DetNet
Internet-Draft
Intended status: Informational
Expires: 24 August 2025

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20 February 2025

OAM Requirements for Enhanced DetNet OAM
draft-yan-detnet-oam-requirements-enhancement-01

Abstract

This document describes the specific requirements of the Operations, Administration, and Maintenance (OAM) for Enhanced DetNet, and analyzes the gaps with the existing OAM methods. It describes related OAM solutions considerations as well.

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1. Introduction

The framework of OAM for DetNet has been specified in [RFC9551]. Aa per[RFC8655], DetNet functionality is divided into forwarding sub-layer and service sub-layer.[RFC9551]lists general functional requirements for DetNet OAM as well as functional requirements in each of the DetNet sub-layers of a DetNet domain. The IP and MPLS DetNet data plane have been defined respectively in[I-D.ietf-detnet-ip-oam]and[RFC9546].

The DetNet data plane enhancement requirements are described in [I-D.ietf-detnet-scaling-requirements] , which demands the enhancement based on the existing bounded latency mechanisms and the corresponding data plane. The data plane enhancement solutions such as ECQF[IEEE 802.1Qdv], Multi-CQF[I-D.dang-queuing-with-multiple-cyclic-buffers], TCQF[I-D.eckert-detnet-tcqf], CSQF[I-D.chen-detnet-sr-based-bounded-latency], TQF[I-D.peng-detnet-packet-timeslot-mechanism], C-SCORE[I-D.joung-detnet-stateless-fair-queuing], EDF[I-D.peng-detnet-deadline-based-forwarding], gLBF[I-D.eckert-detnet-glbf]have been proposed and discussed, with the criteria for classifying data plane solutions is provided in[I-D.ietf-detnet-dataplane-taxonomy]. These queuing mechanisms demand high precision to achieve deterministic latency especially as link speeds increase from 100Mbps to 1Gbps, 10Gbps, 100Gbps, or even higher. with the increasing of link speed from 100Mbps to 1Gbps, 10Gbps, 100Gbps, or even higher.

For DetNet OAM, it is essential to provide DetNet services with high precision in a large-scale network, ensuring OAM performance requirements are strictly met. Existing OAM methods including proactive and reactive techniques are insufficient to meet the monitoring and measurement requirements for Enhanced DetNet.

Based on the consideration above, this document describes the specific requirements of the OAM for Enhanced DetNet, and analyzes the gaps with the existing OAM methods, and describes related OAM solutions considerations.

1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

2. Terminology

The terminology is defined as[RFC8655].

3. Requirements and Gap Analysis

This section presents the enhanced requirements for Enhanced DetNet OAM and analyzes the technical gaps when applying OAM technologies as per [RFC9551]in large-scale networks.

3.1. Support Microsecond-level Measurement Precision

As per [I-D.ietf-detnet-scaling-requirements], deterministic networks can utilize higher-speed links. With the increasing data rates, the network scheduling cycle can be shortened, provided that the amount of application data transmitted at any given time remains unchanged. This requires more precise time control, in the order of microseconds or sub-microseconds. As per[RFC9551], the service protection provided by the DetNet Service sub-layer aims to mitigate network failures more rapidly than the expected response time of the DetNet Controller Plane. Therefore, the time accuracy of the DetNet OAM mechanism must meet or exceed the accuracy requirements specified in

SLAs. For instance, if service delay measurements require microsecond-level precision, the OAM mechanism should support sub-microsecond precision to assess whether service delay and jitter performance comply with SLA requirements.

The precision of time measurements depends on both the time synchronization protocol utilized in the network and the specific location where timestamps are captured during the forwarding process. According to [I-D.ietf-detnet-scaling-requirements], , Enhanced DetNet, which targets large-scale networks, should accommodate time asynchrony, making the efficient one-way delay measurement critical. Furthermore, based on the assumption of time asynchrony, synchronization technologies leveraging network effects, especially in metropolitan area networks with spine-leaf topologies, provide solutions capable of achieving synchronization accuracy down to the microsecond level.

3.2. Support Per-packet Performance Monitoring

According to [I-D.ietf-detnet-scaling-requirements], large-scale networks are becoming increasingly complex to meet the growing demands for higher bandwidth, lower latency and jitter, customized traffic prioritization, and SLA-grade network resilience. A more complex network infrastructure requires deeper visibility into Enhanced DetNet. The OAM of Enhanced DetNet should be capable of analyzing network behavior at the packet level. Legacy network monitoring technologies are insufficient since they do not provide real-time and granular visibility required for such detailed analysis.

DetNet requires high reliability to meet the demands of service flows. However, detecting SLA violations on a per-packet basis presents significant challenges in large-scale networks with thousands of service flows. The feasibility of implementing per-packet monitoring with the OAM mechanism depends on device capabilities, including counter resources, CPU resources, and port speeds. For instance, if the processing time for forwarding packets at line speed is 10 nanoseconds per packet in in-situ OAM mode, the network processor chip must parse the OAM data fields for each packet within this time frame. Any delay exceeding 10 nanoseconds per packet would hinder the device’s capability to forward packets at line speed..In large-scale networks with thousands of services, mainstream equipment currently operates at capacities typically in the range of a few thousand, making it challenging to implement per-packet OAM effectively.

3.3. Support High-speed Detection and Response

In DetNet, due to the limited network scale, the impact of detection and response time on OAM performance is less noticeable. However, in large-scale networks, long-distance transmission increases latency and the presence of a large number of devices leads to a higher likelihood of network link failures. To achieve real-time monitoring and awareness of the network’ s operating state, high-speed monitoring and rapid response are critical., ensuring that the services are not be interrupted for extended periods or that SLA violations do not occur.

The traditional detection methods relying on switching and notification are ineffective in detecting millisecond-level latency variations and low-probability packet loss issues., making it unsuitable for Enhanced DetNet, as follows:

1. Active OAM protocols, such as Bidirectional Forwarding Detection (BFD) [RFC5880], typically operate at millisecond-level at most.

2. Currently, in-band detection methods include the Alternate-Marking Method [RFC8321]which operates with a detection duration of up to ten-second level, and IOAM Direct Export (DEX)[RFC9326], achieving near real-time monitoring but requires packet encapsulated with a sequence number field. Out-of-band reporting methods such as extensions of[RFC6374]generally offer millisecond-level delay.

3. Telemetry can provide monitoring at minute or hour levels at most. A key limitation of telemetry is its reliance on uniform packet upload and processing. Moreover, fixed round-trip time overhead across node-to-controller paths, node CPU performance, uplink bandwidth, and controller processing capability all serve as bottlenecks of Telemetry.

4. Consideration for Enhanced DetNet OAM Solutions

OAM methods can be classified into three types according to [RFC7799]:

1. Active OAM mode (e.g., TWAMP [RFC5357]).[RFC9546]defines DetNet OAM with the MPLS Data Plane, while [I-D.ietf-detnet-ip-oam] discusses DetNet OAM with the IP Data Plane. These drafts focusing on the active OAM mode indicate that the fate sharing between test packets and service packets is theoretically achievable. However, in practical implementation, it encounters significant challenges. While path sharing is relatively simple, achieving fate sharing between test packets and service packets without causing congestion remains a difficult task for network operators.

2. Passive OAM mode. In a strict sense, passive methods do not modify packet encapsulation, making it difficult to calculate packet loss when packets do not carry sequence numbers.

3. Hybrid OAM mode. At present, the two most popular in-band OAM technologies are the Alternate-Marking (coloring) Method [RFC8321]and In-situ Network Telemetry (INT)[RFC9197], , which are both hybrid OAM methods and offers solutions for achieving fate-sharing among test packets and service packets on the forwarding plane. Based on forwarding plane detection technologies utilizing coloring and INT, there are two main OAM solutions:

   * The head-end or tail-end node performs local OAM data computations, such as packet loss rates and delay. Out-of-band OAM technologies (such as[RFC6374], STWAP[RFC8762], and their extensions) can optionally be used for information exchange between head-end and tail-end nodes.

   * Telemetry methods (like iFIT [I-D.song-opsawg-ifit-framework]). The head-end and tail-end nodes transmit their local data to a controller or cloud platform via southbound interfaces. Here, third-party nodes then perform OAM-related computations and notify the nodes to generate responses, also via southbound interfaces.

Based on the above analysis, there are two technical approaches for Enhanced DetNet OAM to meet the high-reliability requirements.

4.1. Based on Traditional OAM Protection Mechanism

Traditional protection switching networks employ the following three types of protection methods, each with different response speeds:

1. End-to-end 1+1 protection: There is a working link serving as the primary path and a protection link as the backup path, both pre-established. At the head-end node, service traffic is replicated

and transmitted over both the working link and the protection link. If the working link fails, the tail-end node switches to receiving traffic from the protection link, a process known as single-end switching. While this method switches relatively quickly, it has low bandwidth utilization both links are allocated for a single service.

2. End-to-end 1:1 protection: Service traffic is transmitted only over the working link, leaving the protection link idle or available for low-priority services. If the working link fails, the tail-end node notifies the head-end node to switch protected service flows from the working link to the protection link. This switching requires actions at both ends, resulting in slower switching but achieving higher bandwidth utilization.

3. Fast Reroute (FRR): Enhanced DetNet requires explicit paths, making rerouting based on distributed protocols unsuitable.

For Enhanced DetNet, where OAM protection is best-effort and primarily focused on deploying protection switching mechanisms, traditional forwarding sub-layer OAM protection methods can be utilized:

1. The INT mechanism which carryies the sequence number and collects data in Direct Export mode offers near real-time detection under limited packet disordering, while the response time depends on the protection method used. This approach achieves optimal detection speed but requires encapsulating/decapsulating in-situ OAM message headers as required and supporting Direct Export Type.

2. The in-situ flow detection mechanism with traffic coloring offers a detection granularity ranging from 1 second to 300 seconds (with an approximate average of 10 seconds), aligning performance monitoring duration within at least the second range.

3. Active OAM mechanisms based on fate sharing compromise the requirements in chapters 3.1 and 3.2. The CC-CV method relies on protocols such as BFD.

Observability technologies introduce extra latency and are thus unsuitable for real-time OAM detection of online services.

4.2. Supporting PREF Protection Function in DetNet

PREF aims to guarantee forwarding sub-layer performance through service sub-layer functionality, employing multi-path packet duplication to mitigate the path-switching delay. According to [IEEE802.1CB]and[RFC8655], ensuring high reliability for time-sensitive services is challenging without the deployment of PREF. When the network supports PREF configuration, it inherently meets reliability requirements including constraints on packet loss rate and latency violation, thus eliminating the need for enhanced detection speed. Another key factor contributing to high reliability is the ability to provide protection at node level and link level rather than solely at the path level. The PREF mechanism requires each packet encapsulated with a unique flow-id and a sequence number to facilitate selective receiving.

While the network supports PREF can guarantee a packet loss rate as low as 0.0001%, it remains essential to proactively monitor the performance of each individual path to promptly detect path defects. This proactive approach helps prevent SLA violations such as link degradation to ensure stable transmission of service traffic under PREF protection.

5. Security Considerations

TBA

6. IANA Considerations

TBA

7. Acknowledgements

TBA

8. References

8.1. Normative References

[I-D.chen-detnet-sr-based-bounded-latency]
Chen, M., Geng, X., Li, Z., Joung, J., and J. Ryoo, "Segment Routing (SR) Based Bounded Latency", 7 July 2023, <https://datatracker.ietf.org/doc/html/draft-chen-detnet-sr-based-bounded-latency-03>.

[I-D.dang-queuing-with-multiple-cyclic-buffers]
Liu, B. and J. Dang, "A Queuing Mechanism with Multiple Cyclic Buffers", 22 February 2021, <https://datatracker.ietf.org/doc/html/draft-dang-queuing-with-multiple-cyclic-buffers-00>.

[I-D.eckert-detnet-glbf]
Eckert, T. T., Clemm, A., Bryant, S., and S. Hommes, "Deterministic Networking (DetNet) Data Plane - guaranteed Latency Based Forwarding (gLBF) for bounded latency with low jitter and asynchronous forwarding in Deterministic Networks", 5 January 2024, <https://datatracker.ietf.org/doc/html/draft-eckert-detnet-glbf-02>.

[I-D.eckert-detnet-tcqf]
Eckert, T. T., Li, Y., Bryant, S., Malis, A. G., Ryoo, J., Liu, P., Li, G., Ren, S., and F. Yang, "Deterministic Networking (DetNet) Data Plane - Tagged Cyclic Queuing and Forwarding (TCQF) for bounded latency with low jitter in large scale DetNets", 5 January 2024, <https://datatracker.ietf.org/doc/html/draft-eckert-detnet-tcqf-05>.

[I-D.ietf-detnet-dataplane-taxonomy]
Joung, J., Geng, X., Peng, S., and T. T. Eckert, "Dataplane Enhancement Taxonomy", 24 May 2024, <https://datatracker.ietf.org/doc/html/draft-ietf-detnet-dataplane-taxonomy-02>.

[I-D.ietf-detnet-ip-oam]
Mirsky, G., Chen, M., and D. L. Black, "Operations, Administration, and Maintenance (OAM) for Deterministic Networks (DetNet) with IP Data Plane", 14 February 2024, <https://datatracker.ietf.org/doc/html/draft-ietf-detnet-ip-oam-13>.

[I-D.ietf-detnet-scaling-requirements]
Liu, P., Li, Y., Eckert, T. T., Xiong, Q., Ryoo, J., zhushiyin, and X. Geng, "Requirements for Scaling Deterministic Networks", 22 May 2024, <https://datatracker.ietf.org/doc/html/draft-ietf-detnet-scaling-requirements-06>.

[I-D.joung-detnet-stateless-fair-queuing]
Joung, J., Ryoo, J., Cheung, T., Li, Y., and P. Liu, "Latency Guarantee with Stateless Fair Queuing", 29 February 2024, <https://datatracker.ietf.org/doc/html/draft-joung-detnet-stateless-fair-queuing-02>.

[I-D.peng-detnet-deadline-based-forwarding]
Peng, S., Du, Z., Basu, K., cheng, Yang, D., and C. Liu, "Deadline Based Deterministic Forwarding", 20 June 2024, <https://datatracker.ietf.org/doc/html/draft-peng-detnet-deadline-based-forwarding-10>.

[I-D.peng-detnet-packet-timeslot-mechanism]
Peng, S., Liu, P., Basu, K., Liu, A., Yang, D., and G. Peng, "Timeslot Queueing and Forwarding Mechanism", 20 June 2024, <https://datatracker.ietf.org/doc/html/draft-peng-detnet-packet-timeslot-mechanism-07>.

[I-D.song-opsawg-ifit-framework]
Song, H., Qin, F., Chen, H., Jin, J., and J. Shin, "Framework for In-situ Flow Information Telemetry", 23 October 2023, <https://datatracker.ietf.org/doc/html/draft-song-opsawg-ifit-framework-21>.

[IEEE802.1CB]
"IEEE Standard for Local and metropolitan area networks--Frame Replication and Elimination for Reliability", 2017, <https://ieeexplore.ieee.org/document/8091139>.

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

[RFC5357] Hedayat, K., Krzanowski, R., Morton, A., Yum, K., and J. Babiarz, "A Two-Way Active Measurement Protocol (TWAMP)", RFC 5357, DOI 10.17487/RFC5357, October 2008, <https://www.rfc-editor.org/info/rfc5357>.

[RFC5880] Katz, D. and D. Ward, "Bidirectional Forwarding Detection (BFD)", RFC 5880, DOI 10.17487/RFC5880, June 2010, <https://www.rfc-editor.org/info/rfc5880>.

[RFC6374] Frost, D. and S. Bryant, "Packet Loss and Delay Measurement for MPLS Networks", RFC 6374, DOI 10.17487/RFC6374, September 2011, <https://www.rfc-editor.org/info/rfc6374>.

[RFC7799] Morton, A., "Active and Passive Metrics and Methods (with Hybrid Types In-Between)", RFC 7799, DOI 10.17487/RFC7799, May 2016, <https://www.rfc-editor.org/info/rfc7799>.

[RFC8321] Fioccola, G., Ed., Capello, A., Cociglio, M., Castaldelli, L., Chen, M., Zheng, L., Mirsky, G., and T. Mizrahi, "Alternate-Marking Method for Passive and Hybrid Performance Monitoring", RFC 8321, DOI 10.17487/RFC8321, January 2018, <https://www.rfc-editor.org/info/rfc8321>.

[RFC8655] Finn, N., Thubert, P., Varga, B., and J. Farkas, "Deterministic Networking Architecture", RFC 8655, DOI 10.17487/RFC8655, October 2019, <https://www.rfc-editor.org/info/rfc8655>.

[RFC8762] Mirsky, G., Jun, G., Nydell, H., and R. Foote, "Simple Two-Way Active Measurement Protocol", RFC 8762, DOI 10.17487/RFC8762, March 2020, <https://www.rfc-editor.org/info/rfc8762>.

[RFC9197] Brockners, F., Ed., Bhandari, S., Ed., and T. Mizrahi, Ed., "Data Fields for In Situ Operations, Administration, and Maintenance (IOAM)", RFC 9197, DOI 10.17487/RFC9197, May 2022, <https://www.rfc-editor.org/info/rfc9197>.

[RFC9326] Song, H., Gafni, B., Brockners, F., Bhandari, S., and T. Mizrahi, "In Situ Operations, Administration, and Maintenance (IOAM) Direct Exporting", RFC 9326, DOI 10.17487/RFC9326, November 2022, <https://www.rfc-editor.org/info/rfc9326>.

[RFC9546] Mirsky, G., Chen, M., and B. Varga, "Operations, Administration, and Maintenance (OAM) for Deterministic Networking (DetNet) with the MPLS Data Plane", RFC 9546, DOI 10.17487/RFC9546, February 2024, <https://www.rfc-editor.org/info/rfc9546>.

[RFC9551] Mirsky, G., Theoleyre, F., Papadopoulos, G., Bernardos, CJ., Varga, B., and J. Farkas, "Framework of Operations, Administration, and Maintenance (OAM) for Deterministic Networking (DetNet)", RFC 9551, DOI 10.17487/RFC9551, March 2024, <https://www.rfc-editor.org/info/rfc9551>.

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