Juniper® Validated Design

# JVD Test Report Brief: Data Center Interconnect over IPoDWDM

test-report-brief-JVD-Optics-Base-01-01

## Introduction

The traditional Dense Wave Division Multiplexing (DWDM) networks have transponders to convert the Ethernet signals into a DWDM signal suitable for DWDM transport. Converged Optical Routing Architecture (CORA) integrates DWDM optics into our routers and switches. DWDM optics in a router can connect directly to a DWDM multiplexer, so there is no need for a separate transponder. In this model, the Internet Protocol (IP) and Optical network management operates as a single domain controller which in turn:

- Simplifies operations
- Lowers operational expenses
- Increases network efficiency
- Lowers power consumption
- Allows router to monitor the performance of the DWDM link
- Allows router to take routing decision based on the DWDM link performance
- Helps in faster troubleshooting and reduces downtime

The testing demonstrates Juniper 400G Coherent Optics capabilities and validates the Internet Protocol over Dense Wavelength-Division Multiplexing (IPoDWDM) solution.

Major technical attributes include:

- For Amplified Path:
  - Receives minimum optical signal-to-noise ratio
  - Maximum chromatic dispersion
- For Unamplified Path:
  - RX sensitivity
  - Telemetry
  - Configurability
  - Performance monitoring
- Following are the two Juniper 400G Coherent Optics are tested:
  - JCO400-QDD-ZR-M-HP
  - QDD-400G-ZR-M-HP

# Test Topology

Figure 1: Logical Topology

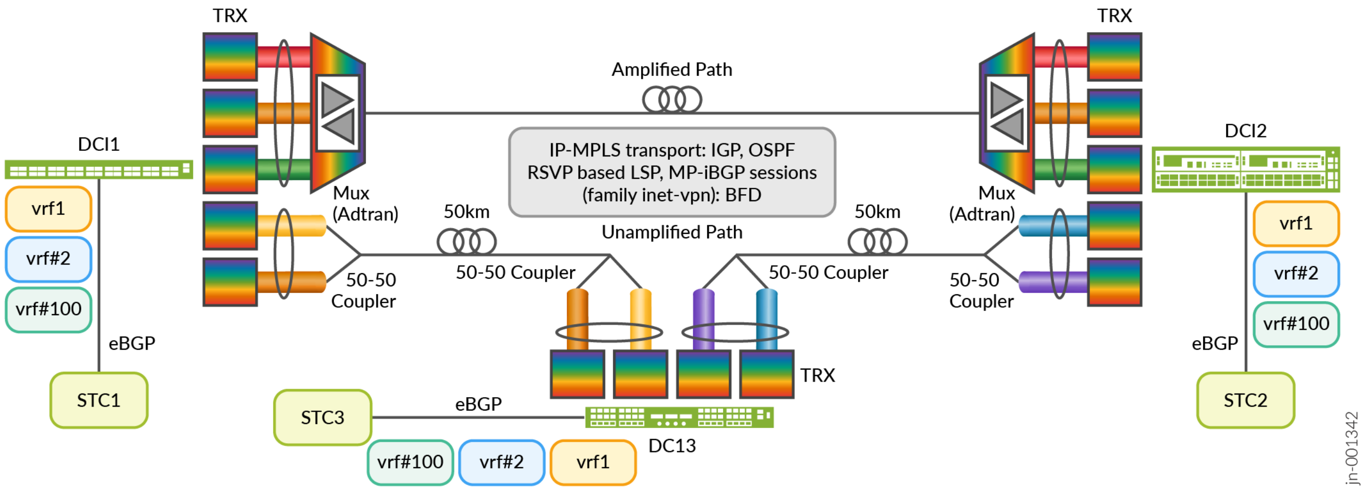



Figure 2: Amplified Path Topology

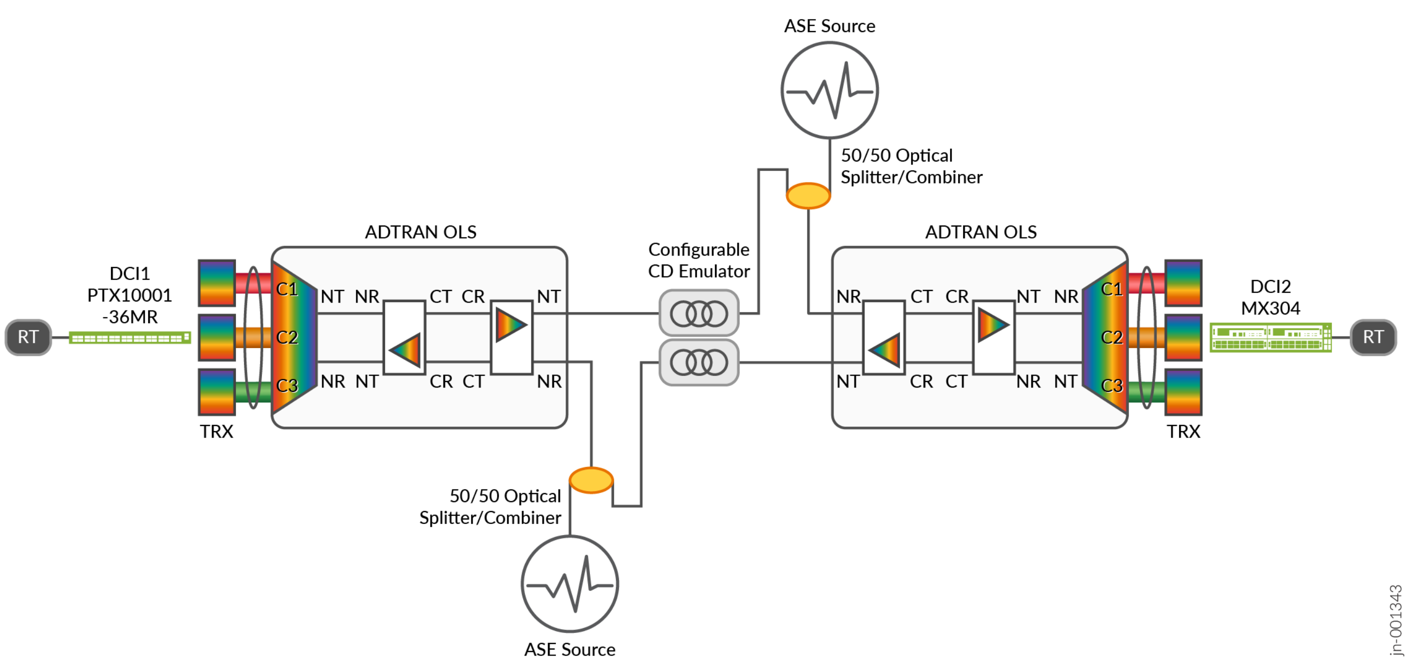
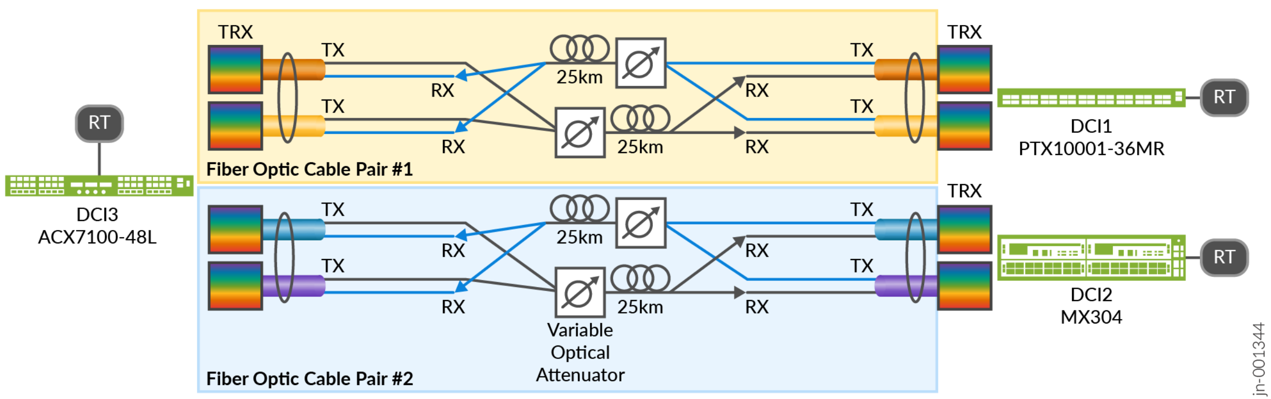


Figure 3: Unamplified Path Topology




# Platforms Tested

**Table 1** lists the platforms tested for this JVD during initial qualification. For more details on all supported platforms and OS versions, see the **Validated Platforms and Software** section in the JVD document.

Table 1: Devices Under Test

| Role | Model | OS |
|---|---|---|
| DCI-Edge1 | PTX10001-36MR | Junos OS Evolved Release 24.2R2 |
| DCI-Edge2 | MX304 | Junos OS Release 24.2R2 |
| DCI-Edge3 | ACX7100-48L | Junos OS Evolved Release 24.2R2 |
| Transceiver | JCO400-QDD-ZR-M-HP | N/A |
| Transceiver | QDD-400G-ZR-M-HP | N/A |

# Version Qualification History

This JVD was initially qualified on Junos OS Release 24.2R2 and Junos OS Evolved Release 24.2R2. For more details on all the supported platforms and OS versions, see the **Validated Platforms and Software** section in the JVD document.

# Scale Data

The scaling data is as follows:

- MPLS: 100 RSVP based LSP between DCIs
- Routing Instances: 100VPNv4
- Route: 20000
- 100 eBGP sessions

# Performance Data

Performance tests are performed as follows:

## Amplified Path

For the amplified path (**Figure 2**), three optical transceivers are used on both DCI1 and DCI2 routers. All transceivers and Reconfigurable Optical Add-Drop Multiplexer (ROADM) ports are tuned to a specific wavelength or frequency.

EDFA noise is emulated by injecting noise using an Amplified Spontanous Emission (ASE) source. For every iteration step in the testcase, the noise is increased gradually using the Variable Optical Attenuator (VOA). Chromatic Dispersion (CD) is also emulated by using Chromatic Dispersion Emulators (CDE).

The process is repeated until the traffic loss is observed in the traffic generator or when the channel goes down. The noise is decreased until the traffic is stable for 2 hours. Then, the Pre-Forward Error Correction Bit Error Rate (Pre-FEC BER), uncorrected Frame Error Rate (FER), and OSNR are measured. The measured OSNR is the minimum receive-OSNR requirement of the transceiver. The OSNR is also measured by an Optical Spectrum Analyzer (OSA) to verify the OSNR reported by the transceiver.

Table 2: Amplified Path Test Results with JCO400-QDD-ZR-M-HP as Rx

| Speed/Media Code | CD | rOSNR (reported by the transceiver) | | | rOSNR (measured by an OSA) | Pre-FEC BER (reported by the transceiver) | | |
|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Avg | | Min | Max | Avg |
| 400GE ZR400-OFEC-16QAM | 0 ns/nm | 22.2 dB | 22.4 dB | 22.2 dB | 21.2 dB | 1.74E-02 | 1.83E-02 | 1.78E-02 |
| | 5 ns/nm | 22.2 dB | 22.4 dB | 22.4 dB | 21.5 dB | 1.70E-02 | 1.84E-02 | 1.77E-02 |
| | 10 ns/nm | 22.4 dB | 22.7 dB | 22.4 dB | 22.0 dB | 1.65E-02 | 1.80E-02 | 1.72E-02 |
| | 15 ns/nm | 22.7 dB | 22.9 dB | 22.9 dB | 22.6 dB | 1.47E-02 | 1.60E-02 | 1.53E-02 |
| | 20 ns/nm | 23.7 dB | 23.9 dB | 23.9 dB | 24.4 dB | 1.04E-02 | 1.16E-02 | 1.09E-02 |
| 3x100GE ZR300-OFEC-8QAM | 0 ns/nm | 18.9 dB | 19.2 dB | 19.0 dB | 18.3 dB | 1.58E-02 | 1.74E-02 | 1.66E-02 |
| | 20 ns/nm | 19.4 dB | 19.7 dB | 19.4 dB | 19.5 dB | 1.29E-02 | 1.40E-02 | 1.34E-02 |
| 2x100GE ZR200-OFEC-QPSK | 0 ns/nm | 15.0 dB | 15.0 dB | 15.0 dB | 14.2 dB | 1.44E-02 | 1.59E-02 | 1.51E-02 |
| | 20 ns/nm | 15.0 dB | 15.0 dB | 15.0 dB | 14.5 dB | 1.51E-02 | 1.63E-02 | 1.57E-02 |
| 1x100GE ZR100-OFEC-QPSK | 0 ns/nm | 12.0 dB | 12.0 dB | 12.0 dB | 11.1 dB | 1.49E-02 | 1.65E-02 | 1.57E-02 |
| | 20 ns/nm | 12.0 dB | 12.0 dB | 12.0 dB | 11.3 dB | 1.46E-02 | 1.64E-02 | 1.54E-02 |

Table 3: Amplified Path Test Results with QDD-400G-ZR-M-HP as Rx

| Speed/Media Code | CD | rOSNR (reported by the transceiver) | | | rOSNR (measured by an OSA) | Pre-FEC BER (reported by the transceiver) | | |
|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Avg | | Min | Max | Avg |
| 400GE ZR400-OFEC-16QAM | 0 ns/nm | 19.1 dB | 19.4 dB | 19.2 dB | 21.6 dB | 1.70E-02 | 1.83E-02 | 1.70E-02 |
| | 5 ns/nm | 19.2 dB | 19.6 dB | 19.4 dB | 22.0 dB | 1.73E-02 | 1.83E-02 | 1.70E-02 |
| | 10 ns/nm | 19.2 dB | 19.5 dB | 19.4 dB | 22.2 dB | 1.78E-02 | 1.87E-02 | 1.80E-02 |
| | 15 ns/nm | 19.4 dB | 19.7 dB | 19.5 dB | 22.5 dB | 1.74E-02 | 1.84E-02 | 1.70E-02 |

| Speed/Media Code | CD | rOSNR (reported by the transceiver) | | | rOSNR (measured by an OSA) | Pre-FEC BER (reported by the transceiver) | | |
|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Avg | | Min | Max | Avg |
| | 20 ns/nm | 19.4 dB | 19.9 dB | 19.7 dB | 22.8 dB | 1.70E-02 | 1.81E-02 | 1.70E-02 |
| 3x100GE ZR300-OFEC-8QAM | 0 ns/nm | 18.4 dB | 18.7 dB | 18.5 dB | 18.4 dB | 1.73E-02 | 1.86E-02 | 1.70E-02 |
| | 20 ns/nm | 18.7 dB | 19.0 dB | 18.8 dB | 19.0 dB | 1.74E-02 | 1.82E-02 | 1.78E-02 |
| 2x100GE ZR200-OFEC-QPSK | 0 ns/nm | 13.6 dB | 13.9 dB | 13.7 dB | 13.7 dB | 1.86E-02 | 1.92E-02 | 1.89E-02 |
| | 20 ns/nm | 14.0 dB | 14.1 dB | 14.0 dB | 14.1 dB | 1.80E-02 | 1.91E-02 | 1.80E-02 |
| 1x100GE ZR100-OFEC-QPSK | 0 ns/nm | 10.6 dB | 10.8 dB | 10.7 dB | 10.7 dB | 1.82E-02 | 1.94E-02 | 1.80E-02 |
| | 20 ns/nm | 10.7 dB | 10.9 dB | 10.8 dB | 10.9 dB | 1.81E-02 | 1.94E-02 | 1.80E-02 |

For both transceivers, it is observed from the results there are increasing rOSNR penalties as CD increases. This should be considered when designing the network.

## Unamplified Path

For the unamplified/dark-fiber path (**Figure 3**), two optical transceivers are used on each DCI router. All transceivers are tuned to a specific wavelength or frequency. Two pairs of fiber optic cables are used, and each pair carries two wavelengths. In the unamplified path, as the light goes through the fiber optic cable, some signal is lost mainly due to light absorption by the fiber material. This is called Span Loss. The Echola Variable Optical Attuneuator (VOA) is used to emulate span loss.

The link is attuneuated gradually until the traffic loss is observed in the traffic generator or when channel goes down. The noise is decreased until traffic is stable for 2 hours. Then, the Pre-Forward Error Correction Bit Error Rate (Pre-FEC BER), uncorrected Frame Error Rate (FER), and Rx Power are measured. The measured Rx Power will be the Rx Sensitivity of the transceiver. The Rx Power will be measured by a power meter to verify the Rx Power reported by the transceiver.

The results show two tables per transceiver. First table shows Receive (Rx) Signal Power, while the second table shows Rx Total Power. Rx Signal Power is the power received from the desired wavelength/frequency seen on the cable. Rx Total Power is the power received from all wavelengths/frequencies seen on the cable. For this test case, there are 2 wavelengths/frequencies per cable. Since the Transmit (Tx) Power for both signals are equal, the Rx Total Power will be 3dB more than the Rx Signal Power. Converting 3dB into a linear value means twice as much.

Table 4: Unamplified Path Test Results – Rx Signal Power for JCO400-QDD-ZR-M-HP

| Speed/Media Code | Rx Signal Power (reported by the transceiver) | | | Rx Signal Power (measured by a power meter) | Pre-FEC BER (reported by the transceiver) | | |
|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | | Min | Max | Avg |
| 400GE ZR400-OFEC-16QAM | -26.64 dBm | -26.36 dBm | -26.50 dBm | -26.90 dBm | 1.30E-02 | 1.41E-02 | 1.35E-02 |
| 3x100GE ZR300-OFEC-8QAM | -29.19 dBm | -28.95 dBm | -29.07 dBm | -30.00 dBm | 1.22E-02 | 1.31E-02 | 1.27E-02 |
| 2x100GE ZR200-OFEC-QPSK | -33.03 dBm | -30.72 dBm | -31.30 dBm | -34.20 dBm | 1.12E-02 | 1.32E-02 | 1.24E-02 |
| 1x100GE ZR100-OFEC-QPSK | -32.97 dBm | -32.72 dBm | -32.84 dBm | -37.80 dBm | 1.15E-02 | 1.26E-02 | 1.21E-02 |

JCO400-QDD-ZR-M-HP on 100GE Mode, ZR100-OFEC-QPSK can only link up at -32dBm Rx Power. The link can degrade to -37.80dBm after linking up. Thus, design the link at -32dBm Rx Sensitivity or higher.

Table 5: Unamplified Path Test Results – Rx Total Power for JCO400-QDD-ZR-M-HP

| | Rx Total Power (reported by the transceiver) | | | Rx Total Power (measured by a power meter) | Pre-FEC BER (reported by the transceiver) | | |
|---|---|---|---|---|---|---|---|
| Speed/Media Code | Min | Max | Avg | | Min | Max | Avg |
| 400GE ZR400-OFEC-16QAM | -24.44 dBm | -23.87 dBm | -24.21 dBm | -24.00 dBm | 1.30E-02 | 1.41E-02 | 1.35E-02 |
| 3x100GE ZR300-OFEC-8QAM | -27.70 dBm | -26.58 dBm | -27.20 dBm | -27.10 dBm | 1.22E-02 | 1.31E-02 | 1.27E-02 |
| 2x100GE ZR200-OFEC-QPSK | -32.22 dBm | -29.59 dBm | -30.81 dBm | -31.30 dBm | 1.12E-02 | 1.32E-02 | 1.24E-02 |
| 1x100GE ZR100-OFEC-QPSK | -36.99 dBm | -31.55 dBm | -33.60 dBm | -34.80 dBm | 1.15E-02 | 1.26E-02 | 1.21E-02 |

JCO400-QDD-ZR-M-HP on 100GE Mode, ZR100-OFEC-QPSK can only link up at -32dBm Rx Power. The link can degrade to -37.80dBm after linking up. Thus, design the link at -32dBm Rx Sensitivity or higher.

Table 6: Unamplified Path Test Results -Rx Signal Power for QDD-400G-ZR-M-HP

| | Rx Signal Power (reported by the transceiver) | | | Rx Signal Power (measured by a power meter) | Pre-FEC BER (reported by the transceiver) | | |
|---|---|---|---|---|---|---|---|
| Speed/Media Code | Min | Max | Avg | | Min | Max | Avg |
| 400GE ZR400-OFEC-16QAM | -20.82 dBm | -20.60 dBm | -20.71 dBm | -20.50 dBm | 1.38E-02 | 1.43E-02 | 1.41E-02 |
| 3x100GE ZR300-OFEC-8QAM | -26.99 dBm | -25.14 dBm | -26.17 dBm | -24.60 dBm | 1.62E-02 | 1.68E-02 | 1.65E-02 |
| 2x100GE ZR200-OFEC-QPSK | -40.00 dBm | -40.00 dBm | -40.00 dBm | -29.40 dBm | 1.37E-02 | 1.43E-02 | 1.40E-02 |
| 1x100GE ZR100-OFEC-QPSK | -40.00 dBm | -40.00 dBm | -40.00 dBm | -32.30 dBm | 6.14E-03 | 7.05E-03 | 6.43E-03 |

QDD-400G-ZR-M-HP's Rx Signal Power Monitor is only accurate down to -21dBm. Any Rx Signal Power values below -21dBm are not guaranteed.

Table 7: Unamplified Path Test Results -Rx Total Power for QDD-400G-ZR-M-HP

| | Rx Total Power (reported by the transceiver) | | | Rx Total Power (measured by a power meter) | Pre-FEC BER (reported by the transceiver) | | |
|---|---|---|---|---|---|---|---|
| Speed/Media Code | Min | Max | Avg | | Min | Max | Avg |
| 400GE ZR400-OFEC-16QAM | -17.72 dBm | -17.62 dBm | -17.67 dBm | -17.40 dBm | 1.38E-02 | 1.43E-02 | 1.41E-02 |

| Speed/Media Code | Rx Total Power (reported by the transceiver) | | | Rx Total Power (measured by a power meter) | Pre-FEC BER (reported by the transceiver) | | |
|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | | Min | Max | Avg |
| 3x100GE ZR300-OFEC-8QAM | -21.94 dBm | -21.80 dBm | -21.87 dBm | -21.60 dBm | 1.62E-02 | 1.68E-02 | 1.65E-02 |
| 2x100GE ZR200-OFEC-QPSK | -26.78 dBm | -26.58 dBm | -26.65 dBm | -26.30 dBm | 1.37E-02 | 1.43E-02 | 1.40E-02 |
| 1x100GE ZR100-OFEC-QPSK | -31.55 dBm | -30.97 dBm | -30.99 dBm | -29.20 dBm | 6.14E-03 | 7.05E-03 | 6.43E-03 |

### Channel Sweep Tests

Link stability and integrity is evaluated across various channel frequencies by performing controlled channel sweep tests across the Frequency Range: 191.300 THz to 196.100 THz and for the following frequency step size.

- 50 GHz Grid
- 75 GHz Grid
- 100 GHz Grid
- Flex Grid (6.25GHz)

For each frequency size given above, the tests verify that:

- The optical link is successfully established and remained stable.
- No alarms are triggered during the testing process.
- No traffic loss is observed once the link is stabilized.

## High-Level Features Tested

The high-level features tested successfully are OSPF, IBGP, EBGP, MPLS(RSVP and LDP), BFD, AE(LACP), FRR, and EVPN-VXLAN.

## Event Testing

The following is the list of test cases tested successfully:

- Restart DUT
- FPC restart
- PIC offline/online
- PFE off/on
- Restart apps
- Laser off/on
- Link Flap
- Unplug/plug optics

- Clear ospf
- Clear bgp
- Deactivate/activate AE member
- Trigger Link Fault
- GRES
- NSR

## Known Limitations

The known limitation detail is as follows:

- **Limitation:** Changing bandwidth causes interface/optics to remain in down state.
- **Workaround:** A soft OIR of the optical module will restore the interface to an operational (up) state.

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