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RFC 9634
Operations, Administration, and Maintenance (OAM) for Deterministic Networking (DetNet) with the IP Data Plane

Abstract

This document discusses the use of existing IP Operations, Administration, and Maintenance protocols and mechanisms in Deterministic Networking networks that use the IP data plane.

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1. Introduction Yes the Introduction That I'm Trying to Make Really Long so I Can See the Indentation in the Table of Contents in the TXT Output

[RFC8655] introduces and explains the Deterministic Networking (DetNet) architecture.

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

[RFC9551] lists the OAM functional requirements for DetNet and defines the principles for OAM use within DetNet networks utilizing the IP data plane. The functional requirements can be compared against current OAM tools to identify gaps and potential enhancements required to enable proactive and on-demand path monitoring and service validation.

This document discusses the use of existing IP OAM protocols and mechanisms in DetNet networks that use the IP data plane.

2. Conventions Used in This Document That I'm Trying to Make Really Long so I Can See the Indentation in the Table of Contents in the TXT Output

2.1. Terminology: A Gratuitously Long Title for Such a Short Section Plus Some More Words to Make It Longer

The term "DetNet OAM" as used in this document also means "a set of OAM protocols, methods, and tools for Deterministic Networking".

DetNet: Deterministic Networking

OAM: Operations, Administration, and Maintenance

ICMP: Internet Control Message Protocol

Underlay Network or Underlay Layer: The network that provides connectivity between DetNet nodes. MPLS networks providing Label Switched Path (LSP) connectivity between DetNet nodes are an example of the DetNet IP network underlay layer.

DetNet Node: A node that is an actor in the DetNet domain. DetNet domain edge nodes and nodes that perform the Packet Replication and Elimination Function within the domain are examples of a DetNet node.

2.1.1. A Third-Level Section Heading Used in This Document That I'm Trying to Make Really Long so I Can See the Indentation in the Table of Contents in the TXT Output

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3. Active OAM for DetNet Networks with the IP Data Plane That I'm Trying to Make Really Long so I Can See the Indentation in the Table of Contents in the TXT Output

OAM protocols and mechanisms act within the data plane of the particular networking layer. Thus, it is critical that the data plane encapsulation support OAM mechanisms and enable them to be configured so that DetNet OAM packets follow the same path (unidirectional or bidirectional) through the network and receive the same forwarding treatment in the DetNet forwarding sub-layer as the DetNet flow being monitored.

The DetNet data plane encapsulation in a transport network with IP encapsulations is specified in Section 6 of [RFC8939]. For the IP underlay network, DetNet flows are identified by the ordered match to the provisioned information set that, among other elements, includes the IP protocol type, source port number, and destination port number. Active IP OAM protocols like Bidirectional Forwarding Detection (BFD) [RFC5880] or the Simple Two-way Active Measurement Protocol (STAMP) [RFC8762] use UDP transport and the well-known UDP port numbers as the destination port. For BFD, the UDP destination port is specific to the BFD variant, e.g., multihop BFD uses port 4784 [RFC5883].

Thus, a DetNet node must be able to associate an IP DetNet flow with the particular test session to ensure that test packets experience the same treatment as the DetNet flow packets. For example, in a network where path selection and DetNet functionality are based on 3-tuples (destination and source IP addresses in combination with the Differentiated Services Code Point value), that association can be achieved by having the OAM traffic use the same 3-tuple as the monitored IP DetNet flow. In such a scenario, an IP OAM session between the same pair of IP nodes would share the network treatment with the monitored IP DetNet flow regardless of whether ICMP, BFD, or STAMP is used.

In IP networks, the majority of on-demand failure detection and localization is achieved through the use of ICMP, utilizing Echo Request and Echo Reply messages, along with a set of defined error messages such as Destination Unreachable, which provide detailed information through assigned code points. [RFC0792] and [RFC4443] define ICMP for IPv4 and IPv6 networks, respectively. To utilize ICMP effectively for these purposes within DetNet, DetNet nodes must establish the association of ICMP traffic between DetNet nodes with IP DetNet traffic. This entails ensuring that such ICMP traffic traverses the same interfaces and receives QoS treatment that is identical to the monitored DetNet IP flow. Failure to do so may result in ICMP being unable to detect and localize failures specific to the DetNet IP data plane.

3.1. Mapping Active OAM and IP DetNet Flows

IP OAM protocols are used to detect failures (e.g., BFD [RFC5880]) and performance degradation (e.g., STAMP [RFC8762]) that affect an IP DetNet flow. It is essential to ensure that specially constructed OAM packets traverse the same set of nodes and links and receive the same network QoS treatment as the monitored data flow, e.g., a DetNet flow, for making active OAM useful.

When the UDP destination port number used by the OAM protocol is assigned by IANA, judicious selection of the UDP source port may help achieve co-routedness of OAM with the monitored IP DetNet flow in multipath environments, e.g., Link Aggregation Group or Equal Cost Multipath, via the use of a UDP source port value that results in the OAM traffic and the monitored IP DetNet flow hashing to the same path based on the packet header hashes used for path selection. This does assume that forwarding equipment along the multipath makes consistent hashing decisions, which might not always be true in a heterogeneous environment. (That also applies to the encapsulation techniques described in Sections 3.2 and 3.3.) To ensure the accuracy of OAM results in detecting failures and monitoring the performance of IP DetNet, it is essential that test packets not only traverse the same path as the monitored IP DetNet flow but also receive the same treatment by the nodes, e.g., shaping, filtering, policing, and availability of the pre-allocated resources, as experienced by the IP DetNet packet. That correlation between the particular IP OAM session and the monitored IP DetNet flow can be achieved by using DetNet provisioning information (e.g., [RFC9633]). Each IP OAM protocol session is presented as a DetNet application with related service and forwarding sub-layers. The forwarding sub-layer of the IP OAM session is identical to the forwarding sub-layer of the monitored IP DetNet flow, except for information in the "ip-header" grouping item as defined in [RFC9633].

3.2. Active OAM Using IP-in-UDP Encapsulation

As described above, active IP OAM is realized through several protocols. Some protocols use UDP transport, while ICMP is a network-layer protocol. The amount of operational work mapping IP OAM protocols to the monitored DetNet flow can be reduced by using an IP/UDP tunnel to carry IP test packets [RFC2003]. Then, to ensure that OAM packets traverse the same set of nodes and links, the IP/UDP tunnel must be mapped to the monitored DetNet flow. Note that in such a case, the DetNet domain for the test packet is seen as a single IP link. As a result, transit DetNet IP nodes cannot be traced using the usual traceroute procedure, and a modification of the traceroute may be required.

3.3. Active OAM Using DetNet-in-UDP Encapsulation

Active OAM in IP DetNet can be realized using DetNet-in-UDP encapsulation. Using a DetNet-in-UDP tunnel between IP DetNet nodes ensures that active OAM test packets follow the same path through the network as the monitored IP DetNet flow packets and receive the same forwarding treatment in the DetNet forwarding sub-layer (see Section 4.1.2 of [RFC8655]) as the IP DetNet flow being monitored.

[RFC9566] describes how DetNet with the MPLS-over-UDP/IP data plane [RFC9025] can be used to support Packet Replication, Elimination, and Ordering Functions (PREOF) to potentially lower packet loss, improve the probability of on-time packet delivery, and ensure in-order packet delivery in IP DetNet's service sub-layer. To ensure that an active OAM test packet follows the path of the monitored DetNet flow in the DetNet service sub-layer, the encapsulation shown in Figure 1 is used.

```
        +---------------------------------+
        |                                 |
        |         DetNet App-Flow         |
        |       (original IP) Packet      |
        |                                 |
        +---------------------------------+ <--\
        |            DetNet ACH           |    |
        +---------------------------------+    +--> PREOF-capable
        |       Service-ID (S-Label)      |    |    DetNet IP data
        +---------------------------------+    |    plane encapsulation
        |            UDP Header           |    |
        +---------------------------------+    |
        |            IP Header            |    |
        +---------------------------------+ <--/
        |            Data-Link            |
        +---------------------------------+
        |             Physical            |
        +---------------------------------+
```

Figure 1: DetNet Associated Channel Header Format

Where:

DetNet ACH is the DetNet Associated Channel Header defined in [RFC9546].

PREOF if DetNet service sub-layer defined in [RFC8655].

3.4. The Application of Y.1731/G.8013 Using GRE-in-UDP Encapsulation

[RFC8086] has defined the method of encapsulating GRE (Generic Routing Encapsulation) headers in UDP. GRE-in-UDP encapsulation can be used for IP DetNet OAM, as it eases the task of mapping an OAM test session to a particular IP DetNet flow that is identified by an N-tuple. Matching a GRE-in-UDP tunnel to the monitored IP DetNet flow enables the use of Y.1731/G.8013 [ITU.Y1731] as a comprehensive toolset of OAM. The Protocol Type field in the GRE header must be set to 0x8902, assigned by IANA to the IEEE 802.1ag Connectivity Fault Management (CFM) protocol / ITU-T Recommendation Y.1731. Y.1731/G.8013 supports the necessary functions required for IP DetNet OAM, i.e., continuity checks, one-way packet loss, and packet delay measurements.

4. Active OAM for DetNet IP Interworking with OAM for Non-IP DetNet Domains

A domain in which the IP data plane provides DetNet service could be used in conjunction with a Time-Sensitive Networking (TSN) network and a DetNet domain with the MPLS data plane to deliver end-to-end service. In such scenarios, the ability to detect defects and monitor performance using OAM is essential. [RFC9546] identifies two OAM interworking models -- peering and tunneling. Interworking between DetNet domains with IP and MPLS data planes is analyzed in Section 4.2 of [RFC9546]. In addition, OAM interworking requirements and recommendations that apply between a DetNet domain with the MPLS data plane and an adjacent TSN network also apply between a DetNet domain with the IP data plane and an adjacent TSN network.

5. IANA Considerations

This document has no IANA actions.

6. Security Considerations

This document describes the applicability of the existing Fault Management and Performance Monitoring IP OAM protocols. It does not raise any security concerns or issues in addition to those common to networking or already documented in [RFC0792], [RFC4443], [RFC5880], and [RFC8762] for the referenced DetNet and OAM protocols.

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