DetNet Working Group
Internet-Draft
Intended status: Standards Track
Expires: January 14, 2021

Y. Jiang
N. Finn
Huawei Technologies
J. Ryoo
ETRI
B. Varga
Ericsson
L. Geng
China Mobile

July 13, 2020

Deterministic Networking Application in Ring Topologies
draft-jiang-detnet-ring-06

Abstract

Deterministic Networking (DetNet) provides a capability to carry data flows for real-time applications with extremely low data loss rates and bounded latency. This document describes how DetNet can be used in ring topologies to support Point-to-Point (P2P) and Point-to-Multipoint (P2MP) real-time services.

Table of Contents

1. Introduction

The overall architecture for Deterministic Networking (DetNet), which provides a capability to carry specified unicast or multicast data flows for real-time applications with extremely low data loss rates and bounded latency, is specified in [RFC8655], and the generic data plane framework, which is common to any DetNet data plane implementations, is provided at [I-D.ietf-detnet-data-plane-framework]. In addition to the DetNet architecture documents, RFC 8578 [RFC8578] outlines several DetNet

use cases where multicast capability is needed. If a multicast service replicates all of its packets from the source (as a traditional Virtual Private LAN Service (VPLS) does), the requirements of deterministic delay and high availability for all these replicated packets will pose a great challenge to the DetNet network.

Ring topologies have been very popular and widely deployed in network arrangements for various transport networks, such as Synchronous Digital Hierarchy, Synchronous Optical Network, Optical Transport Network, and Ethernet. For Multi-Protocol Label Switching - Transport Profile (MPLS-TP), the applicability of the MPLS-TP linear protection [RFC6378][RFC7271] for ring topologies and the ring-specific protection mechanism are specified in RFC 6974 [RFC6974] and RFC 8227 [RFC8227], respectively. All these works, except Ethernet ring protection, typically use swapping or steering as the protection mechanism. As ring topologies are widely deployed for transport networks, it is also necessary for the DetNet to support ring topologies.

This document demonstrates how the DetNet can be used in a ring topology. Specifically, DetNet ring supports for Point-to-Point (P2P) and Point-to-Multipoint (P2MP, for multicast services) are discussed in details. This document assumes that the Multi-Protocol Label Switching (MPLS) encapsulation for DetNet is supported as specified in [I-D.ietf-detnet-mpls] and all nodes in a ring network can support the MPLS functionalities. It should be noted that it is more convenient for the DetNet to support a ring topology with the intrinsic duplication and elimination mechanism, as there is no need of swapping or steering operations (consequently, its Operations, Administration and Maintenance (OAM) can also be simplified) for service protection.

2. Conventions Used in This Document

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. Abbreviations

This document uses the following abbreviations:

DetNet	Deterministic Networking
LSP	Label Switched Path
MPLS	Multi-Protocol Label Switching
MPLS-TP	Multi-Protocol Label Switching - Transport Profile
P2MP	Point-to-Multipoint
P2P	Point-to-Point
PEF	Packet Elimination Function
POF	Packet Ordering Function
PRF	Packet Replication Function
PW	Pseudowire

4. P2P DetNet Ring

This section describes how the DetNet can deliver P2P traffic over a single ring.

4.1. DetNet applications on a single ring for P2P traffic

Figure 1 shows an example of the DetNet ring for P2P real time traffic. Nodes A and C are DetNet aware devices, and P2P DetNet traffic is transported from node A to node C.

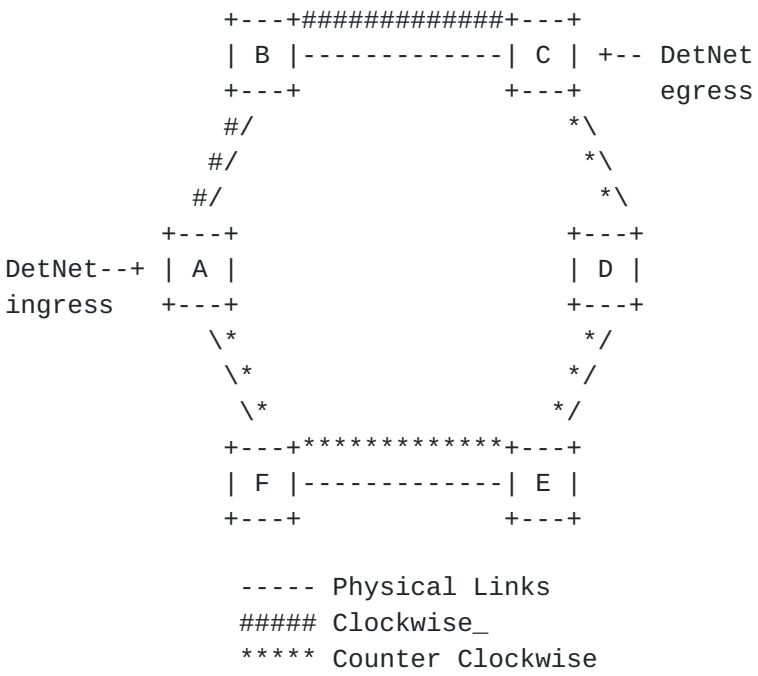

Figure 1: DetNet Ring for P2P traffic

A clockwise and a counter clockwise Label Switched Paths (LSPs) are configured from node A to node C using the DetNet forwarding labels

(F-Labels) are configured from node A to node C. The DetNet service sub-layer functions are provided at nodes A and C utilizing the DetNet service label(s) (S-Label) and DetNet control word (d-CW) as described in [I-D.ietf-detnet-mpls]. The P2P traffic is replicated by a Packet Replication Function (PRF) in node A, encapsulated with the d-CW and specific S-Label and F-Label(s), and transported on both LSP paths towards node C. Upon reception of the traffic, node C terminates the LSP and is aware of the DetNet traffic by inspection of the S-Label carried in each packet. A Packet Elimination Function (PEF) in node C guarantees that only one copy of the DetNet service exits on egress with the help of the DetNet sequence number. A Packet Ordering Function (POF) can further reorder packets in node C before transport of these packets to the destination.

4.2. Implementation implications of a DetNet ring for P2P traffic

In a DetNet ring for P2P traffic, one path may be far longer than the other path. The buffer for reordering at the egress needs to be large enough to accommodate for the sequence number difference between these two paths.

5. P2MP DetNet Ring

5.1. DetNet applications on a single ring for P2MP traffic

Figure 2 shows an example of the DetNet ring for P2MP real time traffic. Nodes A, B, C, E and F are DetNet aware devices, and P2MP DetNet traffic is transported from head-end node A to multiple tail-end nodes C, E and F.

Two approaches are described in Section 5.2 and Section 5.3 for P2MP traffic.

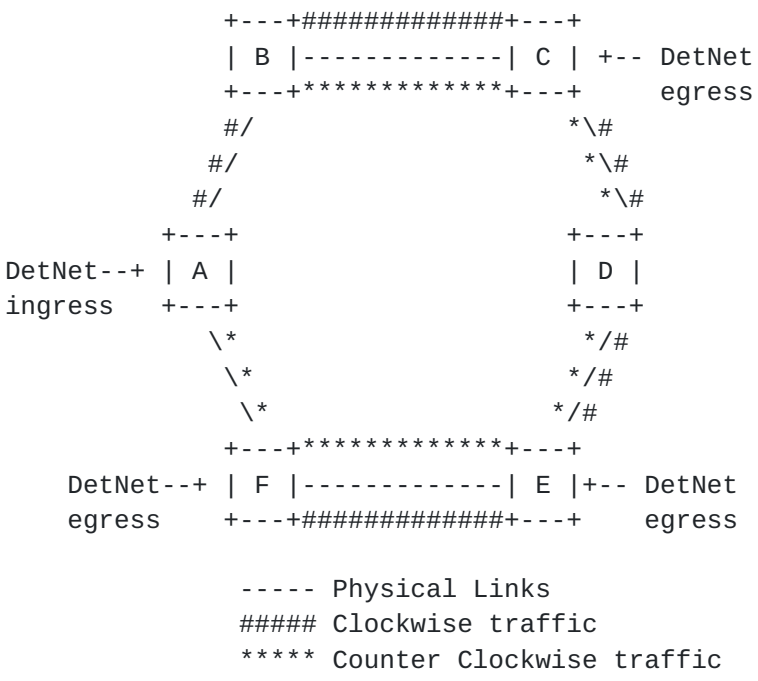

Figure 2: DetNet Ring for P2MP traffic

5.2. Section LSPs as underlay (service sub-layer replication)

If section LSPs are used as an underlay for DetNet services, a bidirectional section LSP tunnel is set up between each pair of neighboring nodes in the ring (e.g., node A and node B, ..., node F and node A). In this case, the DetNet sub-layer replicates the DetNet packets from one tail-end to another neighboring tail-end.

The DetNet head-end (i.e., node A) in the ring needs to support DetNet replication function. Upon reception on node A, the DetNet traffic is replicated with a d-CW, encapsulated with a S-Label and a section LSP label per DetNet member flow, and transported on both section LSPs (i.e., A-B and A-F).

All intermediate nodes (non tail-ends) on the ring MUST transparently forward the DetNet packet, which contains a d-CW and S-Label, to the next hop on the ring.

All DetNet tail-ends except the penultimate node (egress nodes such as nodes C and E in the clockwise, and nodes F, E and C in the counter clockwise) on the ring MUST support both DetNet PRF and PEF functions, and MAY further support a DetNet POF function. For the example of Figure 2, upon reception of the clockwise traffic, node C terminates the section LSP and recognizes the DetNet flow by inspection of the S-label in the packet. Firstly, node C needs to forward the DetNet packet to the next hop on the ring in the

clockwise direction. Secondly, the DetNet packet is also directed to a DetNet PEF associated with the DetNet flow, only one copy is egressed from the ring by inspection of the sequence number in the d-CW. Furthermore, if the DetNet POF function is enabled, the packets in the DetNet flow are reordered before exit to DetNet egress.

If multiple endpoints are attached to a tail-end node, a multicast module can be used to forward the traffic to all these endpoints.

To avoid a loop of DetNet service, the penultimate node in the ring (such as node B on the counter clock-wise LSP) MUST terminate the DetNet flow. For example, upon reception of the clockwise DetNet traffic, node F terminates the DetNet traffic by inspection of the S-Label in the packet. As an alternative, the last DetNet tail-end (such as node C on the counter clock-wise LSP) MAY terminate the DetNet flow, so that the bandwidth from this node to the penultimate node can be saved.

5.3. P2MP LSP tunnels as underlay (forwarding sub-layer replication)

If P2MP LSPs are used as an underlay for the DetNet service, a P2MP unidirectional LSP tunnel in clockwise is set up from head-end (ingress node A) to all the tail-ends (egress nodes C, E and F) for the ring, and another P2MP unidirectional LSP tunnel in counter clockwise is set up from head-end (ingress node A) to all the tail-ends (egress nodes F, E and C) for the ring. Thus, a PRF in LSP layer replicates the DetNet packets from one tail-end to another neighboring tail-end.

The DetNet head-end (i.e., node A) in the ring needs to support the DetNet PRF function. Upon reception on node A, the DetNet traffic is replicated with a d-CW, encapsulated with a S-Label per DetNet member flow, and transported on both P2MP LSP tunnels in the ring.

All DetNet tail-ends (egress nodes such as nodes C, E and F in Figure 2) on the ring need to support the DetNet PEF function. For example, upon reception of the traffic, node C pops the P2MP LSP label and is aware of the DetNet traffic by inspection of the S-Label label in the label stack. Two DetNet member flows are identified with their S-Labels and directed to the same PEF so that only one copy of the DetNet service is selected by inspection of the DetNet sequence number in the d-CW. Furthermore, if DetNet POF function is enabled, the packets in the DetNet flow are reordered before exit to DetNet egress.

If multiple endpoints are attached to a tail-end node, a multicast module can be used to forward the filtered DetNet traffic to all these endpoints

6. DetNet Ring Interconnections

Two DetNet rings can be connected via one or more interconnection nodes. Figure 3 shows the ring interconnection scenarios with a single node and dual nodes. In the interconnected rings, each ring operates in the same way as described in Section 4 and Section 5 except the node or nodes that are used to interconnect two rings.

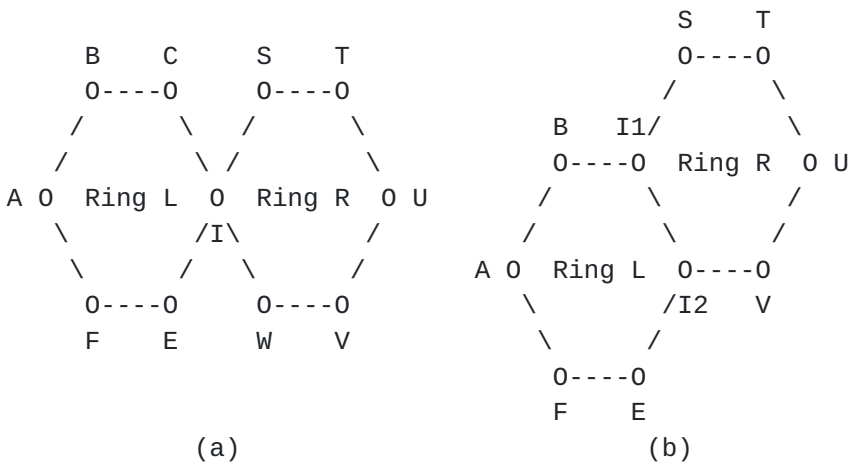

Figure 3: DetNet ring interconnection with: (a) single node (node I), and (b) dual nodes (nodes I1 and I2)

In this section, we describe the behavior of interconnection nodes with the traffic going from Ring L to Ring R. Symmetrical description is assumed for the traffic in the other direction (i.e., from Ring R to Ring L).

6.1. Single node interconnection

In the case of the single node interconnection, as shown in Figure 3(a), both P2P and P2MP DetNet traffic that needs to be transported between Ring L and Ring R use a single interconnection node between two rings. Thus, the interconnection node acts as a DetNet relay node, which provides both PRF and PEF functions.

For P2P DetNet traffic going from Ring L to Ring R, interconnection node I receives the same DetNet flow traffic from both node C and node E (i.e., clockwise and counter-clockwise), a PEF in node I performs packet elimination, and a PRF in node I replicates the packet, node I then sends one copy to node S and another copy to node W.

For P2MP DetNet traffic going from Ring L to Ring R, interconnection node I performs the same packet elimination and replication functions as described above. In addition, node I further transparently forwards the P2MP DetNet traffic on Ring L in the same direction if it is not the last tail-end node.

6.2. Dual node interconnection

In order to prevent a single point of failure, two interconnection nodes can be used as shown in Figure 3(b). To provide high availability for DetNet services, dual node interconnection is recommended. Two interconnection nodes act as DetNet relay nodes, each provides both packet replication and elimination functions.

6.2.1. Dual node interconnection for P2P traffic

For the P2P DetNet traffic that flows from Ring L to Ring R in Figure 3(b), the operations of interconnection nodes I1 and I2 are described below.

When interconnection node I1 receives clockwise traffic from node B, it replicates the traffic and sends one copy to interconnection node I2 and the other copy to a PEF in interconnection node I1.

When interconnection node I1 receives counter-clockwise traffic from interconnection node I2, it forwards the traffic to the PEF of interconnection node I1.

At the PEF of interconnection node I1, duplicate elimination is performed for the clockwise traffic from node B and the counter-clockwise traffic from interconnection node I2, and only one copy is sent to the clockwise direction of Ring R (i.e., sent towards node S). Furthermore, if DetNet POF function is enabled on interconnection node I1, the packets in the DetNet flow are reordered before being forwarded to Ring R.

When interconnection node I2 receives counter-clockwise traffic from node E, it replicates the traffic and sends one copy to interconnection node I1 and the other copy to a PEF in interconnection node I2.

When interconnection node I2 receives clockwise traffic from interconnection node I1, it forwards the traffic to the PEF of interconnection node I2.

At the PEF of interconnection node I2, duplicate elimination is performed for the counter-clockwise traffic from node E and the clockwise traffic from interconnection node I1, and only one copy is

sent to the counter-clockwise direction of Ring R (i.e., sent towards node V). Furthermore, if DetNet POF function is enabled on interconnection node I2, the packets in the DetNet flow are reordered before being forwarded to Ring R.

6.2.2. Dual node interconnection for P2MP traffic using section LSP

For the P2MP traffic that flows from Ring L to Ring R in Figure 3(b), each ring is configured and operated as described in Section 5.2 except the interconnection nodes, whose operations are described below.

When interconnection node I1 receives clockwise traffic from node B, its PRF replicates the traffic and sends one copy to interconnection node I2 and the other copy to interconnection node I1's PEF.

When interconnection node I1 receives the counter-clockwise traffic from interconnection node I2, its PRF replicates the traffic and sends one copy to node B and the other copy to interconnection node I1's PEF unless interconnection node I1 is the penultimate node for the counter-clockwise traffic on Ring L. In the case that interconnection node I1 is the penultimate node for the counter-clockwise traffic on Ring L, the counter-clockwise traffic from interconnection node I2 is only forwarded to interconnection node I1's PEF.

At interconnection node I1's PEF, duplicate elimination is performed for the clockwise traffic from node B and the counter-clockwise traffic from interconnection node I2, and only one copy is sent to the clockwise direction of Ring R (i.e., sent towards node S). Furthermore, if DetNet POF function is enabled on node I1, the packets in the DetNet flow are reordered before being forwarded to Ring R.

When interconnection node I2 receives the counter-clockwise traffic from node E, its PRF replicates the traffic and sends one copy to interconnection node I1 and the other copy to node I2's PEF.

When interconnection node I2 receives the clockwise traffic from interconnection node I1, its PRF replicates the traffic and sends one copy to node E and the other copy to interconnection node I2's PEF unless interconnection node I2 is the penultimate node for the clockwise traffic on Ring L. In the case that interconnection node I2 is the penultimate node for the clockwise traffic on Ring L, the clockwise traffic from interconnection node I1 is only forwarded to node I2's PEF.

At node I2's PEF, duplicate elimination is performed for the counter-clockwise traffic from node E and the clockwise traffic from interconnection node I1, and only one copy is sent to the counter-clockwise direction of Ring R (i.e., sent towards node V). Furthermore, if DetNet POF function is enabled on interconnection node I2, the packets in the DetNet flow are reordered before being forwarded to Ring R.

6.2.3. Dual node interconnection for P2MP traffic using P2MP LSP

If P2MP LSPs are used in the interconnected rings, two P2MP unidirectional LSP tunnels are used on each ring for the clockwise and counter-clockwise directions.

When the P2MP traffic is forwarded from one ring to another ring, for example from Ring L to Ring R in Figure 3(b), each P2MP LSP in Ring L MUST include interconnection nodes I1 and I2 as its tail-ends. For Ring R, one P2MP LSP is set up from interconnection node I1 to all the tail-ends in the clockwise direction on Ring R, and the other P2MP LSP is set up from interconnection node I2 to all the tail-ends in the counter-clockwise direction on Ring R. Therefore, an interconnection node acts as a tail-end for one ring and a head-end for another ring in one direction, and performs the same operation of tail-end and head-end as specified in Section 5.3.

7. Resource Reservation

In order to guarantee that DetNet flows do not suffer from network congestion, the DetNet data plane considerations on resource reservation and allocation as described in [I-D.ietf-detnet-data-plane-framework] apply here.

8. IANA Considerations

There are no IANA actions required by this document

9. Security Considerations

This document describes the application of DetNet MPLS on ring topologies. Thus, the security considerations described in [I-D.ietf-detnet-mpls] are also applied to this document. If any new security considerations specific to ring topologies are identified, they will be added in a future version of this draft.

10. Editor's Note

This section lists current issues raised by experts in DetNet and other ring protection technologies. This section will be removed once the issues are addressed.

- See if Resilient MPLS Ring (RMR) can be used for automatic configuration of a DetNet ring topology network.
- Consideration of coexistence with existing ring protection solutions in the DetNet forwarding sublayer.
- Consideration on scalability
- Explain why this document is needed when the DetNet architecture and data plane documents exist.

11. References

11.1. Normative References

[I-D.ietf-detnet-data-plane-framework]
Varga, B., Farkas, J., Berger, L., Malis, A., and S. Bryant, "DetNet Data Plane Framework", draft-ietf-detnet-data-plane-framework-06 (work in progress), May 2020.

[I-D.ietf-detnet-mpls]
Varga, B., Farkas, J., Berger, L., Malis, A., Bryant, S., and J. Korhonen, "DetNet Data Plane: MPLS", draft-ietf-detnet-mpls-09 (work in progress), July 2020.

[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>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[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>.

11.2. Informative References

[RFC6378] Weingarten, Y., Ed., Bryant, S., Osborne, E., Sprecher, N., and A. Fulignoli, Ed., "MPLS Transport Profile (MPLS-TP) Linear Protection", RFC 6378, DOI 10.17487/RFC6378, October 2011, <https://www.rfc-editor.org/info/rfc6378>.

[RFC6974] Weingarten, Y., Bryant, S., Ceccarelli, D., Caviglia, D., Fondelli, F., Corsi, M., Wu, B., and X. Dai, "Applicability of MPLS Transport Profile for Ring Topologies", RFC 6974, DOI 10.17487/RFC6974, July 2013, <https://www.rfc-editor.org/info/rfc6974>.

[RFC7271] Ryoo, J., Ed., Gray, E., Ed., van Helvoort, H., D'Alessandro, A., Cheung, T., and E. Osborne, "MPLS Transport Profile (MPLS-TP) Linear Protection to Match the Operational Expectations of Synchronous Digital Hierarchy, Optical Transport Network, and Ethernet Transport Network Operators", RFC 7271, DOI 10.17487/RFC7271, June 2014, <https://www.rfc-editor.org/info/rfc7271>.

[RFC8227] Cheng, W., Wang, L., Li, H., van Helvoort, H., and J. Dong, "MPLS-TP Shared-Ring Protection (MSRP) Mechanism for Ring Topology", RFC 8227, DOI 10.17487/RFC8227, August 2017, <https://www.rfc-editor.org/info/rfc8227>.

[RFC8578] Grossman, E., Ed., "Deterministic Networking Use Cases", RFC 8578, DOI 10.17487/RFC8578, May 2019, <https://www.rfc-editor.org/info/rfc8578>.

Authors' Addresses

Yuanlong Jiang
Huawei Technologies
Bantian, Longgang district
Shenzhen 518129
China

Phone: +86-18926415311
Email: jiangyuanlong@huawei.com

Norman Finn
Huawei Technologies
3755 Avocado Blvd
California 91941
USA

Phone: +1 925 980 6430
Email: norman.finn@mail01.huawei.com

Jeong-dong Ryoo
ETRI
218 Gajeongno
Yuseong-gu, Daejeon 34129
South Korea

Phone: +82-42-860-5384
Email: ryoo@etri.re.kr

Balazs Varga
Ericsson
Konyves Kalman krt. 11/B
Budapest 1097
Hungary

Email: balazs.a.varga@ericsson.com

Liang Geng
China Mobile
Beijing
China

Email: gengliang@chinamobile.com