A compression mechanism for the RPL option
draft-thubert-6lo-rpl-nhc-01

Abstract

   This document proposes a compression mechanism for the RPL option.
   This operation saves up to 48 bits in each frame compared to RFC
   6553.

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   provisions of BCP 78 and BCP 79.

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1. Introduction

   The emergence of radio technology enabled a large variety of new
   types of devices to be interconnected, at a very low marginal cost
   compared to wire, at any range from Near Field to interplanetary
   distances, and in circumstances where wiring would be less than
   practical, for instance rotating devices.

   In particular, IEEE802.14.5 [IEEE802154] that is chartered to specify
   PHY and MAC layers for radio Lowpower Lossy Networks (LLNs), defined
   the TimeSlotted Channel Hopping [I-D.ietf-6tisch-tsch] (TSCH) mode of
   operation as part of the IEEE802.15.4e MAC specification in order to
   address Time Sensitive applications.

   The 6TiSCH architecture [I-D.ietf-6tisch-architecture] specifies
   the operation IPv6 over TSCH wireless networks attached and
   synchronized by backbone routers.

   With 6TiSCH, the route Computation may be achieved in a centralized
   fashion by a Path Computation Element (PCE), in a distributed fashion
   using the Routing Protocol for Low Power and Lossy Networks
   [RFC6550] (RPL), or in a mixed mode.

   6TiSCH was created to simplify the adoption of IETF technology by
   other Standard Defining Organizations (SDOs), in particular in the
   Industrial Automation space, which already relies on variations of
   IEEE802.15.4e TSCH for Wireless Sensor Networking.

   ISA100.11a [ISA100.11a] (now IEC62734) is an example of such
   industrial WSN standard, using IEEE802.15.4e over the classical
   IEEE802.14.5 PHY. In that case, after security is applied, roughly 80
   octets are available per frame for IP and Payload. In order to 1)
   avoid fragmentation and 2) conserve energy, the SDO will scrutinize
   any bit in the frame and reject any waste.

   The challenge to obtain the adoption of IPv6 in the original standard
   was really to save any possible bit in the frames, including the UDP
   checksum which was an interesting discussion on its own. This work
   was actually one of the roots for the 6LoWPAN Header Compression
   [RFC6282] work, which goes down to the individual bits to save space

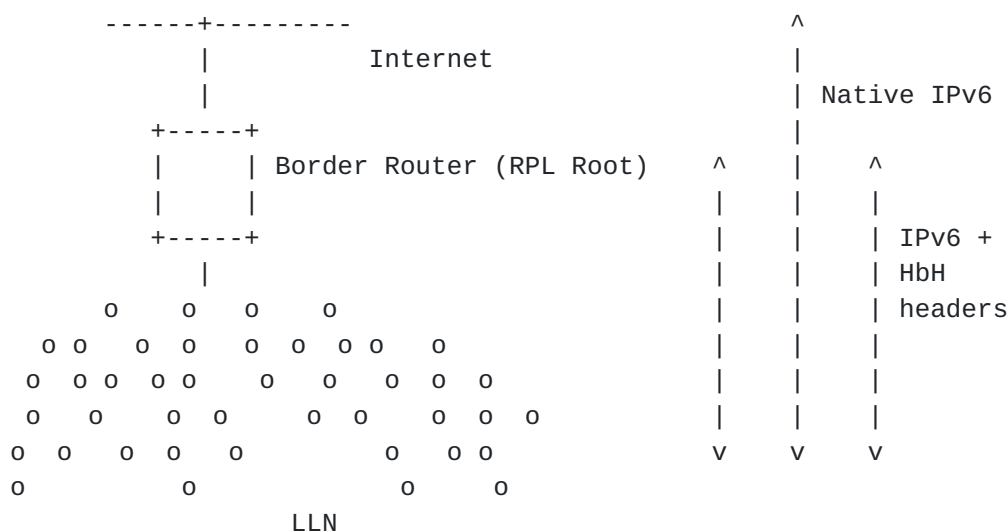in the frames for actual data, and allowed ISA100.11a to adopt IPv6.

In order to get an SDO such as ISA100 to adopt RPL and 6TiSCH, it is mandatory to maintain the same degree to requirement and maximize the compression of all possible protocol information, and in particular the overhead that RPL imposes on all packets.

2. **On Wasted Resources**

   The design of Lowpower Lossy Networks is generally focussed on saving
   energy, which is the most constrained resource of all. The other
   constraints, such as the memory capacity and the duty cycling of the
   LLN devices, derive from that primary concern. Energy is typically
   available from batteries that are expected to last for years, or
   scavenged from the environment in very limited quantities. Any
   protocol that is intended for use in LLNs must be designed with the
   primary concern of saving energy as a strict requirement.

   The Routing Protocol for Low Power and Lossy Networks (RPL)
   [RFC6550] specification defines a generic Distance Vector protocol
   that is indeed designed for very low energy consumption and adapted
   to a variety of LLNs. RPL forms Destination Oriented Directed
   Acyclic Graphs (DODAGs) which root often acts as the Border Router to
   connect the RPL domain to the Internet. The root is responsible to
   select the RPL Instance that is used to forward a packet coming from
   the Internet into the RPL domain and set the related RPL information
   in the packets.

   A classical RPL implementation will use the RPL Option for Carrying
   RPL Information in Data-Plane Datagrams [RFC6553] to tag a packet
   with the Instance ID and other information that RPL requires for its
   operation within the RPL domain. In particular, the Rank, which is
   the scalar metric computed by an specialized Objective Function such
   as [RFC6552], is modified at each hop and allows to validate that the
   packet progresses in the expected direction each upwards or downwards
   in along the DODAG.

```
            ------+---------                          ^
               |          Internet                    |
               |                                       | Native IPv6
          +-----+                                      |
          |     | Border Router (RPL Root)    ^    |    ^
          |     |                             |    |    |
          +-----+                             |    |    | IPv6 +
             |                                |    |    | HbH
        o    o   o    o                       |    |    | headers
      o o   o  o   o o  o o    o              |    |    |
      o  o o  o o    o    o    o  o  o         |    |    |
       o   o    o  o       o o     o  o  o     |    |    |
      o o   o  o   o            o    o o       v    v    v
       o          o                o     o
                   LLN
```

With [RFC6553], the RPL option is encoded as 6 Octets; it must be placed in a Hop-by-Hop header that represents 2 additional octets for a total of 8. In order to limit its range to the inside the RPL domain, the Hop-by-Hop header must be added to (or removed from) packets that cross the border of the RPL domain. For reasons such as the capability to send ICMP errors back to the source, this operation involves an extra IP-in-IP encapsulation inside the RPL domain for all the packets which path is not contained within the RPL domain.

The 8-octets overhead is detrimental to the LLN operation, in particular with regards to bandwidth and battery constraints. These octets may cause a containing frame to grow above maximum frame size, leading to Layer 2 or 6LoWPAN [RFC4944] fragmentation, which in turn cause even more energy spending and issues discussed in the LLN Fragment Forwarding and Recovery [I-D.thubert-6lo-forwarding-fragments].

Considering that, in the classical IEEE802.14.5 PHY that is used by 6TiSCH, roughly 80 octets are available per frame after security is applied, and any additional transmitted bit weights in the energy consumption and drains the batteries.

For timing reasons, [RFC6282] failed to provide an adapted compression for the RPL option so the cost in current implementations can not be alleviated in any fashion. This document provides thus the much-needed efficient compression of the RPL option as a logical extension to [RFC6282].

3. Terminology

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].

The Terminology used in this document is consistent with and incorporates that described in `Terminology in Low power And Lossy Networks' [RFC7102] and [RFC6550].

4. Updating RFC 6282

This specification proposes a new 6LoWPAN Next Header Compression (NHC) for the RPL option [RFC6553], called RPL_NHC, to be placed in an [RFC6282]-compressed packet.

It updates [RFC6282] in that the necessary property of encoding headers using LOWPAN_NHC becomes that the immediately preceding header must be encoded using either LOWPAN_IPHC, RPL_NHC or LOWPAN_NHC.

Additionally, the necessary property of encoding headers using
RPL_NHC is that the immediately preceding header must be encoded
using either LOWPAN_IPHC or LOWPAN_NHC.

5. New RPL Next Header Compression

[RFC6550] section 11.2 specifies the RPL information as a set of
fields that are to be placed into the packets for the purpose of
Instance Identification, as well as Loop Avoidance and Detection.
Those fields include an 'O', an 'R' and an 'F' bits, a 8-bit
RPLInstanceID, which is in fact an encoded structure, and a 16-bit
SenderRank.

The SenderRank is the result of the DAGRank operation on the rank of
the sender, here the DAGRank operation is defined in section 3.5.1
as:

   DAGRank(rank) = floor(rank/MinHopRankIncrease)

If MinHopRankIncrease is set to a multiple of 256, it appears that
the least significant 8 bits of the SenderRank will be all zeroes and
can be elided, in which case the SenderRank can be compressed into
one octet. This idea is leveraged in [RFC6552] that uses a
MinHopRankIncrease of 256 by default.

[RFC6553] defines an encoding for the RPL information as a RPL option
located in a Hop-by-hop header. The RPL_NHC provides a compressed
form for that the RPL information and is constructed as follows:

```
    0   1   2   3   4   5   6   7
  +---+---+---+---+---+---+---+---+
  | 1 | 0 | I | K | O | R | F |NH |
  +---+---+---+---+---+---+---+---+
```

The RPL_NHC is immediately followed by the RPLInstanceID, unless it
is elided, and then the SenderRank, which is either compressed into
one octet or fully inlined as the whole 2 octets. Bits in the
RPL_NHC indicate whether the RPLInstanceID is elided and/or the
SenderRank is compressed:

O, R, and F bits The O, R, and F bits are defined in [RFC6550]
        section 11.2.

NH: 1-bit. The Next Header (NH) bit is defined in [RFC6282]
        section 4.2, and it is set to indicate that the next header is
        encoded using LOWPAN_NHC

I: 1-bit. If it is set, the Instance ID is elided and the
        RPLInstanceID is the Global RPLInstanceID 0. If it is not set,
        the octet immediately following the RPL_NHC contains the
        RPLInstanceID as specified in [RFC6550] section 5.1.

K: 1-bit. If it is set, the SenderRank is be compressed into one
        octet, and the lowest significant octet is elided. If it is
        not set, the SenderRank, is fully inlined as 2 octets.

In the following case, the RPLInstanceID is the Global RPLInstanceID
0, and the MinHopRankIncrease is a multiple of 256 so the least
significant octet is all zeroes and can be elided:

```
      0                   1
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|0|1|1|O|R|F|N|  SenderRank   |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In the following case, the RPLInstanceID is the Global RPLInstanceID
0, but both octets of the SenderRank are significant so it can not be
compressed:

```
      0                   1                   2
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|0|1|0|O|R|F|N|       SenderRank              |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In the following case, the RPLInstanceID is not the Global
RPLInstanceID 0, and the MinHopRankIncrease is a multiple of 256:

```
      0                   1                   2
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|0|0|1|O|R|F|N| RPLInstanceID |  SenderRank   |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

In the following case, the RPLInstanceID is not the Global
RPLInstanceID 0, and both octets of the SenderRank are significant:

```
      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
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
     |1|0|0|0|O|R|F|N| RPLInstanceID |        SenderRank             |
     +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Depending on the RPLInstanceID and the MinHopRankIncrease, the
proposed format thus squeezes the RPL information in 16 to 32 bits,
which compares to 64 bits when using a Hop-by-hop option with the RPL

option as specified in [RFC6553].

6. Security Considerations

Using a compressed format as opposed to the full inline RPL option is logically equivalent and does not create an opening for a new threat when compared to [RFC6553].

7. IANA Considerations

This document updates IANA registry for the LOWPAN_NHC defined in [RFC6282] and assigns the previously unassigned:

    10IOKRFN: RPL Information   [this]

Capital letters in bit positions represent class-specific bit assignments. IOKRF represents variables specific to RPL Information compression defined in Section 5. N indicates whether or not additional LOWPAN_NHC encodings follow, as defined in Section 4.2 of [RFC6553].

8. Acknowledgements

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