6lo
Internet-Draft
Intended status: Standards Track
Expires: May 1, 2017

Lijo Thomas
C-DAC
P. Akshay
Indian Institute of Science
Satish Anamalamudi
Individual Contributor
S.V.R.Anand
Malati Hegde
Indian Institute of Science
C. Perkins
Futurewei

October 28, 2016

Packet expiration time in 6LoWPAN Routing Header
draft-lijo-6lo-expiration-time-00

Abstract

This document specifies a new type to the 6LoWPAN Dispatch Page 1 [I-D.ietf-roll-routing-dispatch] 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.

Status of This Memo

Table of Contents

1. Introduction

Low Power and Lossy Networks (LLNs) could be employed for implementing real time industrial applications that require end-to-end delay guarantees [I-D.grossman-detnet-use-cases]. The Deterministic Network requires that data packets generated by the senders have to reach the receivers within strict time bounds. Including an expiration time information in the packets enables intermediate nodes to make appropriate packet forwarding and scheduling decisions to meet this requirement.

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 RPI field [RFC6553], and IP-in-IP encapsulation. This document specifies a new Timestamp-6LoRH type to the 6LoWPAN Dispatch Page 1 for including the expiration time of data packets 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 and 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].

3. 6LoRHC Header Format

The generic header format of the 6LoRHC header is specified in [I-D.ietf-roll-routing-dispatch]. Figure 1 describes the generic header format for the 6LoRHC header.

```
    0                   1
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-             ...              -+
   |1|0|X|   TSE    |      Type     |                                |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-             ...              -+
                                    <-- Length implied by Type/TSE -->
```

Figure 1: 6LoRHC header format

1. X bit: In Figure 1, if 'X' is 0 then it is a critical header. If 'X' is 1, then it is a elective header.

2. TSE: Type Specific Extension. The meaning depends on the Type, which must be known to all the nodes. The interpretation of the TSE depends on the Type field that follows. For instance, it may be used to transport control bits, the number of elements in an array, or the length of the remainder of 6LoRHC expressed in a unit other than bytes.

3. Type: Type of the 6LoRHC.

4. Length: variable

4. Timestamp-6LoRH header

The Timestamp-6LoRH header (see Figure 2) is an elective 6LoRH header that provides a compressed form of expiration time for an IPv6 datagram. All nodes within the network SHOULD support the Timestamp-6LoRH header in order to support delay-sensitive deterministic applications. In this specification, the packet origination time is represented in microseconds. In the case of 6tisch networks which is explained below, the origination time is the current ASN [I-D.vilajosana-6tisch-minimal] converted into microseconds.

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-  -+-    -+ ... +- ... ...-+
|1|0|1|D| Size  |6LoRH Type TBD |Expiration time in microsec |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-  -+-    -+ ... +-  .. .. -+
```

Figure 2: Timestamp-6LoRH header format

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 can choose to ignore the expiration time and forward it.

Size (4 bits): Size represents the total length of expiration time measured in octets. In this specification, the maximum length of the expiration time is 8 octets (64 bits).

For example, Size = 0001 means the expiration time in the 6LoRHC timestamp header is 1 octet (8 bits) long. Likewise, Size = 1000 means the expiration time in the 6LoRHC timestamp header is 8 octet (64 bits) long.

6LoRH Type: In this specification, Type value for the Timestamp-6LoRH is TBD.

Expiration time: This field describes the time limit before which the packet SHOULD be delivered to the Receiver:

expiration_time = packet_origination_time + max_allowable_transmission_delay.

Whenever the Sender initiates the IP datagram, it includes the Timestamp-6LoRH header along with other 6LoRH routing header information. The 6LoRH timestamp contains the expiration time as given in the above expression. Since the maximum allowable transmission delay is specific to each application, the expiration time is of variable length.

Example: In a 6TiSCH network let the time-slot length be 10ms. If the packet_origination_time = Current ASN is 200, and the max_allowable_delay is 1 second, then:

expiration_time = packet_origination_time + max_allowable_delay
= 200*10ms + 1 second

      = 3 * 10^6 microseconds

This expiration time requires 22 bits, or 3 octets, in length. The Size is represented as x0011.

5. Timestamp-6LoRH Header in Heterogeneous Network Scenarios

In this section, Timestamp-6LoRH header operation is described for 3 different network scenarios. Figure 3 depicts a constrained time-synchronized LLN that has two subnets N1 and N2, connected through BBRs [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 (N1 sub-net)   6LoWPAN Network (N2 sub-net)
```

Figure 3: Intra-network Timezone Scenario

Case 1: Endpoints in the same DODAG(N1 sub-net) in non-storing mode.

Let us consider the scenario, as shown in Figure 4, where 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 Timestamp-6LoRH header. Subsequently, 6LR will perform hop-by-hop operation to forward the packet towards the 6LBR. Once the IP datagram reaches 6LBR, it generates IPv6-in-IPv6 encapsulated packet when sending the packet downwards to the Receiver [I-D.ietf-roll-useofrplinfo]. The 6LBR copies the Timestamp-6LoRH header from the Sender originated IP header to the outer IP header. The Timestamp-6LoRH header contained in the inner IP header is elided.

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

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

Figure 4: End points within same DODAG(N1 sub-net)

Case 2: Packet transmission in Heterogeneous Deterministic Networks (Heterogeneous L2 Technologies)

Let us consider the scenario, as shown in Figure 5, where 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 Timestamp-6LoRH header.

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

Figure 5: Packet transmission in different Deterministic Networks or Internet

Subsequently, 6LR will perform hop-by-hop operation to forward the packet towards the 6LBR. Once the IP datagram reaches 6LBR of DODAG1, it performs the following operation. It computes the remaining time by subtracting the elapsed time from the expiration time. The Timestamp-6LoRH header is updated with the remaining time. This value can then be encoded into In-band OAM Edge to Edge option [I-D.brockners-inband-oam-data] and handed over to IPv6 layer for further routing. Since the IP datagram is routed to another time synchronized deterministic network following its own distinct reference clock, the expiration time in In-band OAM is updated by adding the remaining time to the current time according to the time synchronization of the network of the outgoing interface.

Case 3: Packet transmission across different DODAGs (N1 to N2)

Let us consider the scenario, as shown in Figure 6, where the Sender ’S’ (belonging to DODAG 1) has an IP datagram to be sent to Receiver ’R’ belonging to another DODAG (DODAG 2). For the route segment from ’S’ to 6LBR, ’S’ includes the Timestamp-6LoRH header. Subsequently, each 6LR will perform hop-by-hop operation to forward the packet towards the 6LBR. Once the IP datagram reaches 6LBR of DODAG1, it performs the following operation. It computes the remaining time by subtracting the elapsed time from the expiration time. The expiration time in the Timestamp-6LoRH header is updated with the remaining time. It will then forward the packet to 6LBR of DODAG2. Once the IP datagram reaches 6LBR of DODAG2, it updates the Timestamp-6LoRH header by adding the current time of DODAG2. Further, it generates IPv6-in-IPv6 encapsulated packet when sending the packet downwards to the Receiver [I-D.ietf-roll-useofrplinfo].

```
                     Time synchronized network
                  -+---------------------------+-
                   |                           |
      DODAG1   +---+---+                   +---+---+   DODAG2
    Instance 1 | 6LBR  |                   | 6LBR  | 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)

Let us consider an example of a 6TiSCH network where S in DODAG1 generates the packet at ASN 200 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 Timestamp-6LoRH header, the packet is forwarded to LBR of DODAG1. Let us say the packet reaches LBR of DODAG1 at ASN 250.

current_time = ASN at LBR * slot_length_value.

remaining_time = expiration_time - current_time.

= ((packet_origination_time + max_allowable_transmission_delay) - current time)

```
   = (200*10 ms + 1 second) - 2.5 seconds
   = 0.5 second
   = 5 * 10^5 microseconds.
```

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 Timestamp-6LoRH header is re-calculated by adding to it the current ASN, before forwarding the packet to its connected 6TiSCH network.

6. IANA Considerations

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

6LoRH Type	Value
Timestamp-6LoRH	TBD

Figure 7: Timestamp-6LoRH header type

7. 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].

8. Acknowledgements

The authors thank Pascal Thubert for suggesting the idea and encouraging the work. Thanks to Shwetha Bhandari’s suggestions which were instrumental in extending the timing information to heterogeneous networks. The authors acknowledge the 6TiSCH WG members for their inputs on the mailing list. Special thanks to Jerry Daniel J for his support and valuable feedback.

9. References

9.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <http://www.rfc-editor.org/info/rfc2119>.

[RFC4944] Montenegro, G., Kushalnagar, N., Hui, J., and D. Culler, "Transmission of IPv6 Packets over IEEE 802.15.4 Networks", RFC 4944, DOI 10.17487/RFC4944, September 2007, <http://www.rfc-editor.org/info/rfc4944>.

[RFC6282] Hui, J., Ed. and P. Thubert, "Compression Format for IPv6 Datagrams over IEEE 802.15.4-Based Networks", RFC 6282, DOI 10.17487/RFC6282, September 2011, <http://www.rfc-editor.org/info/rfc6282>.

[RFC6550] Winter, T., Ed., Thubert, P., Ed., Brandt, A., Hui, J., Kelsey, R., Levis, P., Pister, K., Struik, R., Vasseur, JP., and R. Alexander, "RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks", RFC 6550, DOI 10.17487/RFC6550, March 2012, <http://www.rfc-editor.org/info/rfc6550>.

[RFC6553] Hui, J. and JP. Vasseur, "The Routing Protocol for Low-Power and Lossy Networks (RPL) Option for Carrying RPL Information in Data-Plane Datagrams", RFC 6553, DOI 10.17487/RFC6553, March 2012, <http://www.rfc-editor.org/info/rfc6553>.

[RFC6554] Hui, J., Vasseur, JP., Culler, D., and V. Manral, "An IPv6 Routing Header for Source Routes with the Routing Protocol for Low-Power and Lossy Networks (RPL)", RFC 6554, DOI 10.17487/RFC6554, March 2012, <http://www.rfc-editor.org/info/rfc6554>.

9.2. Informative References

[I-D.brockners-inband-oam-data]
Brockners, F., Bhandari, S., Pignataro, C., Gredler, H., Leddy, J., and S. Youell, "Data Formats for In-band OAM", draft-brockners-inband-oam-data-01 (work in progress), July 2016.

[I-D.grossman-detnet-use-cases]
Grossman, E., Gunther, C., Thubert, P., Wetterwald, P., Raymond, J., Korhonen, J., Kaneko, Y., Das, S., and Y. Zha, "Deterministic Networking Use Cases", draft-grossman-detnet-use-cases-01 (work in progress), November 2015.

[I-D.ietf-6lo-backbone-router]
Thubert, P., "IPv6 Backbone Router", draft-ietf-6lo-backbone-router-02 (work in progress), September 2016.

[I-D.ietf-roll-routing-dispatch]
Thubert, P., Bormann, C., Toutain, L., and R. Cragie, "6LoWPAN Routing Header", draft-ietf-roll-routing-dispatch-05 (work in progress), October 2016.

[I-D.ietf-roll-useofrplinfo]
Robles, I., Richardson, M., and P. Thubert, "When to use RFC 6553, 6554 and IPv6-in-IPv6", draft-ietf-roll-useofrplinfo-09 (work in progress), October 2016.

[I-D.vilajosana-6tisch-minimal]
Vilajosana, X. and K. Pister, "Minimal 6TiSCH Configuration", draft-vilajosana-6tisch-minimal-00 (work in progress), October 2013.

Authors' Addresses

Lijo Thomas
C-DAC
Trivandrum 695033
India

Email: lijo@cdac.in

P.M. Akshay
Indian Institute of Science
Bangalore 560012
India

Email: akshaypm@ece.iisc.ernet.in

Satish Anamalamudi
Individual Contributor

Email: satishnaidu80@gmail.com

S.V.R Anand
Indian Institute of Science
Bangalore 560012
India

Email: anand@ece.iisc.ernet.in

Malati Hegde
Indian Institute of Science
Bangalore 560012
India

Email: malati@ece.iisc.ernet.in

Charles E. Perkins
Futurewei
2330 Central Expressway
Santa Clara 95050
Unites States

Email: charliep@computer.org