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

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

Status of This Memo

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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 with a low packet loss rates and assured maximum end-to-end delivery latency. General background and concepts of DetNet can be found in [I-D.ietf-detnet-architecture].

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) leveraging MPLS Traffic Engineering mechanisms.

[I-D.ietf-detnet-mpls] specifies the DetNet data plane operation for MPLS-based Packet Switched Network (PSN). MPLS encapsulated DetNet flows can be carried over network technologies that can provide the DetNet required level of service. This document focuses on the scenario where MPLS (DetNet) nodes are interconnected by a IEEE 802.1 TSN sub-network.

2. Terminology

[Editor's note: Needs clean up.].

2.1. Terms Used in This Document

This document uses the terminology established in the DetNet architecture [I-D.ietf-detnet-architecture] and [I-D.ietf-detnet-mpls], and the reader is assumed to be familiar with that document and its terminology.

2.2. Abbreviations

The following abbreviations are used in this document:

CW	Control Word.
DetNet	Deterministic Networking.
DF	DetNet Flow.
FRER	Frame Replication and Elimination for Redundancy (TSN function).
L2	Layer 2.
L3	Layer 3.
LSR	Label Switching Router.
MPLS	Multiprotocol Label Switching.
PE	Provider Edge.
PREOF	Packet Replication, Elimination and Ordering Functions.
PSN	Packet Switched Network.
PW	PseudoWire.
S-PE	Switching Provider Edge.
T-PE	Terminating Provider Edge.
TSN	Time-Sensitive Network.

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 MPLS Data Plane Overview

The basic approach defined in [I-D.ietf-detnet-mpls] supports the DetNet service sub-layer based on existing pseudowire (PW) encapsulations and mechanisms, and supports the DetNet forwarding sub-layer based on existing MPLS Traffic Engineering encapsulations and mechanisms.

A node operating on a DetNet flow in the Detnet service sub-layer, i.e. a node processing a DetNet packet which has the S-Label as top of stack uses the local context associated with that S-Label, for example a received F-Label, to determine what local DetNet operation(s) are applied to that packet. An S-Label may be unique when taken from the platform label space [RFC3031], which would enable correct DetNet flow identification regardless of which input interface or LSP the packet arrives on. The service sub-layer functions (i.e., PREOF) use a DetNet control word (d-CW).

The DetNet MPLS data plane builds on MPLS Traffic Engineering encapsulations and mechanisms to provide a forwarding sub-layer that is responsible for providing resource allocation and explicit routes. The forwarding sub-layer is supported by one or more forwarding labels (F-Labels).

```
         Edge          Transit        Relay
         Node           Node           Node
        (T-PE)          (LSR)         (S-PE)
      +---------+
   <--|Svc Proxy|-- End to End Service ----------->
      +---------+                   +---------+
      |IP | |Svc|<-- DetNet flow ---| Service |--->
      +---+ +---+    +---------+    +---------+
      |Fwd| |Fwd|    |   Fwd   |    |Fwd| |Fwd|
      +-.-+ +-.-+    +--.----.-+    +-.-+ +-.-+
        :    /  ,-----.  \   :  Link  :     :
   .....+    +-[TSN Sub]-+   +........+     +.....
               [Network]
                `-----'
           |<----------- LSP ---------->| |<--- LSP -->|
           |<------------- DetNet MPLS ------------
```

Figure 1: Part of a Simple DetNet MPLS Network using a TSN sub-net

Figure 1 illustrates an extract of a DetNet enabled MPLS network. Edge/relay nodes sit at MPLS LSP boundaries and transit nodes are LSRs. In this figure, two MPLS nodes (the edge node and the transit node) are interconnected by a TSN sub-network.

DetNet edge/relay nodes are DetNet service sub-layer aware, understand the particular needs of DetNet flows and provide both DetNet service and forwarding sub-layer functions. They add, remove and process d-CWs, S-Labels and F-labels as needed. MPLS enabled DetNet nodes can enhance the reliability of delivery by enabling the replication of packets where multiple copies, possibly over multiple paths, are forwarded through the DetNet domain. They can also eliminate surplus previously replicated copies of DetNet packets. MPLS (DetNet) nodes also include DetNet forwarding sub-layer functions, support for notably explicit routes, and resources allocation to eliminate (or reduce) congestion loss and jitter.

DetNet transit nodes reside wholly within a DetNet domain, and also provide DetNet forwarding sub-layer functions in accordance with the performance required by a DetNet flow carried over an LSP. Unlike other DetNet node types, transit nodes provide no service sub-layer processing.

4. DetNet MPLS Operation Over IEEE 802.1 TSN Sub-Networks

The DetNet WG collaborates with IEEE 802.1 TSN in order to define a common architecture for both Layer 2 and Layer 3, what maintains consistency across diverse networks. Both DetNet MPLS and TSN use the same techniques to provide their deterministic service:

- o Service protection.

- o Resource allocation.

- o Explicit routes.

As described in the DetNet architecture [I-D.ietf-detnet-architecture] and also illustrated here in Figure 1 a sub-network provides from MPLS perspective a single hop connection between MPLS (DetNet) nodes. Functions used for resource allocation and explicit routes are treated as domain internal functions and does not require function interworking across the DetNet MPLS network and the TSN sub-network.

In case of the service protection function due to the similarities of the DetNet PREOF and TSN FRER functions some level of interworking is possible. However, such interworking is out-of-scope in this document and left for further study.

Figure 2 illustrates a scenario, where two MPLS (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.

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

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

Note: * no service sub-layer required for transit nodes

Figure 2: DetNet Enabled MPLS 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 those require TSN treatment.

TSN capabilities of the TSN sub-network are made available for MPLS (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 MPLS (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. MPLS (DetNet) Nodes may or may not support TSN functions. For a given TSN Stream (i.e., DetNet flow) an MPLS (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 MPLS 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 MPLS label(s) of a DetNet MPLS flow and the active stream identification function is used to modify the Ethernet header according to the ID of the mapped TSN Stream.

IEEE P802.1CBdb [IEEEP8021CBdb] defines a Mask-and-Match Stream identification function that can be used as a passive function for MPLS 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 MPLS DetNet nodes

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

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

In cases of TSN-unaware MPLS DetNet nodes the TSN relay nodes within the TSN sub-network must modify the Ethernet encapsulation of the DetNet MPLS 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 MPLS DetNet nodes in this document.

MPLS (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 MPLS (DetNet) node must provide the TSN sub-network specific Ethernet encapsulation over the link(s) towards the sub-network.

```
              MPLS (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 ------->
```

Note: * no service sub-layer required for transit nodes

Figure 3: MPLS (DetNet) Node with TSN Functions

A TSN-aware MPLS (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) Mask-and-Match Stream identification function and (3) the related managed objects in Clause 9 of IEEE 802.1CB [IEEE8021CB] and IEEE P802.1CBdb [IEEEP8021CBdb].

A TSN-aware MPLS (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 MPLS (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 MPLS (DetNet) node represents a L3 border and as such it terminates all related information elements encoded in the L2 frames.

As the Stream-ID and the TSN sequence number are paired with the similar MPLS flow parameters, FRER can be combined with PREOF functions. Such service protection interworking scenarios may require to move sequence number fields among TSN (L2) and PW (MPLS) encapsulations and they are left for further study.

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

[Editor’s note: This section covers management/control plane related implications of creation, mapping, removal of TSN Stream IDs, their related parameters and, when needed, the configuration of FRER.]

DetNet flow and TSN Stream mapping related information are required only for TSN-aware MPLS (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 MPLS DetNet nodes are member of both the DetNet domain and the TSN sub-network. Within the TSN sub-network the TSN-aware MPLS (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 MPLS 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 MPLS (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 MPLS 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 MPLS (DetNet) node locally based on information provided for configuration of the TSN Stream identification functions (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 MPLS (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. Service protection interworking scenarios are left for further study.

6. Security Considerations

The security considerations of DetNet in general are discussed in [I-D.ietf-detnet-architecture] 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

This document makes no IANA requests.

8. Acknowledgements

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