Dell EMC Networking and Cisco Spanning Tree Interoperability

This technical white paper describes the Spanning Tree Interoperability between Dell EMC Networking OS10 Enterprise Edition and Cisco Nexus OS

Abstract
This technical white paper provides the results of spanning tree interoperability between Dell EMC Networking switches running OS10 Enterprise Edition and Cisco Nexus 5K switches. This interoperability guide runs through several of the most common spanning tree deployments.

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Revisions

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<td>April 2019</td>
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# Contents

Revisions..............................................................................................................2  
Acknowledgements................................................................................................2  
Executive Summary................................................................................................4  
1 Introduction........................................................................................................5  
  1.1 Hardware Overview.........................................................................................7  
  1.1.1 Dell EMC Networking S4128F-ON.................................................................7  
  1.1.2 Cisco Nexus 5548UP......................................................................................7  
2 Test Methodology..................................................................................................8  
  2.1 Tests – no VLT (Aggregation) and no vPC (Core)...........................................10  
  2.1.1 Test#1 – RPVST+ (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)....11  
  2.1.2 Test#2 – MST (Dell EMC S4128F-ON) and MST (Cisco 5548UP)..............13  
  2.1.3 Test#3 – RSTP (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)....14  
  2.1.4 Test#4 – RSTP (Dell EMC S4128F-ON) and MST (Cisco 5548UP).........19  
  2.2.5 Test#5 – MST (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)....24  
  2.2 Tests – VLT (Aggregation) and vPC (Core)....................................................27  
  2.2.1 Test#1 – RSTP (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)....27  
  2.2.2 Test#2 – RPVST+ (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)....32  
  2.2.3 Test#3 – RSTP (Dell EMC S4128F-ON) and MST (Cisco 5548UP)........34  
3 Summary.............................................................................................................37  
4 Switch Configurations.............................................................................................39  
  Cisco 5548UP - RPVST+ with vPC....................................................................39  
  Dell EMC S4128F - RSTP with VLT....................................................................41  
5 VLT Syslog Messages............................................................................................43  
6 Helpful Troubleshooting Commands.....................................................................46
Executive Summary

Spanning Tree Protocol continues to play an important role in today's networks for loop prevention. Despite the inherent issues of inefficient use of bandwidth, scalability limitations, and overall management complexity, it is one of the most basic implementations deployed on existing legacy networks.

Because of this large install base, any major networking vendor's end-to-end solution must be able to seamlessly integrate its products and solutions into an existing deployment running any basic or enhanced spanning tree modes such as RSTP (Rapid Spanning Tree Protocol also known as 802.1w) or MST (Multiple Spanning Tree also known as 802.1s).

Dell EMC Networking OS10 Enterprise Edition brings this value to the customer by having a complete set of spanning tree features that fully interoperate and integrate into an existing deployment. This interoperability document runs through several of the most common spanning tree deployments and shows how implementations of Dell EMC provide great performance and high-availability during a link failure in the network.
1 Introduction

This interoperability document has been created as a result of performing various tests between Dell EMC Networking and Cisco switches running similar as well as different spanning-tree modes. The document characterizes and provides some insight into the network traffic behavior when different flavors of spanning tree and device redundancy configurations are deployed between Cisco and Dell EMC switching environment.

The intended audience of this technical white paper is the network architect, system engineer, or network administrator. The tests that are performed can be used as a reference point for new designs or integration purposes.

There are two major technologies that will be covered in this interoperability exercise:

1. Spanning Tree Protocol

Originally defined in IEEE 802.1D, Spanning Tree is a network protocol that ensures a loop-free topology for any bridged ethernet Local Area Network (LAN). The basic function of STP is to prevent bridge loops and the broadcast storms that result from these loops. Spanning Tree also allows a network design to include spare (redundant) links to provide automatic backup paths if an active link fails without the danger of creating any bridge loops or the need for manual enabling/disabling of these backup links. Several enhancements or extensions have been made to the original spanning tree implementation. These are:

a. **RSTP (802.1w)** — In 2001, the IEEE standards body introduced Rapid Spanning Tree as 802.1w. This enhancement provides significant faster spanning tree convergence after a network topology change has taken place. While Spanning Tree can take between 30–50 seconds to respond to a topology change, RSTP is typically able to respond to changes within 6 seconds or milliseconds to a physical link failure. RSTP is backward-compatible with legacy spanning tree.

b. **MSTP (802.1s)** — Multiple Spanning Tree Protocol (MSTP) is an extension to RSTP which adds efficiency to the legacy spanning tree instance per VLAN. Prior to MSTP, every VLAN on a network required a spanning tree instance. With the introduction of MSTP, a group of VLANs can now be assigned to a single spanning tree instance and therefore reducing CPU resources from having to create multiple spanning tree instances. The benefits of MSTP are more evident when the network environment consists of 1000s of VLANs. MSTP is fully backward-compatible with RSTP.

c. **Rapid PVST+** — Rapid Per-VLAN Spanning Tree is a Cisco enhancement of RSTP that uses PVST+ which is a Cisco proprietary Layer 2 protocol used to create separate spanning tree instances on a per-VLAN basis. Creating separate per VLAN spanning tree instances allows for the usage of different network links potentially providing load balancing capabilities. There are multiple networking vendors such as Dell EMC, Extreme Networks, and Avaya that support this protocol.

2. VLT/vPC

Dell EMC OS10 Virtual Link Trunking (VLT) — VLT aggregates two identical physical switches to form a single logical extended switch. This single logical entity ensures high availability and high resilience for all its connected access, core switches, and clients. (A Spanning Tree protocol is still required to prevent the initial loop that may occur prior to VLT being established. After VLT is established, RSTP may be used to prevent loops from forming with new links that are incorrectly connected and outside the VLT domain.) VLT provides Layer 2 multi-pathing, creating redundancy through increased bandwidth, enabling multiple parallel paths between nodes, and load-balancing traffic where alternative paths exist. A VLT interconnect (VLTi) synchronizes states between VLT peers. Figure 1 shows the typical network layout with VLT.
Cisco vPC — A Virtual Port Channel (vPC) allows links that are physically connected to two different Cisco Nexus devices to appear as a single port channel to a third device. The third device can be a Cisco Nexus 2000 Series Fabric Extender or a switch, server or any other networking device. A vPC can provide Layer 2 multi-pathing, which allows you to create redundancy by increasing bandwidth, enabling multiple parallel paths between nodes and load-balancing traffic where alternative paths exist. The vPC domain includes both vPC peer devices, the vPC peer keepalive link, the vPC peer link, and all the port-channels in the vPC domain connected to the downstream device. You can have only one vPC domain ID on each device.
1.1 Hardware Overview

1.1.1 Dell EMC Networking S4128F-ON
The Dell EMC Networking S4128F-ON is a 1-Rack Unit (RU) switch with 28 fixed 10GbE SFP+ ports and two fixed 100GbE QSFP28 ports. Two of these switches are used in the deployment examples.

![Figure 3 Dell EMC Networking S4128F-ON](image)

1.1.2 Cisco Nexus 5548UP
The Cisco Nexus 5548UP is a 1-RU, 1/10 Gigabit Ethernet switch with 32 fixed, unified ports on base chassis and one expansion slot totaling 48 ports. The slot can support any of the three modules: Unified Ports, 1/2/4/8 native Fiber Channel, and Ethernet or FCoE. Two of these switches are used in the deployment examples.
2 Test Methodology

Our test methodology consists of three key steps:

1. Enable or disable the redundant device technology

2. Configure spanning tree protocol and the different modes to test interoperability

3. Simulate a link failure between the devices

Figure 4 shows the reference test-bed diagram used for the first set of tests.

---

Figure 4  Physical and logical reference network test-bed (Test Setup without VLT and vPC)

Tagged traffic was generated and transmitted from either ends of the network. Some test cases sourced traffic from ports 1 and 2 to port 3, and others sourced traffic from port 3 to ports 2 and 1. RPVST+ is the spanning tree mode that is enabled by default in Dell EMC Networking OS10EE.
Dell EMC Networking and Cisco Spanning Tree Interoperability

Figure 5 shows the reference test-bed diagram used for the second set of tests

![Figure 5 Test Setup with VLT and vPC](image)

Notice when vPC and VLT are configured, the logical network topology creates a very straightforward simple pair of switches connected back to back via a quad member port-channel link.

The quad member port-channel link comes from the dual homed links from each switch (Cisco 5548s and Dell EMC S4128s) where the Cisco single port-channel links are marked in red and green from each switch, and the Dell EMC dual port-channel links are marked by a circle icon.

Once spanning tree protocol runs, the port-channel goes into the forwarding mode because to spanning tree, this is a single port-channel with 4 links, not two separate individual port channels where one needs to be blocked in order to avoid a loop in the network.

Two sets of tests were performed using the following configurations –

1. No VLT and no vPC (Figure 4)
   - RPVST+ (Dell EMC) and RPVST+ (Cisco)
   - MST (Dell EMC) and MST (Cisco)
   - RSTP (Dell EMC) and RPVST+ (Cisco)
   - RSTP (Dell EMC) and MST (Cisco)
   - MST (Dell EMC) and RPVST+ (Cisco)

2. With VLT and vPC (Figure 5)
   - RSTP (Dell EMC) and RPVST+ (Cisco)
   - RPVST+ (Dell EMC) and RPVST+ (Cisco)
   - RSTP (Dell EMC) and MST (Cisco)
The following hardware and software were used for this exercise:

Hardware:

• Dell EMC S4128F-ON (2)

• Cisco Nexus 5548UP (2)

• Traffic source: IXIA XM2 Chassis with 4-10GE Module

Software:

• Dell EMC Networking OS10 Enterprise Edition Version 10.4.2.1

• Cisco 5.1 (3) N2 (1)

The following formulae were used to calculate the frame loss and frame loss duration:

**Frame Loss** = \((\text{Total Frames Sent} – \text{Total Frames Received}) \div \text{Total Frames Sent}\)

**Frame Loss Duration** = \((\text{Total Frames Sent} – \text{Total Frames Received}) \div \text{Frames Sent Rate}\)
2.1 Tests – no VLT (Aggregation) and no vPC (Core)

2.1.1 Test#1 – RPVST+ (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)

Figure 6 depicts the physical and logical network topology with traffic flow at steady state. Each Cisco N5K is a root for VLANs 10 and 20 respectively with the other acting as secondary. VLAN 10 is being forwarded on port 9 and blocked on port 8 and vice versa for VLAN 20. This is the normal behavior of having different spanning tree instances for each VLAN.

On VLAN 1, Cisco switches configured for Rapid PVST+ will send two configuration BPDUs; one destined for the IEEE RSTP multicast MAC address of 01:80:C2:00:00:00-DSAP 42-SSAP 42, and one destined for the proprietary PVST+ multicast MAC address of 01-00-0C-CC-CC-CD (SNAP HDLC protocol type 0x010b).

Cisco’s proprietary PVST+ behavior is such that when VLAN 1 is native(untagged), untagged IEEE STP BPDUs (Destination MAC - 01:80:C2:00:00:00) and tagged PVST+ BPDU (01-00-0C-CC-CC-CD) are sent for VLAN 1. Tagged PVST+ BPDUs are sent for all other VLANs. When VLAN 1 is not native, untagged PVST+ BPDUs are sent for that specific VLAN. (For example, if native VLAN is set to VLAN 50 then untagged PVST+ BPDUs are sent for VLAN 50). For Dell EMC switches, if untagged traffic exists on a trunk port, then untagged IEEE STP BPDUs are sent for that VLAN and tagged PVST BPDUs for all tagged VLANs. If only tagged VLANs exist on a trunk port then tagged PVST+ BPDUs are sent for those tagged VLANs.

Rapid PVST+ will work between Dell EMC and Cisco switches when the untagged (native) VLAN is VLAN 1. VLAN 1 is the native VLAN by default on Cisco switches and for Dell EMC switches, VLAN 1 needs to be configured as untagged in this case. This is because for VLAN 1, spanning tree converges on IEEE STP BPDUs between the switches and all other tagged VLANs converge on PVST+ BPDUs. Figure 7 and Figure 8 show the port status and port roles for VLAN 10 and 20 on S4128-SW1.

Note: Dell EMC Networking OS10 does not support interoperability with PVST mode of Cisco. For STP convergence on all the VLANs, the Cisco switch must be configured with RAPID-PVST. If Cisco switch is configured with PVST then convergence will not happen for all the VLANs as it is not supported. But convergence should happen on default VLAN.

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Figure 6 Physical and Logical Network Topology – RPVST+ (Dell EMC) and RPVST+ (Cisco)
Dell EMC Networking and Cisco Spanning Tree Interoperability

**Figure 7**  VLAN 10 link status with rapid-per VLAN spanning tree

**Figure 8**  VLAN 20 link status with rapid-per VLAN spanning tree

**Test Steps**

The following test steps were conducted with Ixia IxExplorer to simulate a fail-over scenario:

1. Create two tagged streams of VLAN ID 10 and 20 with source port 3 and destination ports 1 and 2.
2. Shut down e1/1/9 on S4128-SW1 to simulate a fail-over scenario and check for any traffic disruption.
3. Recover e1/1/9 on S4128-SW1 and check for any traffic disruption and make sure N5K1 becomes the root.
4. Repeat steps 2 and 3 for e1/1/8 on the S4128-SW1 switch.

**Results**

The blocked VLANs started to forward traffic right away upon a link failure. RPVST+ Different per-VLAN spanning tree instances were created. Both spanning tree modes use the same convergence timers therefore convergence times upon link failures are quick as expected. Upon link failure between Dell EMC switch and each of the respective Cisco N5K switches, the timers observed were:

- Frame Loss % = 0
2.1.2 Test#2 – MST (Dell EMC S4128F-ON) and MST (Cisco 5548UP)
For this test, all three switches were placed in the same spanning tree region with both Cisco switches acting as root for specific VLANs. Figure 9 shows our reference test diagram under a common stp mode. Multiple spanning tree instances are created on all switches matching the VLAN to instance as well as region name.

Test Steps
1. Create two tagged streams of VLAN ID 10 and 20 with source port 3, and destination ports 1 and 2.
2. Shut down e1/1/9 on S4128-SW1 switch and measure traffic loss and duration of traffic loss.
3. Recover e1/1/9 on S4128-SW1 and measure traffic loss and duration of traffic loss and make sure N5K1 becomes the root bridge.
4. Repeat steps 2 and 3 for e1/1/8 on the Dell EMC S4128-SW1 switch.

![Figure 9 Physical and logical network topology – MST (Dell EMC) and MST (Cisco)](image)

Results
As expected, the blocked VLANs started to forward right away upon a link failure. Different per-VLAN spanning-tree instances were created. Upon failing the links between the S4128_SW1 and each respective N5Ks, the timers observed were:

- Frame Loss % = 0
2.1.3 Test#3 – RSTP (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)

For this scenario, two set of tests were performed by using the following configuration:

- In the first test, Cisco switches act as the root bridge for the respective VLANs
- Dell EMC S4128-SW1 as the root bridge

Cisco N5K1 and N5K2 as the root bridge

Figure 10 depicts the physical and logical network topology respectively. The logical spanning tree network topology shows how port 9 is forwarding and port 8 is being blocked on S4128-SW1. The black arrow describes the traffic flow for VLANs 10 and 20. This is the normal behavior of having a single spanning tree instance for all VLANs in the case of Dell EMC switch running RSTP.

On the other hand, for Cisco N5Ks running RPVST+ two different spanning tree instances are created. From the N5K1 perspective, root of VLAN 20 traffic is N5K2 and so it creates a separate instance pointing to N5K2 as the root switch. From the N5K2 perspective, root of VLAN 10 traffic is N5K1 and it creates a separate instance pointing to N5K1 as the root switch for that VLAN as shown in Figure 12 and Figure 13.

![Figure 10 Physical and Logical Network Topology – RSTP (Dell EMC) and RPVST+ (Cisco)](image_url)

Test Steps

1. Create two tagged streams of VLAN ID 20 with source port 3, and destination ports 1 and 2.
2. Shut down e1/1/9 on S4128-SW1 to simulate a fail-over scenario and check for any traffic disruption.
3. Recover e1/1/9 on S4128-SW1 and check for any traffic disruption.
Dell EMC Networking: Spanning Tree Interoperability

**S4128-SW1# show spanning-tree active**
Spanning tree enabled protocol rstp with force-version stp
Executing IEEE compatible Spanning Tree Protocol
Root ID  Priority 24577, Address 547f.eeac.13c1
Root Bridge hello time 2, max age 20, forward delay 15
Bridge ID  Priority 32768, Address f48e.385f.3dca
Configured hello time 2, max age 20, forward delay 15
Flush Interval 200 centi-sec, Flush Invocations 50
Flush Indication threshold 65535

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<th>PortID</th>
<th>Prio</th>
<th>Cost</th>
<th>Sts</th>
<th>Cost</th>
<th>Bridge ID</th>
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<td>128</td>
<td>2000</td>
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<td>32769</td>
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</tbody>
</table>

**Figure 11** S4128-SW1 RSTP default instance for VLAN 1

**VLAN0020**
Spanning tree enabled protocol rstp
Root ID  Priority 32788
Address 002a.6a0d.a17c >> N5K2 MAC address
Cost 2
Port 159 (Ethernet1/31)
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

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<th>Bridge ID</th>
<th>Priority 32788 (priority 32768 sys-id-ext 20)</th>
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<tr>
<td>Address</td>
<td>547f.eeac.13c1</td>
</tr>
<tr>
<td>Hello Time</td>
<td>2 sec Max Age 20 sec Forward Delay 15 sec</td>
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</tbody>
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<td>Desg</td>
<td>FWD</td>
<td>128.158</td>
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<td>P2p</td>
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<tr>
<td>Eth1/31</td>
<td>Root</td>
<td>FWD</td>
<td>128.159</td>
<td></td>
<td>P2p</td>
</tr>
</tbody>
</table>

**Figure 12** N5K1 VLAN 20 spanning tree instance
VLAN0010
Spanning tree enabled protocol rstp
Root ID   Priority  24586
Address   547f.eeac.13c1  >> N5K1 MAC address
Cost      2
Port      159 (Ethernet1/31)
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

Bridge ID  Priority 32778 (priority 32768 sys-id-ext 10)
Address   002a.6a0d.a17c
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

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<th>Sts</th>
<th>Cost</th>
<th>Prio.Nbr</th>
<th>Type</th>
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<td>Eth1/28</td>
<td>Desg</td>
<td>FWD 2</td>
<td>128.156</td>
<td>P2p</td>
<td></td>
</tr>
</tbody>
</table>
| Eth1/31   | Root | FWD 2| 128.159 | P2p      | >> pointing to N5K1 as the root switch

Figure 13  N5K2 VLAN 10 spanning tree instance

Results

As expected in this test, there are two different spanning tree modes, one is a purely vendor proprietary implementation (RPVST+) and the other is the standard based (RSTP)

When shutting down e1/1/9,

- Frame Loss % = 0

When e1/1/9 is disabled, the alternate root e1/1/8 on S4128-SW1 moves to the forwarding state immediately. This is the expected behavior you would see in RSTP. Since this is the alternate root port, there is no BPDU exchange that takes place within the network. Because of this, the switchover and forwarding times are extremely fast.

After recovering e1/1/9,

- Frame Loss % = 50

With RSTP, a direct message exchange takes place between point to point links. This exchange consists of an RSTP BPDU proposal message and an agreement message. Proposal and agreement BPDU are used to negotiate fast-convergence parameters in the event of a failure. For 802.1Q tagged VLANs (all VLANs besides VLAN 1), Cisco switches send their BPDU only to the reserved Cisco multicast address of 01-00-0C-CC-CC-CD. Therefore, unless the Dell EMC switch is also listening to this multicast address, it will only have visibility and an understanding of the logical topology of the CST. For a Cisco bridge running PVST+ to be able to converge with a third-party bridge running 802.1w RSTP, VLAN 1 must be allowed on all 802.1Q trunks that interconnect them.

Figure 14 shows for VLAN 20, BPDU are sent only to the Cisco reserved address which Dell EMC switch simply floods on all its other ports. That means that the rapid failover and convergence offered by RSTP will only be evident on VLAN 1.
N5K1# debug spanning-tree all
N5k1# 2019 Jan 7 16:32:40.844091 stp: MTS: dropping MTS_OPCODE_DEBUG_WRAP_MSG msg id (48856751) on q 7
2019 Jan 7 16:32:41.022537 stp: handling batch flush timer
2019 Jan 7 16:32:41.272546 stp: inserting instance 1 hello timer in C queue
2019 Jan 7 16:32:41.272565 stp: Malloc in fu_cq_node_alloc@utils/fsmutils/cqueue.c[922]-
2019 Jan 7 16:32:41.360178 stp: BPDU Rx: Received BPDU on vb 1 VLAN 20 port Ethernet1/31 pkt_len 64 bpdu_len 42 ne
2019 Jan 7 16:32:41.360207 stp: BPDU RX: vb 1 VLAN 20 port Ethernet1/31 len 64 flags 0xed: Ethernet Hdr 01000ccccccd<002a6a0da146 type/len 0032: SNAP aa aa 03 00000c 010b SSTP CFG P:0000 V:02 T:02 F:3c R:60:14:00:2a:6a:0d:a1:7c 00000000 B:60:14:00:2a:6a:0d:a1:7c 809f A:0000 M:0014

Figure 14   Cisco N5K1 RPVST+ Spanning Tree Debug

Figure 15   Screen shot during fail-over
Dell EMC S4128F-ON as the root bridge

The spanning tree network topology in Figure 16 below shows how port 9 & port 8 on S4128-SW1 are forwarding and port 31 on N5K2 is being blocked. In this case when Dell EMC is acting as root bridge, Cisco N5Ks will converge only for default instance (VLAN1) and port 31 on N5K2 is placed in blocking state shown in Figure 17.

Figure 16  Physical and Logical Network Topology – RSTP (Dell EMC) and RPVST+ (Cisco)

```
NSK2# show spanning-tree
VLAN0001
  Spanning tree enabled protocol rstp
  Root ID   Priority  8192
  Address   f48e.385f.3dca
  Cost      2
  Port      156 (Eth1/28)
  Hello Time 2 sec  Max Age 20 sec Forward Delay 15 sec
  Bridge ID Priority 32769 (priority 32768 sys-id-ext 1)
  Address   002a.6a8d.417c
  Hello Time 2 sec  Max Age 20 sec Forward Delay 15 sec

  Interface  Role Sts Cost   Prio.Nbr  Type
  ---------  ------ ----- -----  ----------  ------
  Eth1/3    Desg FWD 2   128.131  P2p
  Eth1/28   Root FWD 2   128.156  P2p Peer(STP)
  Eth1/31   Altn BLK 2   128.159  P2p

Figure 17  VLAN 1 - N5K2
```

Figure 18 shows how BPDUs for VLAN 10 are sent only to the Cisco reserved multicast address, 01-00-0C-CC-CC-CD. For non-default VLANs 10 and 20, Dell EMC S4128 switch acts as a hub and simply floods the RPVST BPDUs on all other ports, which will be received by Cisco N5K2 on port 28 and it will place one of its ports in blocking mode (e1/31) to avoid a loop in that VLAN.
N5K2# debug spanning-tree all
N5K2# 2019 Jan 28 15:46:33.577122 stp: MTS: dropping MTS_OPCODE_DEBUG_WRAP_MSG msg id (244602708) on q 8
2019 Jan 28 15:46:33.782530 stp: handling batch flush timer
2019 Jan 28 15:46:34.032568 stp: handling batch flush timer
2019 Jan 28 15:46:35.232858 stp: BPDU Rx: Dropping redundant SSTP packet received on port Ethernet1/31 VLAN VLAN0001
2019 Jan 28 15:46:35.232871 stp: BPDU RX: vb 1 VLAN 10, ifi 0x1a01b000 (Ethernet1/28)
2019 Jan 28 15:46:35.232883 stp: BPDU Rx: Received BPDU on vb 1 VLAN 10 port Ethernet1/28 pkt_len 64 bpd_u_len 42 netstack flags 0x00ed enc_type stp

Figure 18 Cisco N5K2 RPVST+ Spanning Tree Debug

Test Steps

1. Create two tagged streams of VLAN ID 20 with source port 3, and destination ports 1 and 2.

2. Shut down e1/1/9 on S4128-SW1 to simulate a fail-over scenario and check for any traffic disruption.

3. Recover e1/1/9 on S4128-SW1 and check for any traffic disruption.

Results

The blocked link, e1/31 on N5K2 starts forwarding when we shut down e1/1/9.

- Frame Loss % = 0

Figure 19 Screen shot during fail-over
2.1.4 Test#4 – RSTP (Dell EMC S4128F-ON) and MST (Cisco 5548UP)

Figure 20 describes the physical and logical spanning tree view of the network under a common/single spanning tree configuration. Two set of tests were performed using the following configuration –

- Default common/single spanning tree instance created by MST and RSTP
- Two spanning tree instances on the Cisco switches with VLANs 10 and 20 assigned to each instance respectively.

![Graph showing network topologies and spanning tree configurations](image)

**Figure 20  Physical and Logical Network Topology – RSTP (Dell EMC) and MST (Cisco)**

Common/single spanning tree instance

Figure 21 and Figure 22 show how Cisco switches share the same spanning tree region, same instances, and RSTP running under-the-hood. Therefore, it is reasonable to expect great convergence times.

```
N5K1# show spanning-tree mst

##### MST0  VLANs mapped: 1-9,11-19,21-4094
Bridge address 547f.eeac.13c1 priority 24576 (24576 sysid 0)
Root this switch for the CIST
Regional Root this switch
Operational hello time 2, forward delay 15, max age 20, txholdcount 6
Configured hello time 2, forward delay 15, max age 20, max hops 20

<table>
<thead>
<tr>
<th>Interface</th>
<th>Role</th>
<th>Sts</th>
<th>Cost</th>
<th>Prio.Nbr</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eth1/3</td>
<td>Desg</td>
<td>FWD</td>
<td>2000</td>
<td>128.131</td>
<td>Edge P2p</td>
</tr>
<tr>
<td>Eth1/30</td>
<td>Desg</td>
<td>FWD</td>
<td>2000</td>
<td>128.158</td>
<td>P2p Bound(STP)</td>
</tr>
<tr>
<td>Eth1/31</td>
<td>Desg</td>
<td>FWD</td>
<td>2000</td>
<td>128.159</td>
<td>P2p</td>
</tr>
</tbody>
</table>

**Figure 21  MST0 N5K1 Link Status**
N5K2# show spanning-tree mst

```
##### MST0 VLANs mapped: 1-9,11-19,21-4094
Bridge address 002a.6a0d.a17c priority 32768 (32768 sysid 0)
Root address 547f.eeac.13c1 priority 24576 (24576 sysid 0)
    port Eth1/31 path cost 0
Regional Root address 547f.eeac.13c1 priority 24576 (24576 sysid 0)
    internal cost 2000 rem hops 19
Operational hello time 2, forward delay 15, max age 20, txholdcount 6
Configured hello time 2, forward delay 15, max age 20, max hops 20
```

<table>
<thead>
<tr>
<th>Interface</th>
<th>Role</th>
<th>Sts</th>
<th>Cost</th>
<th>Prio</th>
<th>Nbr</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eth1/3</td>
<td>Desg</td>
<td>FWD</td>
<td>2000</td>
<td>128</td>
<td>131</td>
<td>P2p</td>
</tr>
<tr>
<td>Eth1/28</td>
<td>Desg</td>
<td>FWD</td>
<td>2000</td>
<td>128</td>
<td>156</td>
<td>P2p Bound(STP)</td>
</tr>
<tr>
<td>Eth1/31</td>
<td>Root</td>
<td>FWD</td>
<td>2000</td>
<td>128</td>
<td>159</td>
<td>P2p</td>
</tr>
</tbody>
</table>

Figure 22  MST0 N5K2 Link Status

S4128-SW1# show spanning-tree active

```
Spanning tree enabled protocol rstp with force-version stp
Executing IEEE compatible Spanning Tree Protocol
Root ID  Priority 24576, Address 547f.eeac.13c1
Root Bridge hello time 2, max age 20, forward delay 15
Bridge ID  Priority 32768, Address f48e.385f.3dca
Configured hello time 2, max age 20, forward delay 15
Flush Interval 200 centi-sec, Flush Invocations 49
Flush Indication threshold 65535
```

<table>
<thead>
<tr>
<th>Interface</th>
<th>Name</th>
<th>PortID</th>
<th>Prio</th>
<th>Cost</th>
<th>Sts</th>
<th>Cost</th>
<th>Bridge ID</th>
<th>PortID</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethernet1/1/3</td>
<td>128.524</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>2000</td>
<td>32768</td>
<td>f48e.385f.3dca</td>
<td>128.524</td>
</tr>
<tr>
<td>ethernet1/1/8</td>
<td>128.544</td>
<td>128</td>
<td>2000</td>
<td>BLK</td>
<td>0</td>
<td>32768</td>
<td>002a.6a0d.a17c</td>
<td>128.156</td>
</tr>
<tr>
<td>ethernet1/1/9</td>
<td>128.548</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>0</td>
<td>24576</td>
<td>547f.eeac.13c1</td>
<td>128.158</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interface</th>
<th>Name</th>
<th>Role</th>
<th>PortID</th>
<th>Prio</th>
<th>Cost</th>
<th>Sts</th>
<th>Cost</th>
<th>Link-type</th>
<th>Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethernet1/1/3</td>
<td>Desg</td>
<td>128</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
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<td>AUTO</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>ethernet1/1/8</td>
<td>Altr</td>
<td>128</td>
<td>128</td>
<td>2000</td>
<td>BLK</td>
<td>0</td>
<td>AUTO</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>ethernet1/1/9</td>
<td>Root</td>
<td>128</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>0</td>
<td>AUTO</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Figure 23  S4128-SW1 RSTP link status
Test Steps

1. Create two tagged streams of VLAN ID 10 and 20 with source port 3, and destination ports 1 and 2.

2. Shut down e1/1/9 on S4128-SW1 switch and measure traffic loss and duration of traffic loss.

3. Recover e1/1/9 on S4128-SW1 and measure traffic loss and duration of traffic loss.

Results

Ideally, traffic disruption should be negligible due to the fact that all switches are under the same spanning tree region. Upon shutting down e1/1/9, the blocked link (port 8) moves into the forwarding state immediately. Here are the test results:

- Frame Loss % = 0

When we restore e1/1/9, e1/1/8 goes into a blocking status

- Frame Loss % = 0

When Dell EMC switch converged initially, it recognized port 8 as the “ALTR” or alternate port, ready to take over should (root) port 9 fail. When this transition takes place, no BPDUs are transmitted since there is no interaction with another switch; therefore, the only events that take place are related to the link operational status (on e1/1/8 and e1/1/9) and the RSTP timers when transitioning from “Discarding” to the “Forwarding”. In this case, when using RSTP, transitioning from DISCARDING ->LEARNING -> FORWARDING is almost instantaneously.
Multiple spanning tree instance

For this test, multiple spanning tree instances are configured on the Cisco switches.

VLAN 10 was assigned to instance 1 and N5K1 switch is configured as the root switch for this instance.

VLAN 20 was assigned to instance 2 and N5K2 switch is configured as the root switch for this instance.

Although multiple spanning tree instances have been configured on the Cisco switches, we expect the results to be identical such as when having a single spanning tree instance. Figures 24-27 show the spanning tree instances on the Cisco switches.

```
N5K1# show spanning-tree mst 1

### MST1  VLANs mapped:  10
Bridge address 547f.eeac.13c1  priority 24577 (24576 sysid 1)
Root  this switch for MST1

Interface  Role  Sts     Cost      Prio.Nbr Type
----------------- ------- -------- --------- -----------------------------
Eth1/3       Desg FWD 2000  128.131   P2p
Eth1/30      Desg FWD 2000  128.158   P2p
Eth1/31      Desg FWD 2000  128.159   P2p

Figure 24  N5K1 - MST1 port state
```

```
N5K2# show spanning-tree mst 1

### MST1  VLANs mapped:  10
Bridge address 002a.6a0d.a17c  priority 28673 (28672 sysid 1)
Root  address 547f.eeac.13c1     priority 24577 (24576 sysid 1)
port Eth1/31 cost 2000 rem hops 19

Interface  Role  Sts    Cost      Prio.Nbr Type
----------------- ------- -------- --------- -----------------------------
Eth1/3       Desg FWD 2000  128.131   P2p
Eth1/28      Desg FWD 2000  128.156   P2p
Eth1/31      Root FWD 2000  128.159   P2p

Figure 25  N5K2 - MST1 port state
```
### Test Steps

1. Create two tagged streams of VLAN ID 10 and 20 with source port 3, and destination ports 1 and 2.

2. Shut down port 8 on S4128-SW1 switch and measure traffic loss and duration of traffic loss.

3. Recover port 8 on S4128-SW1 and measure traffic loss and duration of traffic loss.

### Results

As expected, the results were identical as having a single spanning tree instance. MST uses RSTP timers, so the convergence times should be identical.
2.1.5 Test#5 – MST (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)

MST maps multiple VLANs to an instance, reducing the no. of spanning tree instance and Rapid-PVST+ calculates an instance for each VLAN. Here, each Cisco N5K is a root for VLANs 10 and 20 with the other acting as secondary.

Test Steps

1. Create two tagged streams of VLAN ID 10 and 20 with source port 3, and destination ports 1 and 2.
2. Shut down e1/1/9 on S4128-SW1 switch and measure traffic loss and duration of traffic loss.
3. Recover e1/1/9 on S4128-SW1 and measure traffic loss and duration of traffic loss.

Results

For VLAN 1, both the switches interoperate and agreed on the root bridge. For VLANs 10 and 20, Dell EMC and Cisco switches saw themselves as root and didn’t interoperate. The different port roles on Dell EMC switch are shown in Figure 30. Ports, e1/1/9 and e1/1/8 on S4128-SW1 will be elected as master & alternate ports since e1/1/9 is the non-blocking boundary port connected to CIST (Common and Internal Spanning Tree) root when Cisco N5K1 is the root bridge for VLAN 1.

- Frame Loss % = 0
**N5K1# show spanning-tree**

**VLAN0001**

Spanning tree enabled protocol rstp  
Root ID Priority 24577  
Address 547f.eeac.13c1  
**This bridge is the root**  
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

Bridge ID Priority 24577 (priority 24576 sys-id-ext 1)  
Address 547f.eeac.13c1  
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

<table>
<thead>
<tr>
<th>Interface</th>
<th>Role</th>
<th>Sts</th>
<th>Cost</th>
<th>Prio. Nbr</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eth1/3</td>
<td>Desg</td>
<td>FWD</td>
<td>2</td>
<td>128.131</td>
<td>Edge P2p</td>
</tr>
<tr>
<td>Eth1/30</td>
<td>Desg</td>
<td>FWD</td>
<td>2</td>
<td>128.158</td>
<td>P2p</td>
</tr>
<tr>
<td>Eth1/31</td>
<td>Desg</td>
<td>FWD</td>
<td>2</td>
<td>128.159</td>
<td>P2p</td>
</tr>
</tbody>
</table>

**VLAN00010**

Spanning tree enabled protocol rstp  
Root ID Priority 24586  
Address 547f.eeac.13c1  
**This bridge is the root**  
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

Bridge ID Priority 24586 (priority 24576 sys-id-ext 10)  
Address 547f.eeac.13c1  
Hello Time 2 sec Max Age 20 sec Forward Delay 15 sec

<table>
<thead>
<tr>
<th>Interface</th>
<th>Role</th>
<th>Sts</th>
<th>Cost</th>
<th>Prio. Nbr</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eth1/3</td>
<td>Desg</td>
<td>FWD</td>
<td>2</td>
<td>128.131</td>
<td>Edge P2p</td>
</tr>
<tr>
<td>Eth1/30</td>
<td>Desg</td>
<td>FWD</td>
<td>2</td>
<td>128.158</td>
<td>P2p</td>
</tr>
<tr>
<td>Eth1/31</td>
<td>Desg</td>
<td>FWD</td>
<td>2</td>
<td>128.159</td>
<td>P2p</td>
</tr>
</tbody>
</table>

**Figure 29** VLAN 1 and VLAN 10 on N5K1
S4128-SW1# show spanning-tree active
Spanning tree enabled protocol msti with force-version mst
MSTI 0 VLANs mapped 1-9,11-19,21-4093
Executing IEEE compatible Spanning Tree Protocol
Root ID Priority 24577, Address 547f.eeac.13c1
Root Bridge hello time 2, max age 20, forward delay 15, max hops 20
Bridge ID Priority 32768, Address f48e.385f.3dca
Configured hello time 2, max age 20, forward delay 15, max hops 20
CIST regional root ID Priority 32768, Address f48e.385f.3dca
CIST external path cost 2000

<table>
<thead>
<tr>
<th>Interface</th>
<th>Designated Name</th>
<th>PortID</th>
<th>Prio</th>
<th>Cost</th>
<th>Sts</th>
<th>Cost</th>
<th>Bridge ID</th>
<th>PortID</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethernet1/1/3</td>
<td></td>
<td>128.524</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>2000</td>
<td>32768</td>
<td>f48e.385f.3dca</td>
</tr>
<tr>
<td>ethernet1/1/8</td>
<td></td>
<td>128.544</td>
<td>128</td>
<td>2000</td>
<td>BLK</td>
<td>2</td>
<td>32769</td>
<td>002a.6a0d.a17c</td>
</tr>
<tr>
<td>ethernet1/1/9</td>
<td></td>
<td>128.548</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>0</td>
<td>24577</td>
<td>547f.eeac.13c1</td>
</tr>
</tbody>
</table>

MSTI 1 VLANs mapped 10
Executing IEEE compatible Spanning Tree Protocol
Root ID Priority 32768, Address f48e.385f.3dca
Root Bridge hello time 2, max age 20, forward delay 15, max hops 20
Bridge ID Priority 32768, Address f48e.385f.3dca

We are the root of MSTI 1
Configured hello time 2, max age 20, forward delay 15, max hops 20
CIST regional root ID Priority 0, Address 0023.00ed.0700
CIST external path cost 0

<table>
<thead>
<tr>
<th>Interface</th>
<th>Designated Name</th>
<th>PortID</th>
<th>Prio</th>
<th>Cost</th>
<th>Sts</th>
<th>Cost</th>
<th>Bridge ID</th>
<th>PortID</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethernet1/1/3</td>
<td></td>
<td>128.524</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>0</td>
<td>32768</td>
<td>f48e.385f.3dca</td>
</tr>
<tr>
<td>ethernet1/1/8</td>
<td></td>
<td>128.544</td>
<td>128</td>
<td>2000</td>
<td>BLK</td>
<td>0</td>
<td>32768</td>
<td>f48e.385f.3dca</td>
</tr>
<tr>
<td>ethernet1/1/9</td>
<td></td>
<td>128.548</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>0</td>
<td>32768</td>
<td>f48e.385f.3dca</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interface</th>
<th>Role</th>
<th>PortID</th>
<th>Prio</th>
<th>Cost</th>
<th>Sts</th>
<th>Cost</th>
<th>Link-type</th>
<th>Edge</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethernet1/1/3</td>
<td>Desg</td>
<td>128.524</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
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<td>AUTO</td>
<td>No</td>
</tr>
<tr>
<td>ethernet1/1/8</td>
<td>Altr</td>
<td>128.544</td>
<td>128</td>
<td>2000</td>
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<td>2</td>
<td>AUTO</td>
<td>No</td>
</tr>
<tr>
<td>ethernet1/1/9</td>
<td>Master</td>
<td>128.548</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>0</td>
<td>AUTO</td>
<td>No</td>
</tr>
</tbody>
</table>

Figure 30  MSTI 0 and MSTI 1 on S4128-SW1
2.2 Tests – VLT (Aggregation) and vPC (Core)

In this set of tests, the Dell EMC switches and Cisco switches have been configured with their respective device redundancy technologies.

2.2.1 Test#1 – RSTP (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)

Rapid PVST+ is configured on the Cisco switches and RSTP on the Dell EMC switches. Both rapid spanning tree protocol (RSTP) and rapid per-VLAN spanning tree (RPVST+) modes of spanning tree protocol is supported in VLT mode. Two set of tests were performed using the following configuration:

- In the first test, Cisco switches act as the root bridge for the respective VLANs
- Dell EMC switch as the root bridge

**Cisco N5Ks as the root bridge**

![Physical and Logical Network Topology - RSTP (Dell EMC) and RPVST+(Cisco)](image)

**Figure 31 Physical and Logical Network Topology - RSTP (Dell EMC) and RPVST+(Cisco)**

**Test Steps**

The following test steps were conducted with Ixia IxExplorer to simulate a fail-over scenario:

1. Create two tagged streams with VLAN ID 10 being sourced from port 1 with MAC address “1” and destination ports 3 & 4 with MAC destination addresses “3” and “4” respectively.

2. Ensure that tagged VLAN 20 traffic from the traffic source port 1 is going through the N5K1 Cisco switch as per the diagram.

3. Shut down both port-channels 100 & 110 on N5K1 to simulate a fail-over scenario and check for any traffic disruption. Data flow from port 1 to ports 3 and 4 now flow through the vPC port-channel to N5K2 and down through each respective link.

4. Recover both ports and check for any traffic disruption and make sure N5K1 becomes the root bridge.
5. Shut down individual ports 30 & 1 on N5K1 and check for any traffic disruptions.

Results

To understand the results achieved, we need to look at the interconnections between switches. When vPC and VLT is configured on the Cisco and Dell EMC switches respectively, a 4-member port-channel link is created between the switches. On the Dell EMC switch, once the discovery interfaces are configured on both the nodes, port-channel 1000 is automatically configured. The ports should be configured as no switchport from the default Layer-2 mode while configuring the discovery interfaces. From the S4128F perspective, 1/1/18 and 1/1/19 interfaces form the discovery interfaces/VLTi (Po-1000) on the VLT Peer1 (S4128-SW1). Similarly, 1/1/18 and 1/1/19 interfaces form the discovery interface on VLT Peer2 (S4128-SW2).

Port-channel 100 is configured on S4128-SW1 and port-channel 110 on S4128-SW2. VLANs 10 and 20 are mapped to both the port channels. The VLAN membership is shown below in Figure 32.

<table>
<thead>
<tr>
<th>Codes:</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Access (Untagged), T</td>
<td>Tagged</td>
</tr>
<tr>
<td>1</td>
<td>Active</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Active</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Active</td>
<td></td>
</tr>
<tr>
<td>4094</td>
<td>Active</td>
<td></td>
</tr>
</tbody>
</table>

Figure 32  VLAN Membership – S4128-SW1

From the Cisco N5K perspective, by shutting down Po100 locally, Po110 continues to forward the traffic since both port-channels are continuously forwarding. VLT ports, similar to vPC ports, are always in the forwarding state by default as per the feature implementation. Shutting down the individual links on the Dell EMC switch, made no difference on the results because there are 3 available links forwarding. Figure 33 is a snapshot of the test results during a fail-over and recovery from ports 1 to ports 3 and 4.

- Frame Loss % = 0.0

Figure 33  Test results during failover
Tables 1 and 2 show the spanning tree link status for all four switches.

**Table 1  S4128-SW1 RSTP link status**

<table>
<thead>
<tr>
<th>Bridge ID</th>
<th>Priority 32768, Address f48e.385f.3dca</th>
<th>Designated</th>
<th>Interface Name</th>
<th>PortID</th>
<th>Prio</th>
<th>Cost</th>
<th>Sts</th>
<th>Cost</th>
<th>Bridge ID</th>
<th>PortID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ethernet1/1/3</td>
<td>128.524</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>501</td>
<td>32768</td>
<td>f48e.385f.3dca 128.524</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>port-channel100</td>
<td>128.2517</td>
<td>128</td>
<td>500</td>
<td>FWD</td>
<td>1</td>
<td>32769</td>
<td>0023.04ee.be01 144.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ethernet1/1/3</td>
<td>128.524</td>
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<td>FWD</td>
<td>501</td>
<td>32768</td>
<td>6400.6af6.faf4 128.524</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>port-channel110</td>
<td>128.2517</td>
<td>128</td>
<td>500</td>
<td>FWD</td>
<td>1</td>
<td>32768</td>
<td>6400.6af6.faf4 128.2517</td>
</tr>
</tbody>
</table>

**S4128-SW2# show spanning-tree active**
Spanning tree enabled protocol rstp with force-version rstp
Executing IEEE compatible Spanning Tree Protocol
Root ID  Priority 24577, Address 547f.eeac.13c1
Bridge ID  Priority 32768, Address 6400.6af6.faf4

<table>
<thead>
<tr>
<th>Bridge ID</th>
<th>Priority 32768, Address 6400.6af6.faf4</th>
<th>Designated</th>
<th>Interface Name</th>
<th>PortID</th>
<th>Prio</th>
<th>Cost</th>
<th>Sts</th>
<th>Cost</th>
<th>Bridge ID</th>
<th>PortID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>ethernet1/1/3</td>
<td>128.524</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>502</td>
<td>32768</td>
<td>6400.6af6.faf4 128.524</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>port-channel110</td>
<td>128.2517</td>
<td>128</td>
<td>500</td>
<td>FWD</td>
<td>502</td>
<td>32768</td>
<td>6400.6af6.faf4 128.2517</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ethernet1/1/3</td>
<td>128.524</td>
<td>128</td>
<td>2000</td>
<td>FWD</td>
<td>502</td>
<td>AUTO</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>port-channel110</td>
<td>128.2517</td>
<td>128</td>
<td>500</td>
<td>FWD</td>
<td>502</td>
<td>AUTO</td>
<td>No</td>
</tr>
</tbody>
</table>
### Table 2  N5K RPVST+ link status

<table>
<thead>
<tr>
<th>VLAN0001</th>
<th>Spanning tree enabled protocol rstp</th>
<th>Root ID</th>
<th>Priority</th>
<th>Address</th>
<th>This bridge is the root</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>Role</td>
<td>Sts</td>
<td>Cost</td>
<td>Prio</td>
<td>Nbr</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>Po1</td>
<td>Desg</td>
<td>FWD</td>
<td>128.4096 (vPC peer-link)</td>
<td>Network P2p</td>
<td></td>
</tr>
<tr>
<td>Po100</td>
<td>Desg</td>
<td>FWD</td>
<td>128.4195 (vPC)</td>
<td>P2p</td>
<td></td>
</tr>
<tr>
<td>Po110</td>
<td>Desg</td>
<td>FWD</td>
<td>128.4205 (vPC)</td>
<td>P2p</td>
<td></td>
</tr>
<tr>
<td>Eth1/3</td>
<td>Desg</td>
<td>FWD</td>
<td>128.131</td>
<td>Edge P2p</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VLAN0010</th>
<th>Spanning tree enabled protocol rstp</th>
<th>Root ID</th>
<th>Priority</th>
<th>Address</th>
<th>This bridge is the root</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>Role</td>
<td>Sts</td>
<td>Cost</td>
<td>Prio</td>
<td>Nbr</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>-----</td>
</tr>
<tr>
<td>Po1</td>
<td>Desg</td>
<td>FWD</td>
<td>128.4096 (vPC peer-link)</td>
<td>Network P2p</td>
<td></td>
</tr>
<tr>
<td>Po100</td>
<td>Desg</td>
<td>FWD</td>
<td>128.4195 (vPC)</td>
<td>P2p</td>
<td></td>
</tr>
<tr>
<td>Po110</td>
<td>Desg</td>
<td>FWD</td>
<td>128.4205 (vPC)</td>
<td>P2p</td>
<td></td>
</tr>
<tr>
<td>Eth1/3</td>
<td>Desg</td>
<td>FWD</td>
<td>128.131</td>
<td>Edge P2p</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VLAN0020</th>
<th>Spanning tree enabled protocol rstp</th>
<th>Root ID</th>
<th>Priority</th>
<th>Bridge ID</th>
<th>Address</th>
<th>This bridge is the root</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interface</td>
<td>Role</td>
<td>Sts</td>
<td>Cost</td>
<td>Prio</td>
<td>Nbr</td>
<td>Type</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>Po1</td>
<td>Root</td>
<td>FWD</td>
<td>128.4096 (vPC peer-link)</td>
<td>Network P2p</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Po100</td>
<td>Desg</td>
<td>FWD</td>
<td>128.4195 (vPC)</td>
<td>P2p</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Po110</td>
<td>Desg</td>
<td>FWD</td>
<td>128.4205 (vPC)</td>
<td>P2p</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eth1/3</td>
<td>Desg</td>
<td>FWD</td>
<td>128.131</td>
<td>Edge P2p</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dell EMC S4128F-ON as the root bridge

S4128-SW1 is configured as root bridge in this test case. Figure 34 depicts how the traffic flow is sent from port 1 to 3 and 4.

Test Steps

1. Create two tagged streams with VLAN ID 10 and 20 being sourced from port 1 with MAC address “1” and destination ports 3 & 4.

2. Ensure that tagged VLAN 20 traffic from the traffic source port 1 is going through the N5K1 Cisco switch as per the diagram.

3. Shut down port-channel 100 and 110 on N5K1 to simulate a fail-over scenario and check for any traffic disruption.

4. Shut down individual ports 30 & 1 and check for any traffic disruptions.

5. Recover ports 30 and 1 and check for any measurable traffic disruption.

6. Repeat steps 4-6 and source traffic from port 3 to ports 1 and 2.

Results

Figure 35 is a snapshot of the test results during a fail-over and recovery from ports 1 to ports 3 & 4.

- Frame Loss % = 0
Dell EMC Networking: Spanning Tree Interoperability

2.2.2 Test#2 – RPVST+ (Dell EMC S4128F-ON) and RPVST+ (Cisco 5548UP)

Rapid PVST+ is configured on Cisco and Dell EMC switches. Rapid PVST+ is enabled by default in OS10EE. There is no need to configure it unless the default spanning tree mode is changed. In this test case, Dell EMC switches are configured as root bridge. S4128-SW1 is the root bridge for VLAN 1 and 10 and S4128-SW2 is the root bridge for VLAN 20. Figure 36 depicts how the traffic flow is sent from port 1 to 3 and 4.

Test Steps

1. Create two tagged streams with VLAN ID 10 and 20 being sourced from port 1 with MAC address “2” and destination ports 3 and 4.

2. Ensure that tagged VLAN 20 traffic from the traffic source port 1 is going through the N5K2 Cisco switch as per the diagram.

3. Shut down port-channel 100 and 110 on N5K1 to simulate a fail-over scenario and check for any traffic disruption.

4. Recover both ports and check for any traffic disruption and make sure S4128F becomes the root bridge.

5. Shut down individual ports 30 & 1 and check for any traffic disruptions.

6. Recover ports 30 and 1 and check for any measurable traffic disruption.

7. Repeat steps 4–6 and source traffic from port 3 to ports 1 and 2.
Dell EMC Networking: Spanning Tree Interoperability

Figure 36  Physical and Logical Network Topology - RPVST+ (Dell EMC) and RPVST+ (Cisco)

Results

Figure 37 is a snapshot of the test results during a fail-over and recovery from ports 1 to ports 3 and 4.

- Frame Loss % = 0

Figure 37  Traffic port statistics during fail-over
2.2.3 Test#3 – RSTP (Dell EMC S4128F-ON) and MST (Cisco 5548UP)

With RSTP and MST enabled, considering that MST uses RSTP’s convergence timers, and the fact that only a single spanning tree instance is running between the two different regions, we should expect to get convergence times ranging between 1-2 seconds or possibly less. Figure 38 depicts how the traffic flow from port 3 to ports 2 and 1 traverse the network.

Figure 38 Physical and Logical Network Topology - RSTP (Dell EMC) and MST (Cisco)

Test Steps

1. Create two tagged streams of VLAN ID 20 with source port 3 and destination ports 1 and 2.

2. Ensure that VLAN 20 traffic from port 3 is going through the N5K1 since this is the common spanning tree root bridge. Interface counters on N5K2 ports 1 and 2 should read zero. The only interface on N5K2 incrementing should be the internal vPC channel and port 3 transmit counter.

3. Shut down port-channel 100 on N5K1 to simulate a fail-over scenario and check for any traffic disruption.

4. Recover Po100 on N5K1 and check for any traffic disruption and make sure N5K1 becomes the root bridge.

5. Shut down individual ports 9 and 8 on S4128-SW1 and check for any traffic disruptions. Traffic should switch-over to Po110 on S4128-SW2 and continue without measurable disruption.

6. Recover ports 9 and 8 and check for any measurable traffic disruption.
Results

Figure 39 shows a snapshot of the counters (highlighted) during and after switch-over failure.

- Frame Loss % = 0.0
- Frame Loss Duration = 0.07 seconds
3 Summary

Running a mixed spanning tree environment although not recommended, is good to know that Dell EMC OS10EE spanning tree options and device redundancy feature provide a solid performance and interoperability capability. The results of these tests (see Table 3), prove that the spanning tree implementations can indeed seamlessly, and in a particular configuration integrate into an existing environment provided a clear understanding is obtained prior to doing any network migration.

Based on the test results, matching the spanning tree flavor or mode is the most efficient recommended type of deployment.

Table 3 Spanning Tree Convergence Results

<table>
<thead>
<tr>
<th>Dell EMC OS10EE</th>
<th>Cisco (NX_OS)</th>
<th>Frame Loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No VLT (RPVST+)</td>
<td>No vPC(RPVST+)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Same mode, 100% interoperable. Both spanning tree modes use the same convergence timers therefore convergence times upon link failures are quick. Although, each VLAN requires an instance that takes up CPU overhead.</td>
<td></td>
</tr>
<tr>
<td>No VLT (MST)</td>
<td>No vPC(MST)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Same mode, 100% interoperable. RSTP timers will be used when a spanning tree event takes place.</td>
<td></td>
</tr>
<tr>
<td>No VLT (RSTP)</td>
<td>No vPC(RPVST+)</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>Not a clear advantage, due to the proprietary nature of RPVST+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Note: For Cisco bridge to converge with a third-party switch running RSTP, VLAN 1 must be allowed on all 802.1Q trunk interfaces that connect these switches. Do not clear or disable VLAN 1 on trunks between RSTP and RPVST+ bridges</td>
<td></td>
</tr>
<tr>
<td>No VLT (RSTP)</td>
<td>No vPC(MST)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Both spanning tree versions interoperate 100% due to MST’s underlying use of RSTP’s convergence timers.</td>
<td></td>
</tr>
<tr>
<td>No VLT (MST)</td>
<td>No vPC(RPVST+)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No clear advantage.</td>
<td></td>
</tr>
<tr>
<td>With VLT: RSTP</td>
<td>With vPC: RPVST+</td>
<td>Frame Loss % = 0</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Most efficient and simpler deployment due to the back to back port-channel links between both logical domains. It requires that both switches have a device redundancy technology to achieve the simple deployment model.</td>
</tr>
<tr>
<td>With VLT: RPVST+</td>
<td>With vPC: RPVST+</td>
<td>Frame Loss % = 0</td>
</tr>
<tr>
<td>With VLT: RSTP</td>
<td>With vPC: MST</td>
<td>Frame Loss % = 0</td>
</tr>
</tbody>
</table>
## Switch Configurations

N5K1# `sh run`

```
!Command: show running-config

version 5.1(3)N2(1)
hostname name N5K1

no feature telnet
no feature http-server
feature lacp
feature vpc
feature lldp

vrf context management
  ip route 0.0.0.0/0 10.11.235.254
VLAN 1,10,20
spanning-tree VLAN 1,10 priority 24576
spanning-tree VLAN 20 priority 28672
vpc domain 1
  role priority 1
  peer-keepalive destination 10.11.235.35

interface port-channel1
  description vpc_peer_channel
  switchport mode trunk
  spanning-tree port type network
  speed 10000
  vpc peer-link

interface port-channel100
  switchport mode trunk
  vpc 10

interface port-channel110
  switchport mode trunk
  vpc 20

interface Ethernet1/1
  description link_to_S4128-SW2
  switchport mode trunk
  channel-group 110 mode active
  no shutdown

interface Ethernet1/2
  no shutdown
```
interface Ethernet1/3
  switchport mode trunk
  spanning-tree port type edge trunk
  no shutdown

interface Ethernet1/30
  description link_to_S4128-SW1
  switchport mode trunk
  channel-group 100 mode active
  no shutdown

interface Ethernet1/31
  description link_between_N5Ks
  switchport mode trunk
  channel-group 1 mode active
  no shutdown

interface Ethernet1/32
  description link_between_N5Ks
  switchport mode trunk
  channel-group 1 mode active
  no shutdown

interface mgmt0
  ip address 10.11.235.34/24
line console
line vty
boot kickstart bootflash:/n5000-uk9-kickstart.5.1.3.N2.1.bin
boot system bootflash:/n5000-uk9.5.1.3.N2.1.bin
ip route 0.0.0.0/0 10.11.235.254
system default switchport shutdown
logging console 7
S4128-SW1# show running-configuration

! Version 10.4.2.1
! Last configuration change at Jan 25 09:11:01 2019
!
hostname S4128-SW1
spanning-tree mode rstp
spanning-tree rstp force-version stp
spanning-tree rstp priority 8192
!
interface VLAN1
  no shutdown
!
interface VLAN10
  no shutdown
!
interface VLAN20
  no shutdown
!
interface port-channel100
  no shutdown
  switchport mode trunk
  switchport access VLAN 1
  switchport trunk allowed VLAN 10,20
  vlt-port-channel 1
!
interface ethernet1/1/3
  no shutdown
  switchport mode trunk
  switchport access VLAN 1
  switchport trunk allowed VLAN 10,20
  flowcontrol receive on
!
interface ethernet1/1/8
  description channel_member_to_Cisco
  no shutdown
  channel-group 100 mode active
  no switchport
  flowcontrol receive on
!
interface ethernet1/1/9
  description channel_member_to_Cisco
  no shutdown
  channel-group 100 mode active
  no switchport
  flowcontrol receive on
!
interface ethernet1/1/12
  no shutdown
  switchport access VLAN 1
  flowcontrol receive on
interface ethernet1/1/18
  description vlt_link_members
  no shutdown
  no switchport
  flowcontrol receive on

interface ethernet1/1/19
  description vlt_link_members
  no shutdown
  no switchport
  flowcontrol receive on

interface mgmt1/1/1
  no shutdown
  no ip address dhcp
  ip address 10.11.235.10/24
  ipv6 address autoconfig

management route 0.0.0.0/0 10.11.235.254

vlt-domain 1
  discovery-interface ethernet1/1/18-1/1/19
  primary-priority 1
5 VLT Syslog Messages

Syslog Messages: SW1

S4128-SW1(config)# vlt-domain 1

S4128-SW1(conf-vlt-1)# <165>1 2019-01-16T07:12:09.691356+00:00 S4128-SW1 dn_ifm 785 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %IFM_ASTATE_UP: Interface admin state up :VLAN 4094

<165>1 2019-01-16T07:12:09.822158+00:00 S4128-SW1 dn_app_vlt 1119 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %VLT_ELECTION_ROLE: VLT unit 1 is elected as primary

Syslog Messages: SW2

S4128-SW2(config)# vlt-domain 1

S4128-SW2(conf-vlt-1)# <165>1 2019-01-16T07:26.961427+00:00 S4128-SW2 dn_ifm 790 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %IFM_ASTATE_UP: Interface admin state up :VLAN4094

<165>1 2019-01-16T07:26.096482+00:00 S4128-SW2 dn_app_vlt 1111 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %VLT_ELECTION_ROLE: VLT unit 1 is elected as primary

S4128-SW2(conf-vlt-1)# discovery-interface ethernet1/1/18

S4128-SW2(conf-vlt-1)# discovery-interface ethernet1/1/19

S4128-SW2(conf-vlt-1)# <165>1 2019-01-16T08:07:26.874209+00:00 S4128-SW2 dn_ifm 790 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %IFM_ASTATE_UP: Interface admin state up :port-channel11000

<165>1 2019-01-16T08:07:26.881440+00:00 S4128-SW2 dn_ifm 790 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %IFM_OSTATE_DN: Interface operational state is down :port-channel11000

<165>1 2019-01-16T08:07:27.102136+00:00 S4128-SW2 dn_ifm 790 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %IFM_OSTATE_UP: Interface operational state is up :port-channel11000

<165>1 2019-01-16T08:07:27.154630+00:00 S4128-SW2 dn_ifm 790 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %IFM_OSTATE_UP: Interface operational state is up :VLAN4094

<165>1 2019-01-16T08:07:27.169110+00:00 S4128-SW2 dn_app_vlt 1111 -- Node.1-Unit.1:PRI [event], Dell EMC (OS10) %VLT_PEER_UP: VLT unit 1 is up
Dell EMC Networking: Spanning Tree Interoperability

1 2019-01-16T08:07:27.173775+00:00 S4128-SW2 dn_app_vlt 1111 - - Node.1-Unit.1:PRI [event], Dell EMC (OS10) %VLT_VLTI_LINK_UP: VLT interconnect link between unit 2 and unit 1 is up

1 2019-01-16T08:07:35.850767+00:00 S4128-SW2 dn_app_vlt 1111 - - Node.1-Unit.1:PRI [event], Dell EMC (OS10) %VLT_ELECTION_R

S4128-SW2(config)# interface port-channel 110

S4128-SW2(config-if-po-110)# vlt-port-channel

S4128-SW2(config-if-eth1/1/8)# channel-group 110 mode active

S4128-SW2(config-if-eth1/1/8)# <165>1 2019-01-16T08:57:48.429078+00:00 S4128-SW2 dn_ifm 790 - - Node.1-Unit.1:PRI [event], Dell EMC (OS10) %IFM_ASTATE_UP: Interface admin state up :port-channel110

S4128-SW2(config-if-eth1/1/8)# <165>1 2019-01-16T08:57:48.498977+00:00 S4128-SW2 dn_lacp 799 - - Node.1-Unit.1:PRI [event], Dell EMC (OS10) %LACP_PORT_GROUPED: Interface joined port-channel port-channel110 : ethernet1/1/8

S4128-SW1# show spanning-tree virtual-interface

VFP(VirtualFabricPort) of RSTP 1 is Designated Forwarding
Edge port: No (default)
Link type: point-to-point (auto)
Boundary: No, Bpdu-filter: Disable, Bpdu-Guard: Disable, Shutdown-on-Bpdu-Guard-violation: No
Root-Guard: Disable, Loop-Guard: Disable
Bpdus (MRecords) Sent: 1706, Received: 941
Interface
Designated
Name Bridge I PortID Prio Cost Sts PortID Cost
-----------------------------------------------
VFP(VirtualFabricPort) 0.1 0 1 FWD 501
32768 f48e.385f.3dca 0.1
6 Helpful Troubleshooting Commands

S4128-SW1# show vlt 1
Domain ID : 1
Unit ID : 1
Role : primary
Version : 2.0
Local System MAC address : f4:8e:38:5f:3d:ca
Role priority : 1
VLT MAC address : f4:8e:38:5f:3d:ca
IP address : fda5:74c8:b79e:1::1
Delay-Restore timer : 90 seconds
Peer-Routing : Disabled
Peer-Routing-Timeout timer : 0 seconds
VLTi Link Status
    port-channel1000 : up

VLT Peer Unit ID    System MAC Address    Status    IP Address
Version
--------------------------------------------------------------------------------
--
  2       64:00:6a:f6:fa:f4     up       fda5:74c8:b79e:1::2
2.0

S4128-SW1# show topology-map

TOPOLOGY MAP
-------------
Topology ID : 1
Topology Pattern : chain
Topology User : VLT
Local Unit ID : 1
Master Unit ID : 1
From-Interface| From-Interface | To-Interface | To-Interface | Link-Speed | Link-Status |
<table>
<thead>
<tr>
<th>Unit ID</th>
<th></th>
<th>Unit ID</th>
<th></th>
<th>(Gb/s)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ethernet1/1/18</td>
<td>2</td>
<td>ethernet1/1/18</td>
<td>10</td>
<td>up</td>
</tr>
<tr>
<td>1</td>
<td>ethernet1/1/19</td>
<td>2</td>
<td>ethernet1/1/19</td>
<td>10</td>
<td>up</td>
</tr>
<tr>
<td>2</td>
<td>ethernet1/1/18</td>
<td>1</td>
<td>ethernet1/1/18</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>ethernet1/1/19</td>
<td>1</td>
<td>ethernet1/1/19</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
S4128-SW1# show vlt 1 vlt-port-detail

vlt-port-channel ID : 1
VLT Unit ID Port-Channel Status Configured ports Active ports
-----------------------------------------------------------------------------------
* 1 port-channel100 up 2 2
  2 port-channel110 up 2 2

S4128-SW1# show port-channel summary
-----------------------------------------------------------------------------------
Group Port-Channel Type Protocol Member Ports
-----------------------------------------------------------------------------------
  100 port-channel100 (U) Eth DYNAMIC 1/1/8(P) 1/1/9(P)
  1000 port-channel1000 Eth STATIC 1/1/18(P) 1/1/19(P)

S4128-SW1# show running-configuration vlt
!
vlt-domain 1
discovery-interface ethernet1/1/18-1/1/19
  primary-priority 1
!
interface port-channel100
  vlt-port-channel 1

S4128-SW1(conf-if-vl-20)# do show vlt 1

Domain ID : 1
Unit ID : 1
Role : primary
Version : 2.0
Local System MAC address : f4:8e:38:5f:3d:ca
Role priority : 1
VLT MAC address : f4:8e:38:5f:3d:ca
IP address : fda5:74c8:b79e:1::1
Delay-Restore timer : 90 seconds
Peer-Routing : Disabled
Peer-Routing-Timeout timer : 0 seconds
VLTi Link Status
  port-channel1000 : up

VLT Peer Unit ID System MAC Address Status IP Address Version
-----------------------------------------------------------------------------------
  2 64:00:6a:f6:fa:f4 up fda5:74c8:b79e:1::2 2.0