which neighbor(s) to replicate the BIERv6 packet to.

It is a local behavior to handle the combination of extension headers, options and the BIER option(s) in destination options header when a 'BIER Specific Handling' indication is got by the preceding

FIB lookup. Early deployment of BIERv6 may require there is only one BIER option TLV in the destination options header followed the IPv6 header. How other extension headers or more BIER option TLVs in a BIERv6 packet is handled is outside the scope of this document.

A packet having a 'BIER Specific Handling' indication but not having a BIER option is supposed to be a wrong packet or an ICMPv6 packet, and the process can be referred to the example in [section 3.2](#).

A packet not having a 'BIER Specific Handling' indication but having a BIER option SHOULD be processed normally as unicast forwarding procedures, which may be a behavior of drop, or send to CPU, or other behaviors in existing implementations.

The Destination Address field in the IPv6 Header MUST change to the nexthop BFR's BFR Prefix if Unicast address is used in BIERv6.

The Hop Limit field of IPv6 header MUST decrease by 1 when sending packets to a BFR neighbor, while the TTL in the BIER header MUST be unchanged.

The BitString in the BIER header in the Destination Options Header may change when sending packets to a neighbor. Such change of BitString MUST be aligned with the procedure defined in [RFC8279](#). Because of the requirement to change the content of the option when forwarding BIERv6 packet, the BIER option type should have chg flag 1 per [section 4.2 of RFC8200](#).

The procedures applies normally if a bit corresponding to the self bfr-id is set in the bit-string field of the Non-MPLS BIER header of the BIERv6 packet. The node is considered to be an Egress BFR (BFER) in this case. The BFER removes the BIERv6 header, including the IPv6 header and the Destination Options header, and copies the packet to the multicast flow overlay. The egress VRF of a packet may be determined by a further lookup on the IPv6 source address instead of the upstream-assigned MPLS Label as described in [\[RFC8556\]](#).

The Fragment Header, AH Header or ESP Header, if exists after the BIER options header, can be processed on BFER only as part of the multicast flow overlay process.

5. Security Considerations

A BIERv6 packet with a special IPv6 Destination Address, the BFR prefix functioning as End.BIER, would be processed by BIER forwarding procedure only when the 'BIER Specific Handling' flag has been obtained ahead in the FIB lookup of the IPv6 header. Otherwise the packet with an IPv6 BIER Option will not be processed by the

procedure but be processed as normal IPv6 packet. A possible way of handling IPv6 packets with extension may be send to CPU for slow path processing.

6. IANA Considerations

6.1. BIER Option Type

Allocation is expected from IANA for a BIER Option Type codepoint from the "Destination Options and Hop-by-Hop Options" sub-registry of the "Internet Protocol Version 6 (IPv6) Parameters" registry. The value 0x70 is suggested.

Hex Value	act	chg	rest	Description	Reference
0x70	01	1	10000	BIER Option	This draft

6.2. End.BIER Function

Allocation is expected from IANA for an End.BIER function codepoint from the "SRv6 Endpoint Behaviors" sub-registry. The value 60 is suggested.

Value	Hex	Endpoint function	Reference
TBD	TBD	End.BIER	This draft

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