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# Deterministic Networking Application in Ring Topologies
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## 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.

## Status of this Memo

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## 1. Introduction

An overview of Deterministic Networking (DetNet) architecture is given in [I-D.ietf-detnet-architecture], and DetNet data plane encapsulations are specified in [I-D.ietf-detnet-dp-sol]. But there is not any discussion on a ring topology in [I-D.ietf-detnet-architecture] yet. Furthermore, [I-D.ietf-detnet-use-cases] 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.

In fact, 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. The IETF has done some work on ring protection in Multi-Protocol Label Switching - Transport Profile (MPLS-TP), such as [RFC6974] and [RFC8227]. 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 DetNet to support ring topologies (currently, there is not any discussion on a ring topology in [I-D.ietf-detnet-architecture] yet).

This draft demonstrates how 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 MPLS encapsulation for DetNet is supported as specified in [I-D.ietf-detnet-dp-sol] and all nodes in a ring network can support the Multi-Protocol Label Switching (MPLS) functionalities. It should be noted that it is more convenient for DetNet to support a ring topology with the intrinsic duplication and elimination mechanism, as there is no need of swapping or steering operations (consequently, Operations, Administration and Maintenance is not needed either for its working) for any service protection.

### 1.1. Conventions used in this document

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].

### 1.2. Terminology

DetNet  Deterministic Networking

LSP    Label Switched Path

MPLS    Multi-Protocol Label Switching

MPLS-TP Multi-Protocol Label Switching - Transport Profile

P2MP   Point-to-Point

P2P    Point-to-Multipoint

PW      Pseudowire

## 2. P2P DetNet Ring

### 2.1. DetNet applications on a single ring for P2P traffic

Figure 1 depicts 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.

A clockwise and a counter clockwise Pseudowire (PW) and Label Switched Path (LSP) tunnel are configured from node A to node C respectively. The DetNet traffic is replicated on node A, encapsulated with the specific PW and LSP labels, 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 PW label carried in each packet. An elimination function in node C guarantees that only one copy of the DetNet service exits on egress with the help of the DetNet sequence number.

```
                          +---+#############+---+
                          | B |-------------| C | +-- DetNet
                          +---+             +---+     egress
                          #/                    *\
                         #/                      *\
                        #/                        *\
                      +---+                     +---+
            DetNet--+ | A |                     | D |
           ingress    +---+                     +---+
                         \*                      */
                          \*                    */
                           \*                  */
                          +---+*************+---+
                          | F |-------------| E |
                          +---+             +---+

                            ----- Physical Links
                            ##### Clockwise_
                            ***** Counter Clockwise
```

Figure 1: DetNet Ring for P2P traffic

## 2.2. 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 for the DetNet (this is a DetNet issue more general than a ring).

The buffer need to be large enough to accommodate for the sequence number difference between these two paths. Otherwise, some packets may get lost when a link fault causes traffic switching from a path to another path.

# 3. P2MP DetNet Ring

## 3.1. DetNet applications on a single ring for P2MP traffic

Figure 2 further depicts 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 3.2 and 3.3 for P2MP traffic.

```
                          +---+#############+---+
                          | B |-------------| C | +-- DetNet
                          +---+*************+---+     egress
                          #/                    *\#
                         #/                      *\#
                        #/                        *\#
                      +---+                     +---+
            DetNet--+ | A |                     | D |
           ingress    +---+                     +---+
                         \*                      */#
                          \*                    */#
                           \*                  */#
                          +---+*************+---+
                DetNet--+ | F |-------------| E |+-- DetNet
                egress    +---+#############+---+    egress

                            ----- Physical Links
                            ##### Clockwise traffic
                            ***** Counter Clockwise traffic
```

Figure 2: DetNet Ring for P2MP traffic

## 3.2. Section LSPs as underlay (Service 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, DetNet PW 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 in node A, encapsulated with the specific PW and section LSP labels, and then transported on both section LSPs (i.e., A-B and A-F) originated from the head-end.

All intermediate nodes (non tail-ends) on the ring SHOULD transparently forward the DetNet traffic with a specific PW to the next hop on the ring in the same direction.

All DetNet tail-ends except the penultimate node (egress nodes such as nodes C and E in the clockwise, and node F, E and C in the counter clockwise) on the ring MUST support both DetNet

replication and elimination functions. For example, upon reception of the clockwise traffic, node C terminates the section LSP and is aware of the DetNet traffic by inspection of the PW label in the packet. Firstly, node C needs to transparently forward the DetNet traffic with a specific PW to the next hop on the ring in the same direction. Secondly, DetNet traffic is directed to a DetNet elimination function associated with a specific PW, only one copy of the DetNet service exits on egress by inspection of the DetNet sequence number.

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.

To avoid a loop of DetNet service, the penultimate node in the ring (such as node B on the counter clock-wise LSP) needs to terminate the DetNet flow. For example, upon reception of the clockwise DetNet traffic, node F terminates the DetNet traffic by inspection of the PW 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.

## 3.3. P2MP LSP tunnels as underlay (LSP 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, 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 DetNet replication function. Upon reception on node A, the DetNet traffic is replicated, encapsulated with the specific PW and P2MP LSP labels, and transported on both P2MP LSP tunnels in the ring.

All DetNet tail-ends (egress nodes such as node C, E and F in Figure 2) on the ring need to support the DetNet elimination 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 PW label in the label stack. Traffic from both directions with the same PW is directed to the same DetNet elimination

function so that only one copy of the DetNet service exits on egress by inspection of the DetNet sequence number.

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.

## 4. DetNet Ring Interconnections

Two DetNet rings can be connected via one or more interconnection nodes. Figures 3a and 3b show ring interconnection scenarios with a single node and dual nodes, respectively. In the interconnected rings, each ring operates in the same way as described in Sections 2 and 3 except the nodes that are used to interconnect two rings.

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.

```
                                         S   T
      B   C     S   T                    O---O
      O---O     O---O                   /     \
     /     \   /     \            B  I1/       \
    /       \ /       \           O---O  Ring R O U
 A O Ring L  O Ring R  O U       /     \       /
    \       /I\       /         /       \     /
     \     /   \     /       A O Ring L  O---O
      O---O     O---O           \       /I2  V
      F   E     W   V            \     /
                                  O---O
                                  F   E
         (a) (b)
```

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

### 4.1. 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 uses the single interconnection node between two rings. Two approaches are described in the following subsections.

### 4.1.1. DetNet relay node as interconnection node

In this approach, the interconnection node acts as a DetNet relay node, which provides packet replication and elimination.

For P2P DetNet traffic going from Ring L to Ring R, interconnection node I performs packet replication on input and sends the packet to the outputs connected to the links on Ring R clockwise and counter-clockwise. Then, after each output of interconnection node I eliminates any duplicates, the packet is transported over Ring R. In Figure 3(a), when interconnection node I receives traffic on input from node C, node I replicates the traffic and send it to both outputs to nodes S and W. For the traffic from input from node E, node I also replicates the traffic and send it to both outputs to nodes S and W. Then, the output to node S eliminates any duplicates, and sends only one copy to node S. Similarly, the output to node W eliminates any duplicates, and sends only one copy to node W.

For P2MP DetNet traffic going from Ring L to Ring R, the input of interconnection node I performs the same packet replication as described for P2P DetNet traffic going from Ring L to Ring R. In addition, the third copy is sent to the other ring port on Ring L, in order to deliver the P2MP DetNet traffic to the remaining tail-end nodes that reside in the other side of Ring L over the interconnected node. The outputs to nodes S and W perform the same duplicate elimination as described for P2P DetNet traffic going from Ring L to Ring R.

### 4.1.2. Elimination first approach

This approach uses two "logical" DetNet relay nodes (or, DA-*-PE as described in [I-D.ietf-detnet-dp-sol]) coupled back-to-back, such that interconnection node I performs the duplicate elimination function first.

For the Detnet traffic arrived from both node C and node E, the interconnection node I performs duplicate elimination first, and then replicates the traffic in both clockwise and counter-clockwise directions of Ring R, i.e., one copy to node S and the other copy to node W. Therefore, this approach reduces the bandwidth used inside the interconnection node when there is a central unit that eliminates any duplicate among the packets arrived from two ring ports before replication.

### 4.2. 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, which provide packet replication and elimination.

#### 4.2.1. Dual node interconnection for P2P traffic

For the P2P DetNet traffic that flows from Ring L to Ring R, the operation of interconnection nodes I1 and I2 follows the description on relay nodes shown in Figure 1 of Section 3.2.4 in [I-D.ietf-detnet-architecture]. In the following, the operation is explained with Figure 3(a).

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 output towards node S.

When interconnection node I1 receives counter-clockwise traffic from interconnection node I2, it forwards the traffic to the output that is connected to node S.

At the output of interconnection node I1 facing to node S, 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).

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 the output that is connected to node V.

When interconnection node I2 receives clockwise traffic from interconnection node I1, it forwards the traffic to the output that is connected to node V.

At the output of interconnection node I2 facing to node V, 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).

#### 4.2.2. Elimination first approach in dual node interconnection for P2P traffic

The elimination first approach described in Section 4.1.2 can also be used for dual node interconnection, so that each interconnection node performs the duplicate elimination function first.

For the traffic arrived from both node B and interconnection node I2, the interconnection node I1 performs duplicate elimination first, and replicates the traffic in both clockwise and counter-clockwise directions of Ring R, i.e., one copy to node S and the other copy to interconnection node I2.

For the traffic arrived from both node E and interconnection node I1, the interconnection node I2 performs duplicate elimination first, and replicates the traffic in both clockwise and counter-clockwise directions of Ring R, i.e., one copy to interconnection node I1 and the other copy to node V.

4.2.3.Dual node interconnection for P2MP traffic using section LSP

For the P2MP traffic that flows from Ring L to Ring R, each ring is configured and operated as described in Section 3.2 except the interconnection nodes, whose operations 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 the output that is connected to node S.

When interconnection node I1 receives the counter-clockwise traffic from interconnection node I2, it replicates the traffic and sends one copy to node B and the other copy to the output that is connected to node S 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 forwarded to the output that is connected to node S.

At the output interface of I1 facing to node S, 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).

When interconnection node I2 receives the counter-clockwise traffic from node E, it replicates the traffic and sends one copy to interconnection node I1 and the other copy to the output that is connected to node V.

When interconnection node I2 receives the clockwise traffic from interconnection node I1, it replicates the traffic and sends one copy to node E and the other copy to the output that is connected to node V unless interconnection node I2 is the penultimate node for the clockwise traffic in Ring L. In the case that interconnection node I2 is the penultimate node for the clockwise traffic in Ring L, the clockwise traffic from interconnection node I1 is forwarded to the output that is connected to node V.

At the output interface of I2 facing to node V, 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).

### 4.2.4. Elimination first approach in dual node interconnection for P2MP traffic using section LSP

The elimination first approach described in Section 4.2.2 is applied without modification for dual node interconnection for P2MP traffic using section LSP only if interconnection nodes I1 and I2 are the penultimate nodes for the counter-clockwise traffic and the clockwise traffic on Ring L, respectively.

When an interconnection node is not the penultimate node for either clockwise or counter-clockwise traffic, the interconnection node replicates the traffic in three ways; one for the remaining tail-ends on Ring L and two for the tail-ends in both clockwise and counter-clockwise directions on Ring R.

For example, assume that interconnection node I2 is not the penultimate node for the clock-wise traffic on Ring L. For the traffic arrived from both node E and interconnection node I1, interconnection node I2 performs duplicate elimination first, and replicates the traffic for the following three outputs; one copy to the output towards node E, another copy to the output towards interconnection node I1, and the other copy to the output towards node V.

#### 4.2.5.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 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 3.3.

## 5. Resource reservation

In order to guarantee that DetNet flows don't suffer from network congestion, resource reservation considerations as outlined in Section 4.3.2 of [I-D.ietf-detnet-architecture] apply here.

## 6. Security Considerations

This document describes the application of DetNet on general ring topologies. Thus the security considerations as described in [I-D.ietf-detnet-dp-sol] also apply to this document.

## 7. IANA Considerations

There are no IANA actions required by this document.

## 8. References

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## 9. Acknowledgments

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