A 6loRH for BitStrings
draft-thubert-6lo-bier-dispatch-05

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 [I-D.ietf-bier-architecture], 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 [I-D.ietf-bier-architecture]. 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.

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.

```
    0                   1
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-     ...      -+
   |1|0|0| Control |6LoRHType 15-29|  BitString    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-     ...      -+
```
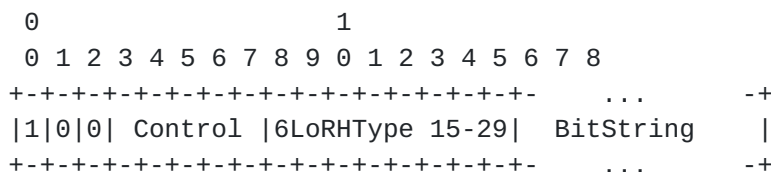
                        Figure 1: The BIER-6LoRH

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    |  Encoding   |    Control field    |  BitString  |
|   Type       |             |                     |    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.

5. Implementation Status

   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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