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DetNet Data Plane: IP over IEEE 802.1 Time Sensitive Networking (TSN)
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Abstract

This document specifies the Deterministic Networking IP data plane when operating over a TSN sub-network.

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1. Introduction

Deterministic Networking (DetNet) is a service that can be offered by a network to DetNet flows. DetNet provides these flows extremely low packet loss rates and assured maximum end-to-end delivery latency. General background and concepts of DetNet can be found in the DetNet Architecture [RFC8655].

[I-D.ietf-detnet-ip] specifies the DetNet data plane operation for IP hosts and routers that provide DetNet service to IP encapsulated data. This document focuses on the scenario where DetNet IP nodes are interconnected by a TSN sub-network.

The DetNet Architecture decomposes the DetNet related data plane functions into two sub-layers: a service sub-layer and a forwarding sub-layer. The service sub-layer is used to provide DetNet service protection and reordering. The forwarding sub-layer is used to provides congestion protection (low loss, assured latency, and limited reordering). As described in [I-D.ietf-detnet-ip] no DetNet specific headers are added to support DetNet IP flows, only the forwarding sub-layer functions are supported inside the DetNet domain. Service protection can be provided on a per sub-network basis as shown here for the IEEE802.1 TSN sub-network scenario.

2. Terminology

2.1. Terms Used In This Document

This document uses the terminology and concepts established in the DetNet architecture [RFC8655], and the reader is assumed to be familiar with that document and its terminology.

2.2. Abbreviations

The following abbreviations used in this document:

DetNet Deterministic Networking.

DF DetNet Flow.

FRER Frame Replication and Elimination for Redundancy (TSN function).

L2 Layer-2.

L3 Layer-3.

PREOF Packet Replication, Ordering and Elimination Function.

TSN Time-Sensitive Networking, TSN is a Task Group of the IEEE 802.1 Working Group.

2.3. Requirements Language

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 BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. DetNet IP Data Plane Overview

[I-D.ietf-detnet-ip] describes how IP is used by DetNet nodes, i.e., hosts and routers, to identify DetNet flows and provide a DetNet service. From a data plane perspective, an end-to-end IP model is followed. DetNet uses "6-tuple" based flow identification, where "6-tuple" refers to information carried in IP and higher layer protocol headers.

DetNet flow aggregation may be enabled via the use of wildcards, masks, prefixes and ranges. IP tunnels may also be used to support flow aggregation. In these cases, it is expected that DetNet aware

intermediate nodes will provide DetNet service assurance on the aggregate through resource allocation and congestion control mechanisms.

Congestion protection, latency control and the resource allocation (queuing, policing, shaping) are supported using the underlying link / sub-net specific mechanisms. Service protections (packet replication and packet elimination functions) are not provided at the DetNet layer end to end due the lack of a unified end to end sequencing information that would be available for intermediate nodes. However, such service protection can be provided on a per underlying L2 link and sub-network basis.

```
      Edge          Transit        Relay
      Node            Node         Node

   +.........+
<--:Svc Proxy:-- End to End Service ----------->
   +-----....+                   +..........+
   |IP | :Svc:<-- DetNet flow ---: Service :--->
   +---+ +---+    +---------+    +---------+
   |Fwd| |Fwd|    |   Fwd   |    |Fwd| |Fwd|
   +-.-+ +-.-+    +--.----.-+    +-.-+ +-.-+
     :    /  ,-----.  \   :  Link  :     :
.....+    +-[TSN Sub]-+   +........+     +.....
            [Network]
             `-----'
         <------------- DetNet IP -------------
```

Figure 1: Part of a Simple DetNet (DN) Enabled IP Network using a TSN sub-net

Figure 1 illustrates an extract of a DetNet enabled IP network, that uses a TSN sub-network as interconnection between two DetNet Nodes. In this figure, an Edge Node sits at the boundary of the DetNet domain and provide DetNet service proxies for the end applications by initiating and terminating DetNet service for the application's IP flows. Node and interface resources are allocated to ensure DetNet service requirements. Dotted lines around the Service components of the Edge and Relay Nodes indicate that they are DetNet service aware but do not perform any DetNet service sub-layer function, e.g., PREOF (Packet Replication, Elimination, and Ordering Functions). In this example the Edge Node and the Transit Node are interconnected by a TSN sub-network, being the primary focus of this document.

DetNet routers ensure that detnet service requirements are met per hop by allocating local resources, both receive and transmit, and by mapping the service requirements of each flow to appropriate sub-

network mechanisms. Such mappings are sub-network technology specific. The mapping of DetNet IP flows to TSN streams and TSN protection mechanisms are covered in Section 4.

4. DetNet IP Flows over an IEEE 802.1 TSN sub-network

This section covers how DetNet IP flows operate over an IEEE 802.1 TSN sub-network. Figure 2 illustrates such a scenario, where two IP (DetNet) nodes are interconnected by a TSN sub-network. Node-1 is single homed and Node-2 is dual-homed to the TSN sub-network.

```
       IP (DetNet)                   IP (DetNet)
         Node-1                        Node-2

      ............                  ............
   <--: Service  :-- DetNet flow ---: Service  :-->
      +----------+                  +----------+
      |Forwarding|                  |Forwarding|
      +--------.-+    <-TSN Str->   +-.-----.--+
                \      ,-------.     /     /
                 +----[ TSN-Sub ]---+     /
                      [ Network ]--------+
                       `-------'
   <----------------- DetNet IP ----------------->
```

Figure 2: DetNet (DN) Enabled IP Network over a TSN sub-network

The Time-Sensitive Networking (TSN) Task Group of the IEEE 802.1 Working Group have defined (and are defining) a number of amendments to IEEE 802.1Q [IEEE8021Q] that provide zero congestion loss and bounded latency in bridged networks. Furthermore IEEE 802.1CB [IEEE8021CB] defines frame replication and elimination functions for reliability that should prove both compatible with and useful to DetNet networks. All these functions have to identify flows that require TSN treatment.

TSN capabilities of the TSN sub-network are made available for IP (DetNet) flows via the protocol interworking function defined in IEEE 802.1CB [IEEE8021CB]. For example, applied on the TSN edge port it can convert an ingress unicast IP (DetNet) flow to use a specific Layer-2 multicast destination MAC address and a VLAN, in order to direct the packet through a specific path inside the bridged network. A similar interworking function pair at the other end of the TSN sub-network would restore the packet to its original Layer-2 destination MAC address and VLAN.

Placement of TSN functions depends on the TSN capabilities of nodes. IP (DetNet) Nodes may or may not support TSN functions. For a given

TSN Stream (i.e., DetNet flow) an IP (DetNet) node is treated as a Talker or a Listener inside the TSN sub-network.

4.1. Functions for DetNet Flow to TSN Stream Mapping

Mapping of a DetNet IP flow to a TSN Stream is provided via the combination of a passive and an active stream identification function that operate at the frame level. The passive stream identification function is used to catch the 6-tuple of a DetNet IP flow and the active stream identification function is used to modify the Ethernet header according to ID of the mapped TSN Stream.

IEEE 802.1CB [IEEE8021CB] defines an IP Stream identification function that can be used as a passive function for IP DetNet flows using UDP or TCP. IEEE P802.1CBdb [IEEEP8021CBdb] defines a Mask-and-Match Stream identification function that can be used as a passive function for any IP DetNet flows.

IEEE 802.1CB [IEEE8021CB] defines an Active Destination MAC and VLAN Stream identification function, what can replace some Ethernet header fields namely (1) the destination MAC-address, (2) the VLAN-ID and (3) priority parameters with alternate values. Replacement is provided for the frame passed down the stack from the upper layers or up the stack from the lower layers.

Active Destination MAC and VLAN Stream identification can be used within a Talker to set flow identity or a Listener to recover the original addressing information. It can be used also in a TSN bridge that is providing translation as a proxy service for an End System.

4.2. TSN requirements of IP DetNet nodes

This section covers required behavior of a TSN-aware DetNet node using a TSN sub-network.

From the TSN sub-network perspective DetNet IP nodes are treated as Talker or Listener, that may be (1) TSN-unaware or (2) TSN-aware.

In cases of TSN-unaware IP DetNet nodes the TSN relay nodes within the TSN sub-network must modify the Ethernet encapsulation of the DetNet IP flow (e.g., MAC translation, VLAN-ID setting, Sequence number addition, etc.) to allow proper TSN specific handling inside the sub-network. There are no requirements defined for TSN-unaware IP DetNet nodes in this document.

IP (DetNet) nodes being TSN-aware can be treated as a combination of a TSN-unaware Talker/Listener and a TSN-Relay, as shown in Figure 3. In such cases the IP (DetNet) node must provide the TSN sub-network

specific Ethernet encapsulation over the link(s) towards the sub-network.

```
               IP (DetNet)
                  Node
   <----------------------------------->

   ............
<--: Service  :-- DetNet flow ------------------
   +----------+
   |Forwarding|
   +----------+    +---------------+
   |    L2    |    | L2 Relay with |<--- TSN ---
   |          |    | TSN function  |    Stream
   +-----.----+    +--.------.---.-+
          \__________/        \   \______
                               \_________
    TSN-unaware
     Talker /          TSN-Bridge
     Listener             Relay
                                       <----- TSN Sub-network -----
   <------- TSN-aware Tlk/Lstn ------->
```

Figure 3: IP (DetNet) node with TSN functions

A TSN-aware IP (DetNet) node impementations MUST support the Stream Identification TSN component for recognizing flows.

A Stream identification component MUST be able to instantiate the following functions (1) Active Destination MAC and VLAN Stream identification function, (2) IP Stream identification function, (3) Mask-and-Match Stream identification function and (4) the related managed objects in Clause 9 of IEEE 802.1CB [IEEE8021CB] and IEEE P802.1CBdb [IEEEP8021CBdb].

A TSN-aware IP (DetNet) node implementations MUST support the Sequencing function and the Sequence encode/decode function as defined in IEEE 802.1CB [IEEE8021CB] if FRER is used inside the TSN sub-network.

The Sequence encode/decode function MUST support the Redundancy tag (R-TAG) format as per Clause 7.8 of IEEE 802.1CB [IEEE8021CB].

A TSN-aware IP (DetNet) node implementations MUST support the Stream splitting function and the Individual recovery function as defined in IEEE 802.1CB [IEEE8021CB] when the node is a replication or elimination point for FRER.

4.3. Service protection within the TSN sub-network

TSN Streams supporting DetNet flows may use Frame Replication and Elimination for Redundancy (FRER) as defined in IEEE 802.1CB [IEEE8021CB] based on the loss service requirements of the TSN Stream, which is derived from the DetNet service requirements of the DetNet mapped flow. The specific operation of FRER is not modified by the use of DetNet and follows IEEE 802.1CB [IEEE8021CB].

FRER function and the provided service recovery is available only within the TSN sub-network as the TSN Stream-ID and the TSN sequence number are not valid outside the sub-network. An IP (DetNet) node represents a L3 border and as such it terminates all related information elements encoded in the L2 frames.

4.4. Aggregation during DetNet flow to TSN Stream mapping

Implementations of this document SHALL use management and control information to map a DetNet flow to a TSN Stream. N:1 mapping (aggregating DetNet flows in a single TSN Stream) SHALL be supported. The management or control function that provisions flow mapping SHALL ensure that adequate resources are allocated and configured to provide proper service requirements of the mapped flows.

5. Management and Control Implications

DetNet flow and TSN Stream mapping related information are required only for TSN-aware IP (DetNet) nodes. From the Data Plane perspective there is no practical difference based on the origin of flow mapping related information (management plane or control plane).

TSN-aware IP DetNet nodes are member of both the DetNet domain and the TSN sub-network. Within the TSN sub-network the TSN-aware IP (DetNet) node has a TSN-aware Talker/Listener role, so TSN specific management and control plane functionalities must be implemented. There are many similarities in the management plane techniques used in DetNet and TSN, but that is not the case for the control plane protocols. For example, RSVP-TE and MSRP behaves differently. Therefore management and control plane design is an important aspect of scenarios, where mapping between DetNet and TSN is required.

In order to use a TSN sub-network between DetNet nodes, DetNet specific information must be converted to TSN sub-network specific ones. DetNet flow ID and flow related parameters/requirements must be converted to a TSN Stream ID and stream related parameters/ requirements. Note that, as the TSN sub-network is just a portion of the end2end DetNet path (i.e., single hop from IP perspective), some parameters (e.g., delay) may differ significantly. Other parameters

(like bandwidth) also may have to be tuned due to the L2 encapsulation used within the TSN sub-network.

In some case it may be challenging to determine some TSN Stream related information. For example, on a TSN-aware IP (DetNet) node that acts as a Talker, it is quite obvious which DetNet node is the Listener of the mapped TSN stream (i.e., the IP Next-Hop). However it may be not trivial to locate the point/interface where that Listener is connected to the TSN sub-network. Such attributes may require interaction between control and management plane functions and between DetNet and TSN domains.

Mapping between DetNet flow identifiers and TSN Stream identifiers, if not provided explicitly, can be done by a TSN-aware IP (DetNet) node locally based on information provided for configuration of the TSN Stream identification functions (IP Stream identification, Mask-and-match Stream identification and active Stream identification function).

Triggering the setup/modification of a TSN Stream in the TSN sub-network is an example where management and/or control plane interactions are required between the DetNet and TSN sub-network. TSN-unaware IP (DetNet) nodes make such a triggering even more complicated as they are fully unaware of the sub-network and run independently.

Configuration of TSN specific functions (e.g., FRER) inside the TSN sub-network is a TSN domain specific decision and may not be visible in the DetNet domain.

6. Security Considerations

The security considerations of DetNet in general are discussed in [RFC8655] and [I-D.ietf-detnet-security]. DetNet IP data plane specific considerations are summarized in [I-D.ietf-detnet-ip]. Encryption may provided by an underlying sub-net using MACSec [IEEE802.1AE-2018] for DetNet IP over TSN flows.

7. IANA Considerations

None.

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