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A 6LoRH for BitStrings
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Abstract

This specification extends the 6LoWPAN Routing Header to signal BitStrings such as utilized in Bit Index Explicit Replication and its Traffic Engineering variant.

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[1.](#) Introduction

The type of information that needs to be present in a packet inside the LLN but not outside of the LLN varies with the routing operation, but there is overall a need for an extensible compression technique that would simplify the IP-in-IP encapsulation, when needed, and optimally compress existing routing artifacts found in LLNs.

The 6LoWPAN Routing Header (6LoRH) [[RFC8025](#)] [[RFC8138](#)] is such a technique, that extends the 6lo adaptation layer framework [[RFC4944](#)], [[RFC6282](#)] so as to carry routing information for Route-over use cases. The original specification includes the formats necessary for RPL such as the Source Route Header (SRH) and is intended to be extended for additional routing artifacts.

The Bit Index Explicit Replication (BIER), as introduced in the BIER Architecture [[RFC8279](#)], can be used as an alternate artifact to route multicast as well as unicast traffic. The Traffic Engineering for Bit Index Explicit Replication [[I-D.eckert-bier-te-arch](#)] (BIER-TE) adds support for traffic engineering by explicit hop-by-hop forwarding and loose hop forwarding of packets along a unicast route.

This specification provides additional formats for the 6LoRH compression to carry BitStrings such as used for Bit Index Explicit Replication and its Traffic Engineering variant (BIER and BIER-TE, respectively).

[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 [\[RFC2119\]](#).

The Terminology used in this document is consistent with and incorporates that described in Terms Used in Routing for Low-Power and Lossy Networks (LLNs). [\[RFC7102\]](#).

Other terms in use in LLNs are found in Terminology for Constrained-Node Networks [\[RFC7228\]](#).

The term "byte" is used in its now customary sense as a synonym for "octet".

"RPL", "RPL Packet Information" (RPI) and "RPL Instance" are defined in the RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks [\[RFC6550\]](#) specification.

The terms Bit-Forwarding Egress Routers (BFR), BFR-id and BitString are defined in [\[RFC8279\]](#). A BitString indicates a continuous sequence of bits indexed by an offset in the sequence. The leftmost bit is bit 0 and corresponds to the value 0x80 of the leftmost octet in the BitString.

[3.](#) Applicability

BIER and other bit-indexed methods that would leverage BitStrings will generally require additional information in the packet to complement the BitString. For instance, BIER has the concept of a BFR-id and an Entropy value in the BIER header. Since those additional fields depend on the bit-indexed method, they are expected to be transported separately from the BitString. This specification concentrates on the BitString and a group identifier which enables a

network to grow beyond the size of one bitString.

Within the context of "the Deterministic Networking (DetNet) Architecture" [[I-D.ietf-detnet-architecture](#)]), the "BIER-TE-based OAM, Replication and Elimination" [[I-D.thubert-bier-replication-elimination](#)] document details how BIER-TE can be leveraged to activate the Deterministic Networking Replication and Elimination functions in a manner that is abstract to the data plane forwarding information. An adjacency, which is represented by a bit in the BIER header, can be mapped in the data plane to an Ethernet hop, a Label Switched Path, or it may correspond to a loose or a strict IPv6 Source Routed Path.

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In the context of LLNs, the 6TiSCH Architecture [[I-D.ietf-6tisch-architecture](#)] introduces the concept of a Track that is a directional traffic-engineered path between a source and a destination. A Track is indicated in a packet by a Source or Destination IPv6 Address and a RPL Local Instance. The RPL Instance is carried in an IPv6 packet as part of the RPL Packet Information (RPI), and a bit in the RPI indicates whether the Instance is Local to the Source or the Destination Address. The RPI can be compressed as a RPI 6LoRH header (RPI-6LoRH) as described in [[RFC8138](#)].

The 6TiSCH requirements for DetNet [[I-D.thubert-6tisch-4detnet](#)] indicate that a 6TiSCH Track may leverage replication and elimination as defined in DetNet. This specification enables this behavior as follows: if a BIER-6LoRH is positioned right after a RPI-6LoRH, then the BitString in the BIER-6LoRH applies to the context of the Track indicated by the source or destination address of the packet and the local Instance ID associated to the source or destination of the packet.

[4.](#) The BIER-6LoRH encoding

The BIER 6LoRH (BIER-6LoRH) is a Critical 6LoWPAN Routing Header that provides a variable-size container for a BitString such as, a but not limited to, a BIER BitString.

The capability to parse the BIER BitString is necessary to forward the packet so the Type cannot be ignored.

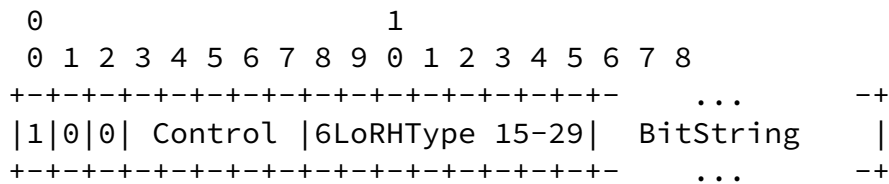


Figure 1: The BIER-6LoRH

This specification provides a 5-bit Control field that can be used to encode information that is specific to the BitString. The type and size of the BitString are encoded in the 6LoRHType.

[4.1.](#) The Bit-by-bit BitStrings

In the bit-by-bit case, each bit is mapped in an unequivocal fashion with a single addressable resource in the network. This may rapidly lead to large BitStrings, and BIER allows to divide a network into groups that partition the network so that a given BitString is

locally significant to one group only. This specification uses the 5-bits Control field to encode the group.

When groups are used, it may be that a packet is sent to different groups at the same time. In that case, multiple BIER-6LoRH headers can be prepended to a same packet, each one for a different group. As the packet flows along the multicast distribution tree, a BIER-6LoRH header that has no more destination in a given branch may be removed to make the packet shorter.

The encoding value indicates the size of the BitString. The size of the BitString used in a given packet is smallest that can represent all of the bits that are set for this particular packet, so for a same network various sizes may be used for different packets depending on the destinations.

[4.2.](#) The Enumeration BitStrings

For unicast and when very few destinations are targeted for a given message, it may be that it is more economical to list the bit offsets one by one than it is to represent the full BitString that can hold all of the bit offsets.

In the Enumeration case, a BitString actually encodes the offset of one bit as an unsigned integer, using the number of bits indicated in the control field, and BitStrings are concatenated without intermediate padding. The overall concatenation must be aligned to a byte boundary. To achieve this, trailing bits are added to the right of the concatenation as padding to the next byte boundary.

To optimize the compression, the lower numbers can be expressed with less bits, and multiple Enumeration BIER-6LoRH headers may be used to encode offsets that require different numbers of bits for their representation.

[4.3.](#) Bloom Filters

A Bloom Filter can be seen as an additional compression technique for the bitString representation. A Bloom Filter may generate false positives, which, in the case of BIER, result in undue forwarding of a packet down a path where no listener exists.

As an example, the Constrained-Cast [[I-D.ietf-roll-ccast](#)] specification employs Bloom Filters as a compact representation of a match or non-match for elements in a set that may be larger than the number of bits in the BitString.

In the case of a Bloom Filter, a number of Hash functions must be run to obtain a multi-bit signature of an encoded element. This specification uses the 5-bits Control field to signal an Identifier of the set of Hash functions being used to generate a certain BitString, so as to enable the migration from a set of Hash functions to the next.

[4.4.](#) Types of BIER-6LoRH header

The Type of a BIER-6LoRH header indicates the size of the BitString and whether the BitString is operated as an uncompressed bit-by-bit mapping, as an enumeration, or as a Bloom filter.

BitString Type	Encoding	Control field	BitString Size
15	bit-by-bit	Group ID	8 bits
16	bit-by-bit	Group ID	16 bits

	17		bit-by-bit		Group ID		32 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	18		bit-by-bit		Group ID		56 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	19		bit-by-bit		Group ID		96 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	20		bit-by-bit		Group ID		160 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	21		bit-by-bit		Group ID		256 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	22		Enumeration		Number of elements		4 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	23		Enumeration		Number of elements		6 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	24		Enumeration		Number of elements		8 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	25		Bloom filter		Hash function Set ID		8 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	26		Bloom filter		Hash function Set ID		16 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	27		Bloom filter		Hash function Set ID		48 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	28		Bloom filter		Hash function Set ID		96 bits	
+-----+		+-----+		+-----+		+-----+		+-----+
	29		Bloom filter		Hash function Set ID		160 bits	
+-----+		+-----+		+-----+		+-----+		+-----+

Table 1: The BIER-6LoRH Types

In order to address a potentially large number of devices, the BitString may grow very large. Yet, the maximum frame size for a given MAC layer may limit the number of bits that can be dedicated to routing. With this specification, a number of BIER-6LoRH headers of a same type (bit-by-bit or Bloom filter) may be placed contiguously in the packet. This results in a larger BitString that is the concatenation of the BitStrings in the individual headers in the order they are appearing in the packet.

A research-stage implementation was developed at Cisco's Paris Innovation Lab (PIRL) by Zacharie Brodard. It was implemented on OpenWSN open-source firmware and tested on the OpenMote-CC2538 hardware. It implements the header types 15, 16, 17, 18 and 19 (bit-by-bit encoding without group ID) in order to allow a BIER-TE protocol over IEE802.15.4e.

Links:

github: <https://github.com/zach-b/openwsn-fw/tree/BIER>

OpenWSN firmware: <https://openwsn.atlassian.net/wiki/pages/viewpage.action?pageId=688187>

OpenMote hardware: <http://www.openmote.com/>

6. Security Considerations

The security considerations of [[RFC8138](#)] apply.

7. IANA Considerations

This document extends the IANA registry created by [[RFC8138](#)] for the 6LoWPAN Routing Header Type, and adds the following values:

15..29 : BIER-6LoRH [[RFCthis](#)]

8. Acknowledgments

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