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Packet expiration time in 6LoWPAN Routing Header
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Abstract

This document specifies a new type for the 6LoWPAN Dispatch Page 1 for carrying the expiration time of data packets within the 6LoWPAN routing header. The expiration time is useful in making forwarding and scheduling decisions for time critical IoT M2M applications that need deterministic delay guarantees over constrained networks and operate within time-synchronized networks.

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1. Introduction

Low Power and Lossy Networks (LLNs) are likely to be employed for implementing real time industrial applications that require end-to-end delay guarantees [I-D.grossman-detnet-use-cases]. A Deterministic Network typically requires that data packets generated by some senders have to reach their receivers within strict time bounds. Intermediate nodes use the expiration time information to make appropriate packet forwarding and scheduling decisions to meet the time bounds.

The draft [I-D.ietf-roll-routing-dispatch] specifies the 6LoWPAN Routing Header (6LoRH), compression schemes for RPL routing (source routing) operation [RFC6554], header compression of RPL Packet Information [RFC6553], and IP-in-IP encapsulation. This document specifies a new Deadline-6LoRH type to the 6LoWPAN Dispatch Page 1,

so that the expiration time of data packets can be included within the 6LoWPAN routing header. In addition, this specification specifies handling of the expiration time when packets traverse through time-synchronized networks operating in different timezones or distinct reference clocks.

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 [RFC6550] and [I-D.ietf-6tisch-terminology].

3. 6LoRHE Generic Format

The generic header format of the 6LoRHE is specified in [I-D.ietf-roll-routing-dispatch]. Figure 1 illustrates the 6LoRHE generic format. Note: this section is not normative. It is included for convenience, and may be deleted in a later revision of this document.

```
  0                   1
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-             ...               -+
 |1|0|1| Length  |      Type     |                                 |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-             ...               -+
                                 <--          length            -->
```

Figure 1: 6LoRHE format

- o Length: Length of the 6LoRHE expressed in bytes, excluding the first 2 bytes. This enables a node to skip a 6LoRHE if the Type is not recognized/supported.
- o Type: Type of the 6LoRHE.
- o length: variable

4. Deadline-6LoRH Description

The Deadline-6LoRH (see Figure 2) is an elective 6LoRH that provides a compressed form of expiration time for an IPv6 datagram. Along with the expiration timer, the header can include the packet

origination time, to enable a close estimate of the total delay incurred by a packet.

The packet expiration time field contains the value of the packet expiration time. The packet SHOULD be delivered to the Receiver before this time.

packet_expiration_time = packet_origination_time + max_delay

All nodes within the network SHOULD process the Deadline-6LoRH in order to support delay-sensitive deterministic applications. In this specification, the packet origination time is represented in different time units according to a scaling parameter value in the routing header. One of the time units is the Network ASN (Absolute Slot Number) which can be used in case of a time slotted synchronized network, for instance a 6TiSCH network, where a global time is maintained in the units of slot lengths of certain resolution.

The delay experienced by packets in the network is a useful metric for network diagnostics and performance monitoring. To support this feature, the specification provides an optional packet Origination Time (OT) field as part of the header which is initialized by the sender using the current clock time of the outgoing network interface through which the packet is forwarded. Whenever the packets crosses over to a network using a different reference clock, the Origination Time field is updated to represent the same Origination Time as expressed using the reference clock of the outgoing interface into the new network. This is the same as the current time when the packet is transmitted into the new network, minus the delay already experienced by the packet, say 't'. In effect, to the newly entered network, the packet will appear to have originated 't' time units earlier with respect to the reference clock of the new network.

```
Origination Time in new network = current_time_in_new_network -
               delay_already_experienced_in_previous_network(s)
```

5. Deadline-6LoRH Format

```
 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|1| Length  |  6LoRH Type   |O|D| ETL | OTL | TU| EXP | Rsv |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      ET (variable length)     | OT(variable length)(optional) |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Deadline-6LoRH format

Length (5 bits): Length represents the total length of the Expiration Time type measured in octets.

6LoRH Type: TBD

O flag (1bit): Indicates the presence of Origination Time field. '1' means the Origination Time is present, and '0' means it is absent.

D flag (1 bit): The 'D' flag, set by the Sender, indicates the action that needs to be taken when an 6LR detects expiration time is elapsed. If 'D' bit is 1, then the 6LR SHOULD drop the packet if the expiration time is elapsed. If 'D' bit is 0, then the 6LR MAY ignore the Expiration Time and forward it.

ETL (3 bits): Length of Expiration Time field.

OTL (3 bits) : Length of Origination Time field.

For example, ETL = 000 means the expiration time in the 6LoRHE is 1 octet (8 bits) long. Similarly, OTL = 111 means the origination time is 8 octets (64 bits) long.

TU (2 bits) : Indicates time units for packet expiration and origination time fields

00 : Time represented in microseconds
01 : Time represented in seconds
10 : Network ASN
11 : Reserved

EXP (3 bits) : Multiplication factor expressed as exponent of 10.

The value of the ET field is multiplied by 10 to this power, to get the actual expiration time in the units represented by TU. The default value of EXP is 000, so that the ET field is unaffected.

Rsv (3 bits) : Reserved

ET Value (8..64-bit) : Expiration Time value

OT Value (8..64-bit) : Origination Time value

Whenever the Sender initiates the IP datagram, it includes the Deadline-6LoRH along with other 6LoRH information.

Example: Consider a 6TiSCH network with time-slot length of 10ms. Let the current ASN when the packet is originated be 54400, and the

maximum allowable delay (max_delay) for the packet delivery is 1 second from the packet origination, then:

```
expiration_time = packet_origination_time + max_delay

   = 55400 + 100 (in Network ASNs)
   = 55500(Network ASNs)
```

Deadline-6LoRH encoding with 'O' flag set to 1 :

```
ETL = 001, OTL = 001, TU = '10', EXP = 2, ET = 0x22B, OT = 0x22A
```

6. Deadline-6LoRH in Three Network Scenarios

In this section, Deadline-6LoRH operation is described for 3 network scenarios. Figure 3 depicts a constrained time-synchronized LLN that has two subnets N1 and N2, connected through LBRs [I-D.ietf-6lo-backbone-router] with different reference clock times T1 and T2.

```
                          +-------------------+
                          | Time Synchronized |
                          |      Network      |
                          +---------+---------+
                                    |
                                    |
                                    |
                     +--------------+--------------+
                     |                             |
                  +-----+                       +-----+
                  |     | Backbone              |     | Backbone
             o    |     | router                |     | router
                  +-----+                       +-----+
             o                  o               o
                 o    o   o               o  o   o  o   o  o
            o      LLN    o                 o  LLN   o  o
               o   o    o      o              o o o     o  o
         6LoWPAN Network (subnet N1)   6LoWPAN Network (subnet N2)
```

Figure 3: Intra-network Timezone Scenario

6.1. Scenario 1: Endpoints in the same DODAG (N1) in non-storing mode.

In scenario 1, shown in Figure 4, the Sender 'S' has an IP datagram to be routed to a Receiver 'R' within the same DODAG. For the route segment from Sender to 6LBR, the Sender includes a Deadline-6LoRH by encoding the expiration time contained in the inband-OAM header extension. Then 6LR begins hop-by-hop operation to forward the

packet towards the 6LBR. Once 6LBR receives the IP datagram, it generates a IPv6-in-IPv6 encapsulated packet when sending the packet downwards to the Receiver [I-D.ietf-roll-useofrplinfo]. The 6LBR copies the Deadline-6LoRH from the Sender originated IP header to the outer IP header. The Deadline-6LoRH contained in the inner IP header is elided.

```
                         +-------+
                ^        | 6LBR  |       |
                |        |       |       |
                |        +-------+       |
        Default |     (F)/     /| \      | IP-in-IP
        routing |     /  \    / |  \     |      Encapsulation
                |    /    \  (C) |  (D)  |
                |  (A)    (B) /   | / |\  |
                |  /|\     |\:   (E)  : R |
                  S : :    :     / \      V
```

Figure 4: End points within same DODAG(subnet N1)

At the tunnel endpoint of IPv6-in-IPv6 encapsulation, the Deadline-6LoRH is copied back from the outer header to inner header, and the inner IP packet is delivered to 'R'.

6.2. Scenario 2: Endpoints in Networks with Dissimilar L2 Technologies.

In scenario 2, shown in Figure 5, the Sender 'S' (belonging to DODAG 1) has IP datagram to be routed to a Receiver 'R' over a time-synchronized IPv6 network. For the route segment from 'S' to 6LBR, 'S' includes a Deadline-6LoRH. Subsequently, 6LR will perform hop-by-hop operation to forward the packet towards the 6LBR. Once the IP datagram reaches 6LBR of DODAG1, it encodes the expiration time (and, if available, the origination time) into the In-band OAM header extension, [I-D.brockners-inband-oam-data] and passes the datagram to the IPv6 layer for further routing.

```
                              +----------------+
                              | Time           |
                              | synchronized   |------R
                              | Network        |
                              +----------------+
                                      |
                                      |
                            ----------+-----------
                     ^                |
                     |            +---+---+
                     |            | 6LBR  |
            Default  |            |       |
             routing |            +------++
                     |        (F)/      /| \
                     |       /  \      / |  \
                     |      /    \   (C) |  (D)
                       :  (A)    (B) /   | / |\
                          /|\     |\:   (E)  :
                         S : :    :     / \
                                       :   :
```

Figure 5: Packet transmission in Dissimilar L2 Technologies or Internet

The IP datagram is routed to another time synchronized deterministic network following its own distinct reference clock, so the expiration time in In-band OAM has to be updated according to the measurement of the current time in the new network.

6.3. Scenario 3: Packet transmission across different DODAGs (N1 to N2).

Consider the scenario depicted in Figure 6, in which the Sender 'S' (belonging to DODAG 1) has an IP datagram to be sent to Receiver 'R' belonging to another DODAG (DODAG 2). The operation of this scenario can be decomposed into combination of case 1 and case 2 scenarios. For the route segment from 'S' to 6LBR, 'S' includes the Deadline-6LoRH. Subsequently, each 6LR will perform hop-by-hop operation to forward the packet towards the 6LBR. Once the IP datagram reaches 6LBR1 of DODAG1, it applies the same rule as described in Case 2 while routing the packet to LBR2 over a (likely) time synchronized wired backhaul. The wired side of LBR2 can be mapped to receiver of Case 2. Once the packet reaches LBR2, it updates the Deadline-6LoRH by adding the current time of DODAG2. Further, it generates an IPv6-in-IPv6 encapsulated packet when sending the packet downstream to the Receiver [I-D.ietf-roll-useofrplinfo].

```
                     Time Synchronized Network
                  -+---------------------------+-
                   |                           |
      DODAG1   +---+---+                   +---+---+   DODAG2
    Instance 1 | 6LBR1  |                  | 6LBR2 | Instance 2
               |       |                   |       |     |
               +-------+                   +-------+     |
           (F)/      /| \              (F)/      /| \    |
          /  \      / |  \            /  \      / |  \   |
         /    \   (C) |  (D)         /    \   (C) |  (D) |IP-in-IP
       (A)    (B) /   | / |\       (A)    (B) /   | / |\ | Encapsulation
       /|\     |\:   (E)  : :      /|\     |\:   (E)  : :|
      S : :    :     / \          : : :    :     / \     |
                    :   :                       :   R    V
   Network N1, time zone T1      NetWork N2, time zone T2
```

Figure 6: Packet transmission in different DODAGs(N1 to N2)

Consider an example of a 6TiSCH network in which S in DODAG1 generates the packet at ASN 20000 to R in DODAG2. Let the maximum allowable delay be 1 second. The time-slot length in DODAG1 and DODAG2 is assumed to be 10ms. Once the expiration time is encoded in Deadline-6LoRH, the packet is forwarded to LBR of DODAG1. Suppose the packet reaches LBR of DODAG1 at ASN 20050.

```
current_time = ASN at LBR * slot_length_value

remaining_time = expiration_time - current_time
= ((packet_origination_time + max_delay) - current time)
= (20000 + 100) - 20050
= 50 (in Network ASNs)
= 50 * 10^3 milliseconds.
```

The remaining time is encoded in In-Band OAM (see Case 2) and forwarded to LBR2 over a different L2-interface, typically wired. Once the packet reaches LBR2, the expiration time in Deadline-6LoRH is adjusted by adding or subtracting the difference between the reference clocks of the two networks, before forwarding the packet to its connected 6TiSCH network.

7. IANA Considerations

This document defines a new 6LoWPAN Timestamp Header Type, and assigns a value (TBD) from the 6LoWPAN Dispatch Page1 number space.

```
          6LoRH Type      Value
     +------------------+--------+
     | Deadline-6LoRH   | TBD    |
     +------------------+--------+
```

Figure 7: Deadline-6LoRH type

8. Security Considerations

The security considerations of [RFC4944], [RFC6282] and [RFC6553] apply. Using a compressed format as opposed to the full in-line format is logically equivalent and does not create an opening for a new threat when compared to [RFC6550], [RFC6553] and [RFC6554].

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