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A 6loRH for BitStrings
draft-thubert-6lo-bier-dispatch-00

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 [I-D.ietf-roll-routing-dispatch] (6LoRH)
specification 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 alone.

The DetNet Data Plane Protocol and Solution Alternatives
[I-D.dt-detnet-dp-alt] 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
[I-D.ietf-roll-routing-dispatch].

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 15-19|  BitString    |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-   ...      -+
```
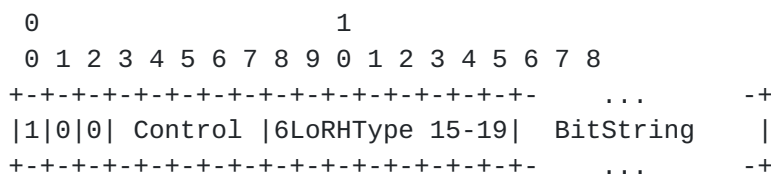
                   Figure 1: The BIER-6LoRH

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.

4.2. Bloom Filters

A Bloom Filter can be seen as a compression technique for the
BitString. 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.bergmann-bier-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.

4.3. Types of BIER-6LoRH header

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

```
+---------+-------------+----------------------+----------------+
|  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       |       64 bits  |
|   19    | bit-by-bit  |       Group ID       |      128 bits  |
+---------+-------------+----------------------+----------------+
|   20    | Bloom filter | Hash function Set ID |        8 bits  |
|   21    | Bloom filter | Hash function Set ID |       16 bits  |
|   22    | Bloom filter | Hash function Set ID |       32 bits  |
|   23    | Bloom filter | Hash function Set ID |       64 bits  |
|   24    | Bloom filter | Hash function Set ID |      128 bits  |
+---------+-------------+----------------------+----------------+
```

Figure 2: 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 implementation was developed at Cisco's Paris Innovation
Lab (PIRL) by Zacharie Brodard.

The implementation is based on openWSN
(https://openwsn.atlassian.net/wiki/pages/
viewpage.action?pageId=688187), and was tested on OpenMote hardware
(http://www.openmote.com/).

The implementation covers 6LoRH Types 15 to 18 for 6TiSCH Tracks, and
does not attempt to support Bloom Filters.

6. Security Considerations

The security considerations of [I-D.ietf-roll-routing-dispatch]
apply.

7. IANA Considerations

This document extends the IANA registry created by
[I-D.ietf-roll-routing-dispatch] for the 6LoWPAN Routing Header Type,
and adds the following values:

    15..24 : BIER-6LoRH [RFCthis]

8. Acknowledgments

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