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Operations, Administration and Maintenance (OAM) for Deterministic  
Networks (DetNet) with MPLS Data Plane  
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#### Abstract

This document lists functional requirements for Operations, Administration, and Maintenance (OAM) toolset in Deterministic Networks (DetNet) and, using these requirements; defines format and use principals of the DetNet service Associated Channel over a DetNet network with the MPLS data plane..

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## 1. Introduction

[RFC8655] introduces and explains Deterministic Networks (DetNet) architecture and how the Packet Replication and Elimination function (PREF) can be used to ensure low packet drop ratio in DetNet domain.

Operations, Administration and Maintenance (OAM) protocols are used to detect, localize defects in the network, and monitor network performance. Some OAM functions, e.g., failure detection, work in the network proactively, while others, e.g., defect localization, usually performed on-demand. These tasks achieved by a combination of active and hybrid, as defined in [RFC7799], OAM methods.

This document lists the functional requirements toward OAM for DetNet domain. The list can further be used for gap analysis of available OAM tools to identify possible enhancements of existing or whether new OAM tools are required to support proactive and on-demand path monitoring and service validation. Also, this document defines format and use principals of the DetNet service Associated Channel over a DetNet network with the MPLS data plane [I-D.ietf-detnet-mpls].

## 2. Conventions used in this document

### 2.1. Terminology and Acronyms

The term "DetNet OAM" used in this document interchangeably with longer version "set of OAM protocols, methods and tools for Deterministic Networks".

CW Control Word

DetNet Deterministic Networks

d-ACH DetNet Associated Channel Header

d-CW DetNet Control Word

DNH DetNet Header

GAL Generic Associated Channel Label

G-ACh Generic Associated Channel

OAM: Operations, Administration and Maintenance

PREF Packet Replication and Elimination Function

POF Packet Ordering Function

PW Pseudowire

RDI Remote Defect Indication

E2E End-to-end

CFM Connectivity Fault Management

BFD Bidirectional Forwarding Detection

TSN Time-Sensitive Network

F-Label A Detnet "forwarding" label that identifies the LSP used to forward a DetNet flow across an MPLS PSN, e.g., a hop-by-hop label used between label switching routers (LSR).

S-Label A DetNet "service" label that is used between DetNet nodes that implement also the DetNet service sub-layer functions. An S-Label is also used to identify a DetNet flow at DetNet service sub-layer.

Underlay Network or Underlay Layer: The network that provides connectivity between the DetNet nodes. MPLS network providing LSP connectivity between DetNet nodes is an example of the underlay layer.

DetNet Node - a node that is an actor in the DetNet domain. DetNet domain edge node and node that performs PREF within the domain are examples of DetNet node.

## 2.2. Keywords

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. Requirements

This section lists requirements for OAM in DetNet domain with MPLS data plane:

1. It MUST be possible to initiate DetNet OAM session from any DetNet node towards another DetNet node(s) within given domain.
2. It SHOULD be possible to initialize DetNet OAM session from a centralized controller.
3. DetNet OAM MUST support proactive and on-demand OAM monitoring and measurement methods.
4. DetNet OAM packets MUST be in-band, i.e., follow precisely the same path as DetNet data plane traffic.
5. DetNet OAM MUST support unidirectional OAM methods, continuity check, connectivity verification, and performance measurement.
6. DetNet OAM MUST support bi-directional OAM methods. Such OAM methods MAY combine in-band monitoring or measurement in the forward direction and out-of-bound notification in the reverse direction, i.e., from egress to ingress end point of the OAM test session.
7. DetNet OAM MUST support proactive monitoring of a DetNet node availability in the given DetNet domain.
8. DetNet OAM MUST support Path Maximum Transmission Unit discovery.

9. DetNet OAM MUST support Remote Defect Indication (RDI) notification to the DetNet node performing continuity checking.
  10. DetNet OAM MUST support performance measurement methods.
  11. DetNet OAM MAY support hybrid performance measurement methods.
  12. DetNet OAM MUST support unidirectional performance measurement methods. Calculated performance metrics MUST include but are not limited to throughput, packet loss, delay and delay variation metrics. [RFC6374] provides excellent details on performance measurement and performance metrics.
  13. DetNet OAM MUST support defect notification mechanism, like Alarm Indication Signal. Any DetNet node in the given DetNet domain MAY originate a defect notification addressed to any subset of nodes within the domain.
  14. DetNet OAM MUST support methods to enable survivability of the DetNet domain. These recovery methods MAY use protection switching and restoration.
  15. DetNet OAM MUST support the discovery of Packet Replication, Elimination, and Order preservation sub-functions locations in the domain.
  16. DetNet OAM MUST support testing of Packet Replication, Elimination, and Order preservation sub-functions in the domain.
  17. DetNet OAM MUST support monitoring any sub-set of paths traversed through the DetNet domain by the DetNet flow.
4. Active OAM for DetNet Networks with MPLS Data Plane

OAM protocols and mechanisms act within the data plane of the particular networking layer. And thus it is critical that the data plane encapsulation supports OAM mechanisms in such a way to comply with the above-listed requirements. One of such examples that require special consideration is requirement #5:

DetNet OAM packets MUST be in-band, i.e., follow precisely the same path as DetNet data plane traffic both for unidirectional and bi-directional DetNet paths.

The Det Net data plane encapsulation in transport network with MPLS encapsulation specified in [I-D.ietf-detnet-mpls]. For the MPLS underlay network, DetNet flows to be encapsulated analogous to pseudowires (PW) over MPLS packet switched network, as described in

[RFC3985], [RFC4385]. Generic PW MPLS Control Word (CW), defined in [RFC4385], for DetNet displayed in Figure 1.

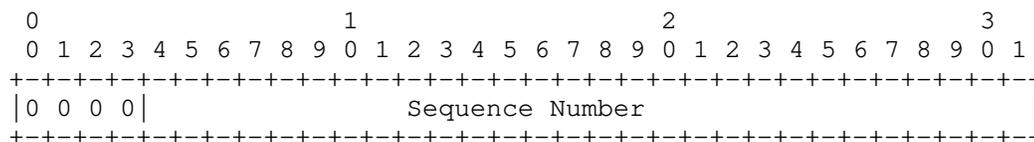


Figure 1: DetNet Control Word Format

PREF in the DetNet domain composed by a combination of nodes that perform replication and elimination sub-functions. The elimination sub-function always uses the S-Label and packet sequencing information, e.g., the value in the Sequence Number field of DetNet CW (d-CW). The replication sub-function uses the S-Label information only. For data packets Figure 2 presents an example of PREF in DetNet domain.

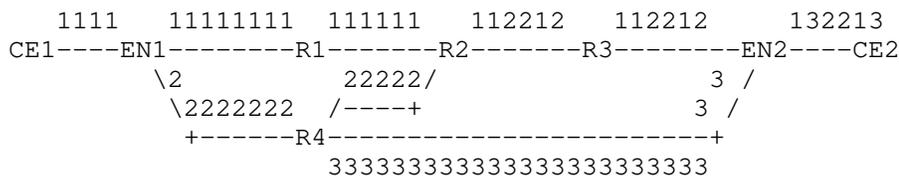


Figure 2: DetNet Data Plane Based on PW

#### 4.1. DetNet Active OAM Encapsulation

DetNet OAM, like PW OAM, uses PW Associated Channel Header defined in [RFC4385]. Figure 3 displays the encapsulation of a DetNet MPLS [I-D.ietf-detnet-mpls] active OAM packet.

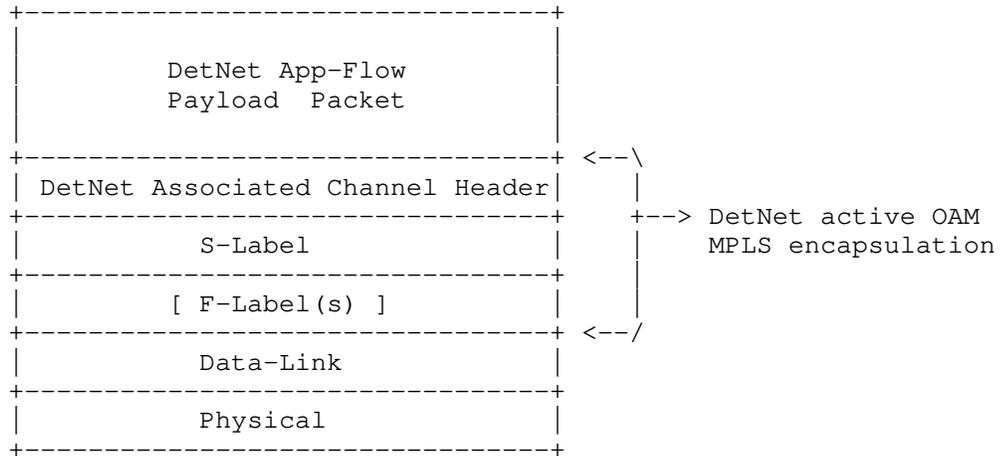


Figure 3: DetNet Active OAM Packet Encapsulation in MPLS Data Plane

Figure 4 displays encapsulation of a test packet of an active DetNet OAM protocol in case of MPLS-over-UDP/IP [I-D.ietf-detnet-mpls-over-udp-ip].

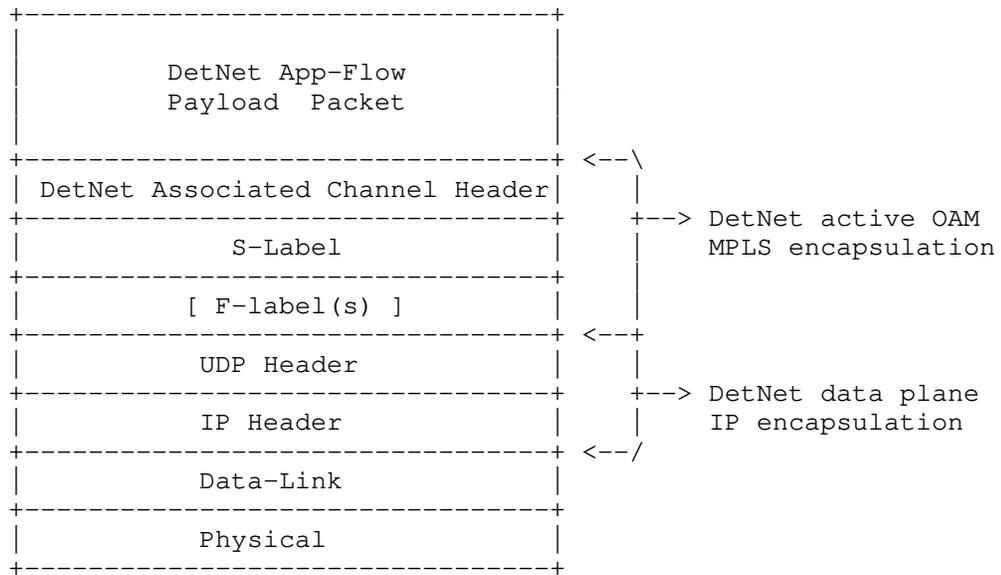


Figure 4: DetNet Active OAM Packet Encapsulation in MPLS-over-UDP/IP

Figure 5 displays the format of the DetNet Associated Channel Header (d-ACH).

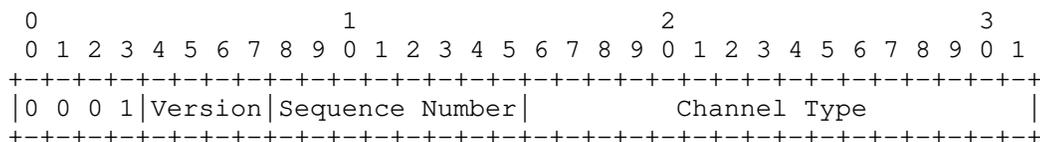


Figure 5: DetNet Associated Channel Header Format

The meanings of the fields in the d-ACH are:

Bits 0..3 MUST be 0b0001. This value of the first nibble allows the packet to be distinguished from an IP packet [RFC4928] and a DetNet data packet [I-D.ietf-detnet-mpls].

Version: this is the version number of the d-ACH. This specification defines version 0.

Sequence Number: this is unsigned eight bits-long field. The originating DetNet node MUST set the value of the Sequence Number field to a non-zero before packet being transmitted. The originating node MUST monotonically increase the value of the Sequence Number field for the every next active OAM packet.

Channel Type: the value of DetNet Associated Channel Type is one of values defined in the IANA PW Associated Channel Type registry.

The DetNet flow, according to [I-D.ietf-detnet-mpls], is identified by the S-label that MUST be at the bottom of the stack. Active OAM packet MUST have d-ACH immediately following the S-label.

#### 4.2. DetNet Replication, Elimination, and Ordering Sub-functions Interaction with Active OAM

At the DetNet service layer, special functions MAY be applied to the particular DetNet flow - PREF to potentially lower packet loss, improve the probability of on-time packet delivery and Packet Ordering Function (POF) to ensure in-order packet delivery. As data and the active OAM packets have the same Flow ID, S-label, sub-functions that rely on sequencing information in the DetNet service layer MUST process 28 MSBs of the d-ACH as the source of the sequencing information for the OAM packet.

## 5. Use of Hybrid OAM in DetNet

Hybrid OAM methods are used in performance monitoring and defined in [RFC7799] as:

Hybrid Methods are Methods of Measurement that use a combination of Active Methods and Passive Methods.

A hybrid measurement method may produce metrics as close to passive, but it still alters something in a data packet even if that is the value of a designated field in the packet encapsulation. One example of such a hybrid measurement method is the Alternate Marking method described in [RFC8321]. Reserving the field for the Alternate Marking method in the DetNet Header will enhance available to an operator set of DetNet OAM tools.

## 6. OAM Interworking Models

Interworking of two OAM domains that utilize different networking technology can be realized either by a peering or a tunneling model. In a peering model, OAM domains are within the corresponding network domain. When using the peering model, state changes that are detected by a Fault Management OAM protocol can be mapped from one OAM domain into another or a notification, e.g., an alarm, can be sent to a central controller. In the tunneling model of OAM interworking, usually, only one active OAM protocol is used. Its test packets are tunneled through another domain along with the data flow, thus ensuring the fate sharing among test and data packets.

### 6.1. OAM of DetNet MPLS Interworking with OAM of TSN

Active DetNet OAM is required to provide the E2E fault management and performance monitoring for a DetNet flow. Interworking of DetNet active OAM with MPLS data plane with the IEEE 802.1 Time-Sensitive Networking (TSN) domain based on [I-D.ietf-detnet-mpls-over-tsn].

In the case of the peering model is used in the fault management OAM, then the node that borders both TSN and DetNet MPLS domains MUST support [RFC7023]. [RFC7023] specified the mapping of defect states between Ethernet Attachment Circuits (ACs) and associated Ethernet PWs that are part of an end-to-end (E2E) emulated Ethernet service. Requirements and mechanisms described in [RFC7023] are equally applicable to using the peering model to achieve E2E FM OAM over DetNet MPLS and TSN domains. The Connectivity Fault Management (CFM) protocol [IEEE.CFM] or in [ITU.Y1731] can provide fast detection of a failure in the TSN segment of the DetNet service. In the DetNet MPLS domain BFD (Bidirectional Forwarding Detection), specified in [RFC5880] and [RFC5885], can be used. To provide E2E failure

detection, the TSN segment might be presented as a concatenated with the DetNet MPLS and the Section 6.8.17 [RFC5880] MAY be used to inform the upstream DetNet MPLS node of a failure of the TSN segment. Performance monitoring can be supported by [RFC6374] in the DetNet MPLS and [ITU.Y1731] in the TSN domains, respectively. Performance objectives for each domain should refer to metrics that additive or be defined for each domain separately.

The following considerations are to be realized when using the tunneling model of OAM interworking between DetNet MPLS and TSN domains:

- o Active OAM test packet MUST be mapped to the same TSN Stream ID as the monitored DetNet flow.
- o Active OAM test packets MUST be treated in the TSN domain based on its S-label and CoS marking (TC field value).

Note that the tunneling model of the OAM interworking requires that the remote peer of the E2E OAM domain supports the active OAM protocol selected on the ingress endpoint. For example, if BFD is used for proactive path continuity monitoring in the DetNet MPLS domain, a TSN endpoint of the DetNet service has also support BFD as defined in [RFC5885].

## 6.2. OAM of DetNet MPLS Interworking with OAM of DetNet IP

Interworking between active OAM segments in DetNet MPLS and DetNet IP domains can also be realized using either the peering or the tunneling model, as discussed in Section 6.1. Using the same protocol, e.g., BFD, over both segments, simplifies the mapping of errors in the peering model. To provide the performance monitoring over a DetNet IP domain STAMP [RFC8762] and its extensions [I-D.ietf-ippm-stamp-option-tlv] can be used.

## 7. IANA Considerations

TBA

## 8. Security Considerations

This document lists the OAM requirements for a DetNet domain and does not raise any security concerns or issues in addition to ones common to networking. Additionally, security considerations discussed in DetNet specifications: [RFC8655], [I-D.ietf-detnet-security], [I-D.ietf-detnet-mpls] are applicable to this document. Security concerns and issues related to MPLS OAM tools like LSP Ping [RFC8029], BFD over PW [RFC5885] also apply to this specification.

## 9. Acknowledgment

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