PoC Reference of End-to-End Deterministic Networking with Software-Defined Optical Interconnect

Classification: APPROVED Reference Document
Confidentiality: PUBLIC
Version: 1
[E2E DN PoC Ref]
July 2026

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1. Purpose, Objective, Scope

1.1. Purpose

Deterministic Networking with Software-Defined Optical Interconnect (DN) [1] provides NIC-to-NIC deterministic connections (connections with deterministic performance) as a Service across optical transport paths, primarily by Open APN, that meet specified requirements with flexibility. The DN is expected to support both the requirements of various use cases and the implementation models defined by RIM-TF.

The purpose of this PoC reference is to facilitate conducting PoCs that demonstrate the concept of DN mentioned in [1] be realized and to accelerate deployment of DN for various use cases under multi-operator/multi-vendor infrastructure.

1.2. Objective

- Documenting reference cases of DN to be tested, and features and benchmarks to be measured for each reference case.
- In particular, this document sets the fundamental points to be tested in the PoC as follows.
    - To demonstrate that logical channels are established and deterministic data transfer is possible over the logical channels. The PoC document sets guidelines (such as delay) to be met.
    - To demonstrate that multiple logical channels are established from one endpoint to multiple endpoints and that multiple logical channels are provisioned over the wavelength path.
- Clarifying technologies (such as logical channels, APIs) and reference implementation models (DN-EP/G/I/C) to realize DN through PoC.

1.3. Scope

For this version of the document, the main scope is network layer (e.g., packet delivery delay and jitter). Ultimate value of DN is application performance enhancement, but this depends on transport layer protocols (such as RDMA) and applications used. As such, this document sets minimum guidelines for measuring transport layer performance and application performance. It is recommended to refer to PoC documents for use cases in RIM-TF if the PoC report includes transport layer performance and application performance.

This document mandates to report technologies (such as logical channels, APIs) and implementation models (DN-EP/G/I/C) used in PoC. Such report may be used as inputs for future revision of Functional Architecture document. Note that it is expected that the concept of DN

can be implemented based on existing technologies, possibly with some enhancements. Such necessary enhancements should be included in the PoC report, to be reflected in the future version of Functional Architecture and/or to be developed in collaboration with related bodies where necessary.

2. Reference Cases

In this document, two reference cases (Section 2.1. Network Only DN and Section 2.2. NIC to NIC DN) are described based on DN Functional Architecture [1]. PoC conductors are to choose at least one of the two reference cases.

2.1. Network Only DN

Figure 1 shows a reference case for network only DN, where a logical channel is established between a pair of client interfaces of DN-Gs specified. A logical channel is established with bandwidth requirement and delay/jitter requirement. In addition, OAM mechanisms (such as real-time monitoring) are provided for the established logical channel, and resiliency mechanisms (such as failure recovery) may be provided for the logical channel in the event of failures.

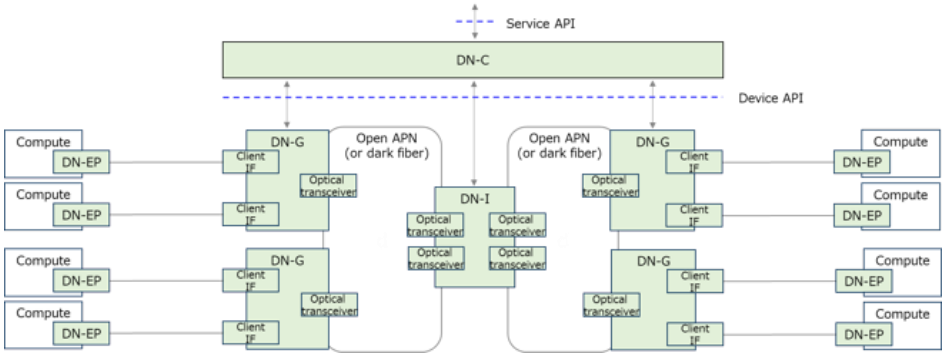

Figure 1: Network Only DN Reference Case

DN-C creates/deletes/updates logical channels based on requests received via a service API, communicating with DN-G and DN-I, via a device API. Furthermore, DN-C monitors performances and failures of logical channels by communicating with DN-G and DN-I via a device API.

This reference case corresponds to (5) DN-G to DN-G control mentioned in Section 4.4 of DN Functional Architecture [1]. It is an option to include data center switches between DN-G and DN-EP (corresponding to (4) Network to Network control).

Note that it is possible not to use DN-I (DN-Gs are directly connected), and it is possible to use multiple DN-Is. Also note that Open APN may or may not be used for connecting optical transceivers of DN-G/I. When Open APN is not used, two optical transceivers hosted on DN-I/G may be directly connected by dark fiber.

Below is the minimum configuration, with recommended configuration in bracket.

- Number of DN-G: 2 (3 or more is recommended)
- Number of DN-I: 0 (1 or more is recommended)

- Number of DN-EP: 3 (6 or more is recommended)
- Number of optical transceiver hosted on DN-G: 1
- Number of DN-EP connected to DN-G: 1 (2 or more is recommended)

The PoC report should include network diagram being used.

2.2. NIC to NIC DN

Figure 2 shows a reference case for NIC to NIC DN, where a logical channel is established between a pair of DN-EPs specified. A logical channel is established with bandwidth requirement and delay/jitter requirement. In addition, OAM mechanisms (such as real-time monitoring) are provided for the established logical channel, and resiliency mechanisms (such as failure recovery) may be provided for the logical channel in the event of failures.

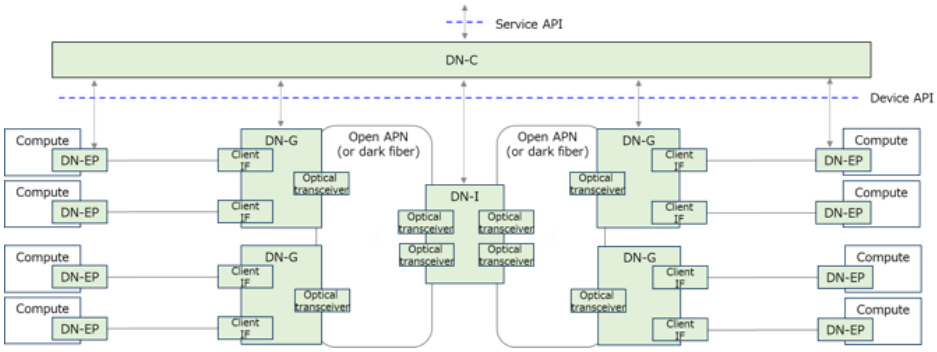

Figure 2: NIC to NIC DN Reference Case

DN-C creates/deletes/updates logical channels based on requests received via a service API, communicating with DN-G, DN-I and DN-EP, via a device API. Furthermore, DN-C monitors performances and failures of logical channels by communicating with DN-G, DN-I and DN-EP via a device API.

This reference case corresponds to (1) DN-EP to DN-EP control mentioned in Section 4.4 of DN Functional Architecture [1]. It is an option to use multiple DN-Cs for scalability or demarcation purposes (corresponding to (2) Network to Network control & DN-EP control and (3) DN-G to DN-G control & DN-EP + network within a site control).

Note that it is possible not to use DN-I (DN-Gs are directly connected), and it is possible to use multiple DN-Is. Also note that Open APN may or may not be used for connecting optical transceivers of DN-G/I. When Open APN is not used, two optical transceivers hosted on DN-I/G may be directly connected by dark fiber.

Below is the minimum configuration, with recommended configuration in bracket.

- Number of DN-G: 2 (3 or more is recommended)
- Number of DN-I: 0 (1 or more is recommended)

- Number of DN-EP: 3 (6 or more is recommended)
- Number of optical transceiver hosted on DN-G: 1
- Number of DN-EP connected to DN-G: 1 (2 or more is recommended)

The PoC report should include network diagram being used.

3. Desired Features

This section describes desired features to be tested. Features 1, 2 and 3 are primarily data plane features, while features 4 and 5 are primarily control plane features. Features 1, 2, 3, 4 and 5 apply to network only DN reference case well as NIC to NIC DN reference case.

Note that this PoC document considers that features 1 and 4 are mandatory features to be tested since these features are essential for DN. Features 2, 3, and 5 are additional features based on features 1 and 4.

3.1. Feature 1: Deterministic data transfer over logical channel

DN supports deterministic data transfer (such as bandwidth and delay/jitter guaranteed) over logical channels. As for desired features, we verify that logical channels with specified parameters (such as bandwidth, delay/jitter) are established. Actual data transfer performance is verified in benchmarks described in Section 4.1. Section 4.1 also describes performance guidelines (such as delay bound) to be met.

Specifically, the following features should be verified.

- Verify that a logical channel with specified parameters (such as bandwidth, delay/jitter) is established between a pair of endpoints. At minimum, bandwidth should be included as parameters. The PoC report should describe parameters being specified for a logical channel.
- Verify that multiple logical channels are established, where one endpoint of these logical channels is identical while the other endpoint of these logical channels is different. This allows one endpoint is divided into multiple logical channels, destined to different locations. A logical channel can be unidirectional or bidirectional. In the case of unidirectional, verify that (1) the endpoint shared by multiple logical channels is a traffic source (traffic from the same endpoint toward multiple different endpoints), and that (2) the endpoint shared by multiple logical channels is a traffic destination (traffic to the same endpoint from multiple different endpoints). Note that this feature requires switching capabilities in DN-G and/or DN-I. The PoC report should describe logical channels being established.
- Verify that multiple logical channels are established over the same wavelength path (or dark fiber if Open APN is not used) between DN-G/I and DN-G/I.
- Note that for network only DN reference case, an endpoint means a client interface of DN-G. For NIC to NIC DN reference case, an endpoint means DN-EP.

3.2. Feature 2: OAM

In DN, OAM mechanisms (such as real-time performance monitoring and fault management) are provided for logical connections being established. Data plane based OAM mechanisms are used and reported/notified to DN-C.

Specifically, the following feature should be verified.

- Verify that OAM mechanisms (such as loss/delay/jitter monitoring, failure detection) are provided for logical channels being established. The PoC report should describe parameters monitored/detected in data plane. Also, the PoC report should describe conditions to be reported/notified to DN-C.

3.3. Feature 3: Resiliency

DN supports resiliency mechanisms (such as protection and restoration) for logical channels.

Specifically, the following feature should be verified.

- Verify that a logical channel is switched over to an alternate route in case of failures (such as link failure and node failure). The PoC report should describe failure scenarios and resiliency mechanisms.

3.4. Feature 4: Logical channel setup/deletion/update

DN supports logical channel setup/deletion/update via a service API. Specifically, logical channel setup/deletion/update is requested via a service API to DN-C, and DN-C communicates with DN-EP/G/I.

Specifically, the following features should be verified.

- Verify that DN-C setups a logical channel with parameters (such as a pair of endpoints, bandwidth, delay/jitter, resiliency) being specified through a service API. At minimum, a pair of endpoints and bandwidth should be included as parameters. The PoC report should describe parameters being specified through a service API. Also, the PoC report should describe addressing format of endpoint.
- Verify that DN-C deletes a logical channel already established through a service API.
- Verify that DN-C updates parameters of logical channels already established through a service API. The PoC report should describe parameters being updated through a service API.

3.5. Feature 5: Status check/notification of logical channel

DN supports logical channel status check/notification via a service API. Specifically, status of logical channels already established is requested via a service API to DN-C and reported, or status for logical channels already established is notified via a service API from DN-C.

Specifically, the following features should be verified.

- Verify that DN-C reports status of logical channels already established based on requests through a service API. The PoC report should describe parameters being reported through a service API.
- Verify that DN-C notifies status of logical channels already established through a service API. The PoC report should describe parameters being notified through a service API. Also, the PoC report should describe conditions for triggering notifications.

3.6. Other considerations

Based on use case requirements, it is necessary to support specific protocols (such as RDMA, PTP) to be supported over logical channels. The PoC report should describe specific protocols supported over logical channels if any. In such cases, it is recommended to refer to appropriate use case PoC references defined in RIM-TF.

When DN interacts with Open APN, more flexible control is possible for resiliency and cost efficiency. It is recommended that the PoC report includes such scenarios and features tested if applicable.

4. Key Benchmarks

This section describes key benchmarks to be measured. Benchmarks 1, 2, and 3 are primarily data plane benchmarks, while benchmark 4 is primarily a control plane benchmark. Benchmarks 1, 2, 3, and 4 apply to network only DN reference case well as NIC to NIC DN reference case.

Note that this PoC document considers that benchmarks 1 and 4 are mandatory benchmarks to be measured since these benchmarks are essential for DN.

4.1. Benchmark 1: Data transfer performance

This benchmark corresponds to feature 1.

- Measure number of logical channels being established (per endpoint, as well as per wavelength path).
- Measure throughput, loss, delay and jitter for data transfer over logical channels being established. This PoC document sets the performance guideline as follows.
  - Bandwidth & throughput: 10Gbps (per logical channel) at minimum
  - Packet/frame loss rate & packet/frame reordering (for all hops one way): none (10^(-6) or less, for MTU size 1500 bytes as a reference)
  - Delay & jitter: Excluding fiber length delay, additional 100us delay or less for all hops one way (average delay 100us and maximum jitter 10us) (See Annex A for reasoning)
  - Measuring duration of time: 1 minute as a reference.
- Measurement method can be a tester (with traffic generator), an in-line capture or OAM mechanisms.
- The PoC report should describe measurement results as well as measurement methods. The PoC report should describe reasons if above-mentioned performance guidelines are not met.
- Note that some use cases require to provide multiple service grades, such as guaranteed type of service and best effort type of service [1]. For best effort type of service, it is not required to achieve loss-less. It is an option that the PoC report includes such results.

4.2. Benchmark 2: OAM performance

This benchmark corresponds to feature 2.

- Measure OAM monitoring interval (for periodic monitoring) and/or detection speed (time between an event happens and an event is detected).
- Measurement method can be a collector or logs.

- The PoC report should describe measurement results as well as measurement methods.

4.3. Benchmark 3: Resiliency performance

This benchmark corresponds to feature 3.

- Measure switch over time of logical channels (time between a failure happens and a failure is recovered by switch over to an alternate route).
- Measurement method can be a tester (with traffic generator) or logs.
- The PoC report should describe measurement results as well as measurement methods.

4.4. Benchmark 4: Control plane performance

This benchmark corresponds to feature 4.

- Measure logical channel setup/deletion/update time of logical channels being requested (time between a request arrives via a service API and a logical channel is setup/deleted/updated). This PoC document sets the performance guideline as follows.
  - Time to setup/delete/update a logical channel: 10 seconds.
- Measurement method can be a tester (with traffic generator) or logs.
- The PoC report should describe measurement results as well as measurement methods. The PoC report should describe reasons if above-mentioned performance guidelines are not met.

4.5. Other considerations

As mentioned in Section 1, although the main scope of this document is network layer, ultimate value of DN is application performance. As such, this document sets minimum guidelines for measuring transport layer performance and application performance.

4.5.1. Transport layer performance

- Measure transport layer performance (such as throughput, data transfer completion time) over logical channels.
- It is recommended to measure with some physical distance (e.g., 0km, 100km). Physical distance can be made by actual fiber cable length or by emulation (e.g., inserting latency using WAN emulator).

- At minimum, UDP and TCP performance should be included in the PoC report. The PoC report should describe TCP congestion control mechanisms and parameters being used.
- It is an option to include RDMA performance (which could be on UDP). In such cases, the PoC report should describe protocols (e.g., RoCEv2) and parameters used. It is recommended to refer to appropriate IOWN GF documents (e.g., RDMA over Open APN PoC reference in case of RDMA).

4.5.2. Application performance

- Measure application performance (such as job completion time) over logical channels.
- It is recommended to measure with some physical distance (e.g., 0km, 100km). Physical distance can be made by actual fiber cable length or by emulation (e.g., inserting latency using WAN emulator).
- In case application performance is included in the PoC report, the PoC report should describe applications (such as remote GPU, remote storage replication) and parameters used. It is recommended to refer to appropriate IOWN GF documents (e.g., PoC reference for use cases).

5. Other Considerations

As mentioned in Section 1, in order to clarify technologies and implementation models as inputs for future works (such as revision of Functional Architecture and creation of new specifications if necessary), the following is mandated.

- The PoC report includes technologies (logical channel, APIs) being used.
- The PoC report includes implementation models of DN-EP/G/I/C being used.

Annexes

A. Guideline for Delay and Jitter

Many use cases prefer shorter delay, but there are no common definitive requirements for delay (see Annex A of [1]). As such, this document sets guidelines for delay and jitter as follows.

- Suppose DN is deployed to connect sites between 200km distance (One way delay is 1ms in fiber length).
- It is likely that 0.1 times additional delay (by DN-I/G) impacts little on performance. Such performance impact for RDMA can be inferred by RDMA over Open APN PoC report [2].
- This means additional 100us (RTT) would be a good target. This means average delay is 100us (RTT), with some jitter. This document sets maximum jitter 10us.

Some use cases may require more stringent jitter requirements, in particular for PTP transport (e.g., mobile front haul and remote media production). The PoC report should describe whether PTP transport with enough accuracy can be obtained for such use cases.

References

[1] Functional Architecture for Deterministic Networking with Software-Defined Optical Interconnect

[2] RDMA over Open APN PoC Report

History

Revision	Release Date	Summary of Changes
1	July 2026	Initial Release