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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Contents

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.

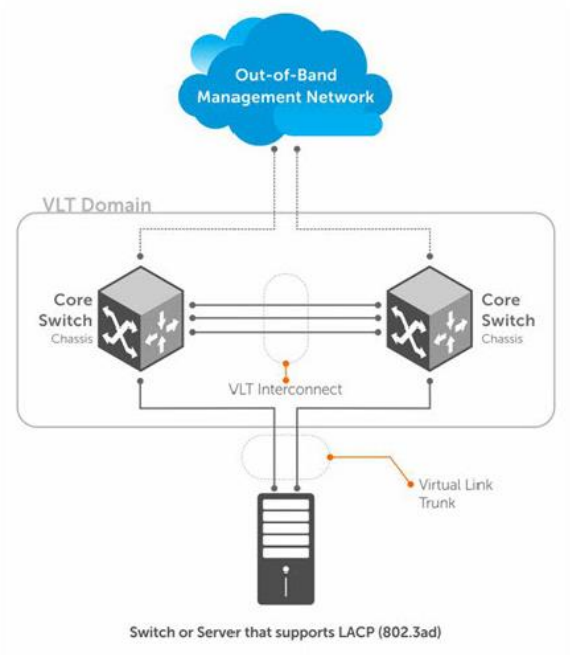


Figure 1 Dell EMC Networking OS10 Enterprise Edition – Virtual Link Trunking

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.

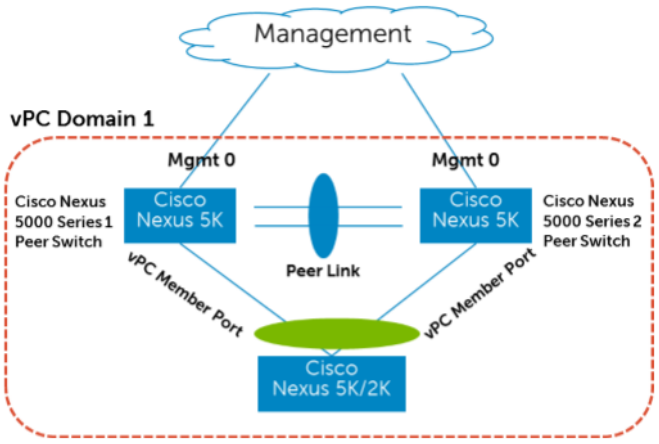


Figure 2 Cisco vPC deployment running Nexus OS

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 to fixed 100GbE QSFP28 ports. Two of these switches are used in the deployment examples.

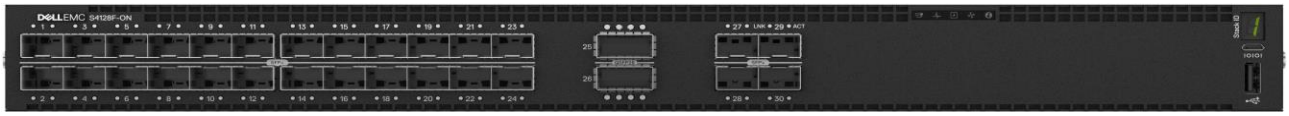


Figure 3 Dell EMC Networking S4128F-ON

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.

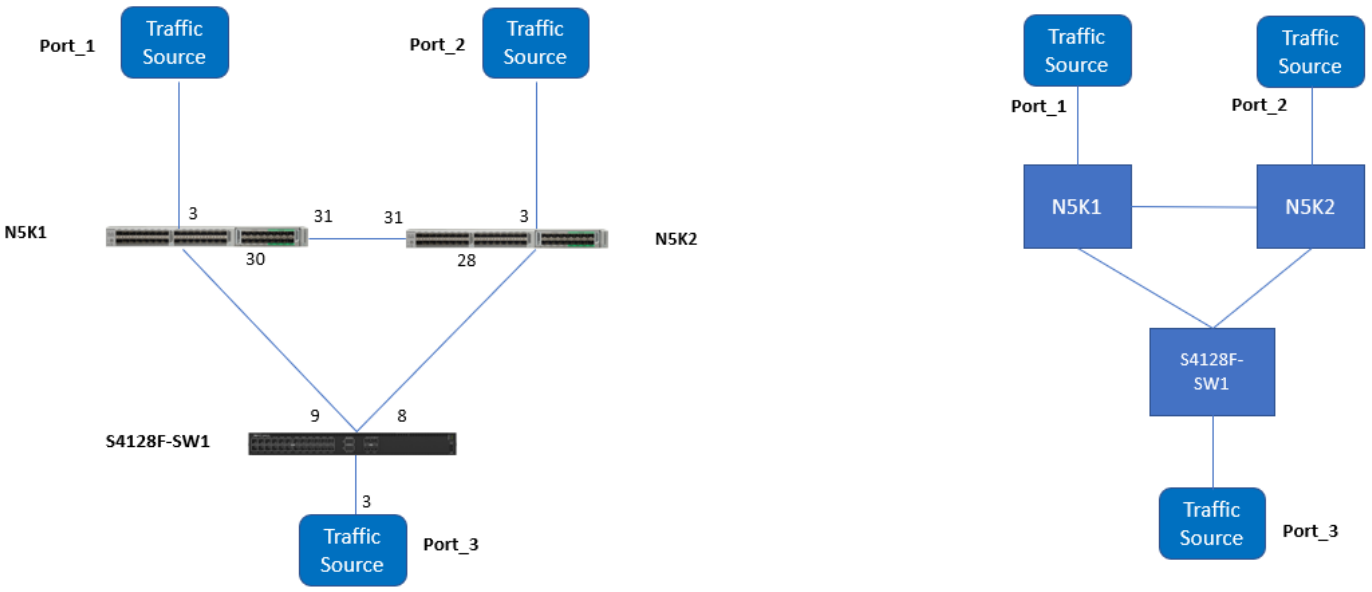


Figure 4 Physical and logical reference network test-bed (Test Setup without VLT and vPC)

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.

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

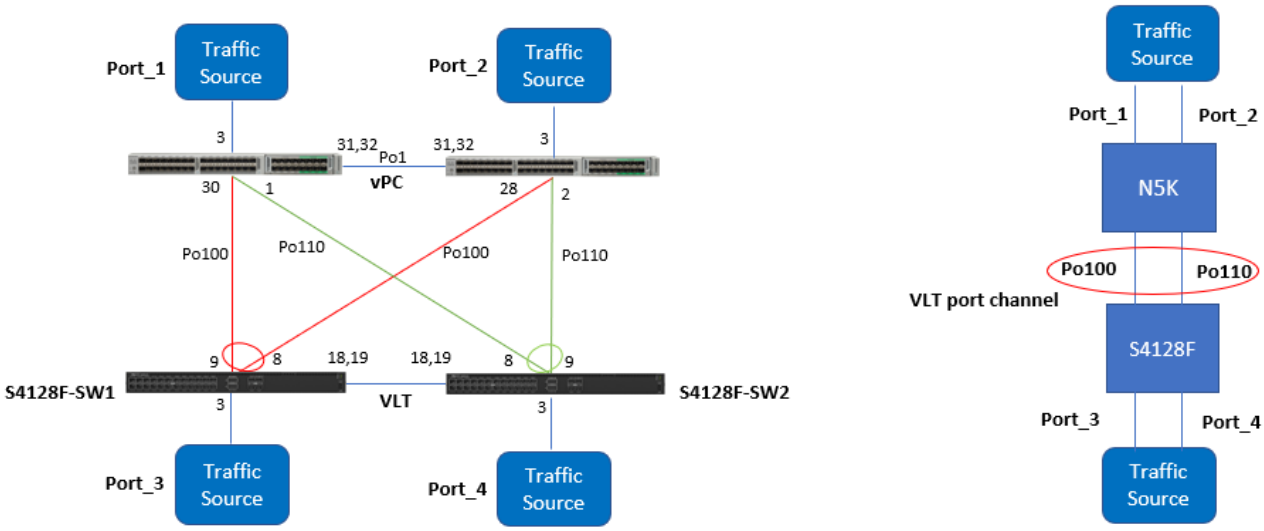


Figure 5 Test Setup with VLT and vPC

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 = (Total Frames Sent – Total Frames Received) \ Total Frames Sent

Frame Loss Duration = (Total Frames Sent – Total Frames Received) \ 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.

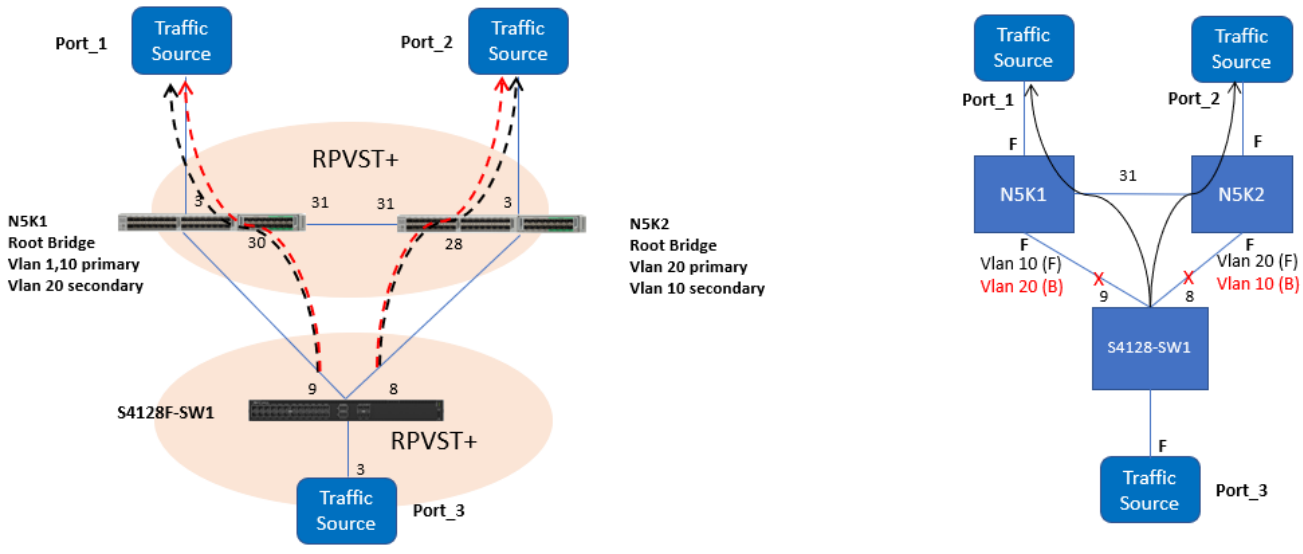


Figure 6 Physical and Logical Network Topology – RPVST+ (Dell EMC) and RPVST+ (Cisco)

```
Spanning tree enabled protocol rapid-pvst
VLAN 10
Executing IEEE compatible Spanning Tree Protocol
Root ID     Priority 24586, Address 547f.eeac.13c1
Root Bridge hello time 2, max age 20, forward delay 15
Bridge ID    Priority 32778, Address f48e.385f.3dca
Configured hello time 2, max age 20, forward delay 15
Interface                                                    Designated
Name              PortID    Prio      Cost      Sts        Cost      Bridge ID              PortID
-------------------------------------------------------------------------------------------------
ethernet1/1/3     128.268   128       2000      FWD        2000      32778    f48e.385f.3dca  128.268
ethernet1/1/8     128.288   128       2000      BLK        2         28682    002a.6a0d.a17c  128.156
ethernet1/1/9     128.292   128       2000      FWD        0         24586    547f.eeac.13c1  128.158
Interface
Name              Role    PortID    Prio      Cost      Sts        Cost      Link-type    Edge
-------------------------------------------------------------------------------------------------
ethernet1/1/3     Desg    128.268   128       2000      FWD        2000      AUTO         Yes
ethernet1/1/8     Altr    128.288   128       2000      BLK        2         AUTO         No
ethernet1/1/9     Root    128.292   128       2000      FWD        0         AUTO         No
```

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

```
Spanning tree enabled protocol rapid-pvst
VLAN 20
Executing IEEE compatible Spanning Tree Protocol
Root ID     Priority 24596, Address 002a.6a0d.a17c
Root Bridge hello time 2, max age 20, forward delay 15
Bridge ID    Priority 32788, Address f48e.385f.3dca
Configured hello time 2, max age 20, forward delay 15
Interface                                                    Designated
Name              PortID    Prio      Cost      Sts        Cost      Bridge ID              PortID
-------------------------------------------------------------------------------------------------
ethernet1/1/3     128.268   128       2000      FWD        2000      32788    f48e.385f.3dca  128.268
ethernet1/1/8     128.288   128       2000      FWD        0         24596    002a.6a0d.a17c  128.156
ethernet1/1/9     128.292   128       2000      BLK        2         28692    547f.eeac.13c1  128.158
Interface
Name              Role    PortID    Prio      Cost      Sts        Cost      Link-type    Edge
-------------------------------------------------------------------------------------------------
ethernet1/1/3     Desg    128.268   128       2000      FWD        2000      AUTO         Yes
ethernet1/1/8     Root    128.288   128       2000      FWD        0         AUTO         No
ethernet1/1/9     Altr    128.292   128       2000      BLK        2         AUTO         No
```

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.

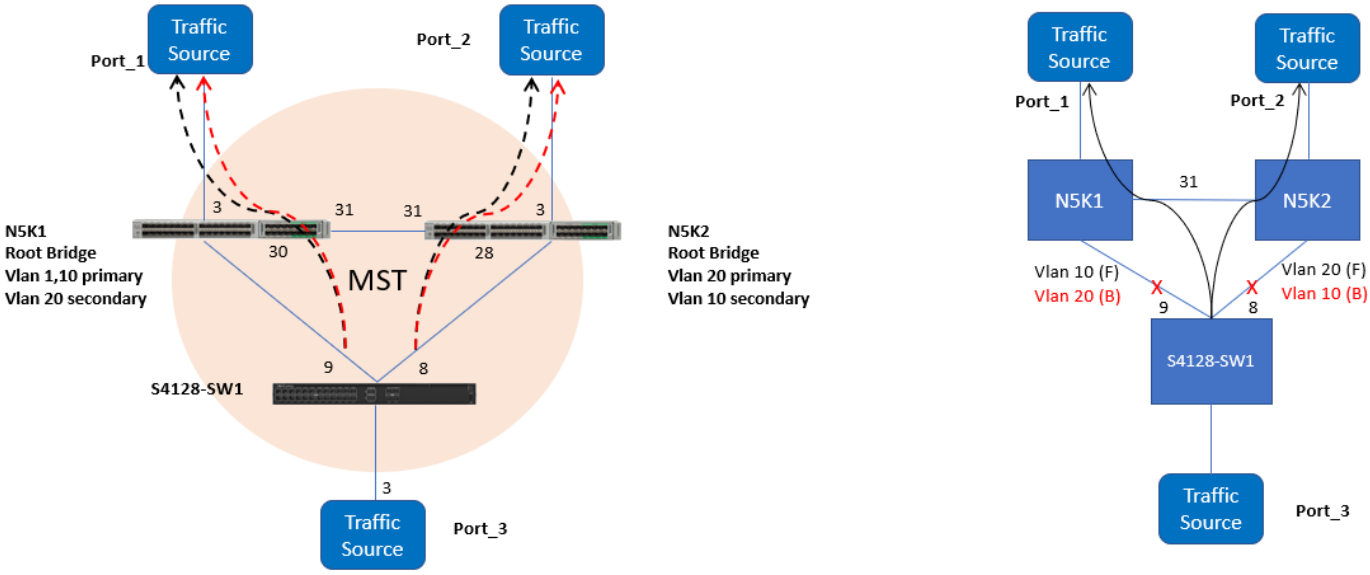


Figure 9 Physical and logical network topology– MST (Dell EMC) and MST (Cisco)

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.

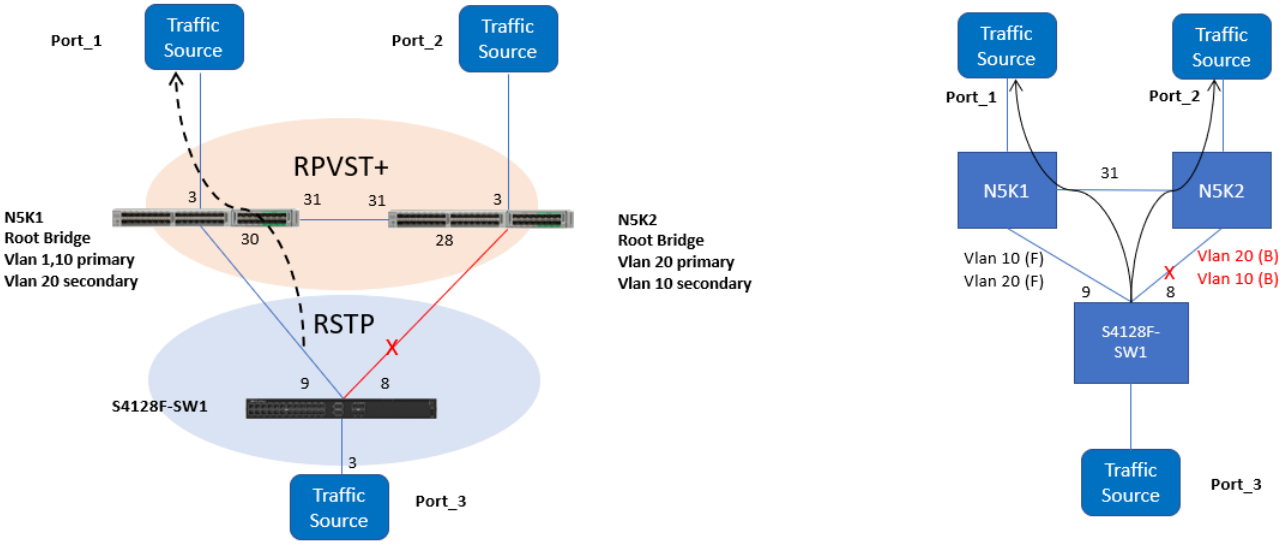


Figure 10 Physical and Logical Network Topology – RSTP (Dell EMC) and RPVST+ (Cisco)

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.

```
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
Interface                                        Designated
Name           PortID    Prio     Cost     Sts       Cost     Bridge ID           PortID
-------------------------------------------------------------------------------------------------
ethernet1/1/3  128.524   128      2000     FWD       2000     32768    f48e.385f.3dca  128.524
ethernet1/1/8  128.544   128      2000     BLK       2        32769    002a.6a0d.a17c 128.156
ethernet1/1/9  128.548   128      2000     FWD       0        24577    547f.eeac.13c1  128.158
Interface
```

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

 Bridge ID  Priority      32788  (priority 32768 sys-id-ext 20)
            Address       547f.eeac.13c1
            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
Eth1/30         Desg FWD 2         128.158      P2p
Eth1/31         Root FWD 2         128.159      P2p
```

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

Interface        Role  Sts Cost      Prio.Nbr     Type
---------------- ---- --- --------- -------- --------------------------------
Eth1/3           Desg  FWD 2         128.131      P2p
Eth1/28          Desg  FWD 2         128.156      P2p
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,

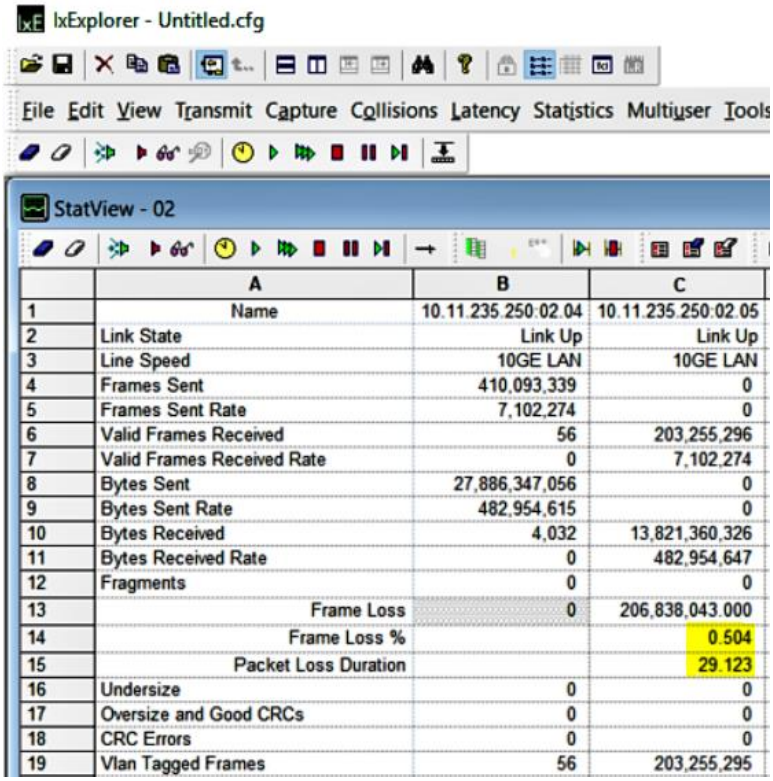
- Frame Loss % = 50

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 BPDUs 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 BPDUs 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, BPDUs 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_OPC_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      tstack flags 0x00ed enc_type sstp
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



	A	B	C
1	Name	10.11.235.250:02.04	10.11.235.250:02.05
2	Link State	Link Up	Link Up
3	Line Speed	10GE LAN	10GE LAN
4	Frames Sent	410,093,339	0
5	Frames Sent Rate	7,102,274	0
6	Valid Frames Received	56	203,255,296
7	Valid Frames Received Rate	0	7,102,274
8	Bytes Sent	27,886,347,056	0
9	Bytes Sent Rate	482,954,615	0
10	Bytes Received	4,032	13,821,360,326
11	Bytes Received Rate	0	482,954,647
12	Fragments	0	0
13	Frame Loss	0	206,838,043,000
14	Frame Loss %		0.504
15	Packet Loss Duration		29.123
16	Undersize	0	0
17	Oversize and Good CRCs	0	0
18	CRC Errors	0	0
19	Vlan Tagged Frames	56	203,255,295

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.

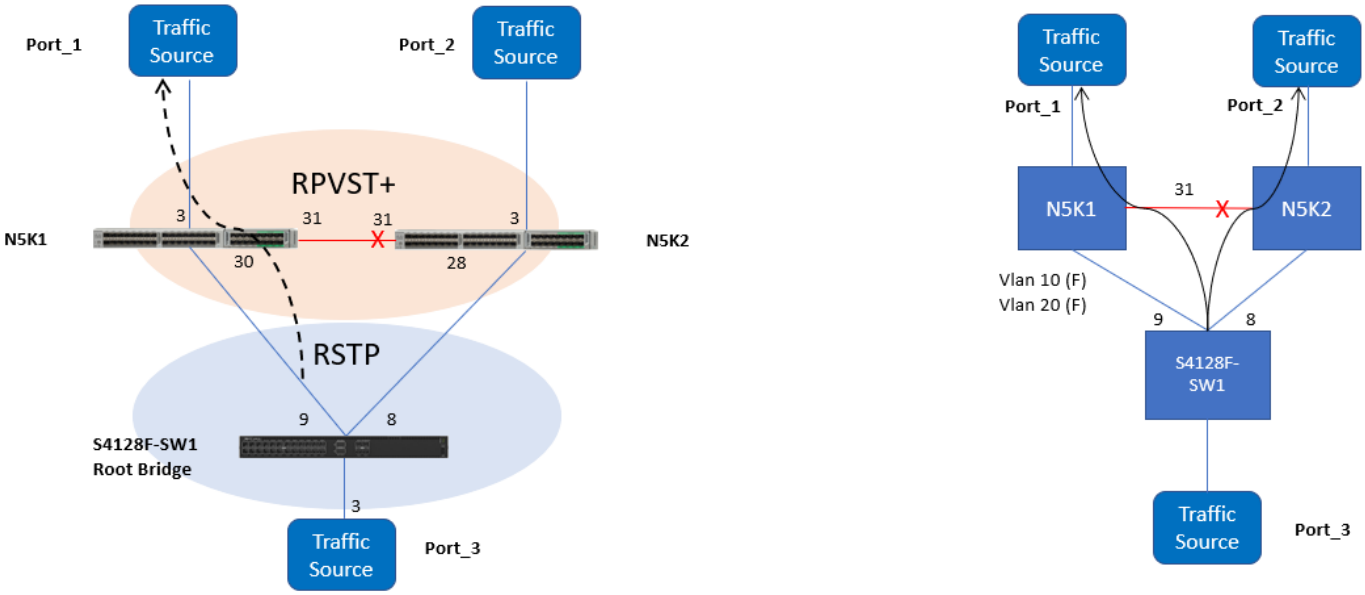


Figure 16 Physical and Logical Network Topology – RSTP (Dell EMC) and RPVST+ (Cisco)

```
N5K2# show spanning-tree

VLAN0001
  Spanning tree enabled protocol rstp
  Root ID    Priority    8192
             Address     f48e.385f.3dca
             Cost        2
             Port        156 (Ethernet1/28)
             Hello Time  2  sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     002a.6a0d.a17c
             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_OPC_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
bpdu_len 42 netstack flags 0x00ed enc_type sstp
2019 Jan 28 15:46:35.232908 stp:  BPDU RX: vb 1 VLAN 10 port Ethernet1/28 len 64 flags 0xed: Ethernet
Hdr 01000ccccccd<-547feeac13a5 type/len 0032: SNAP aa aa 03 00000c 0 10b SSTP CFG P:0000 V:02 T:02
F:3c R:60:0a:54:7f:ee:ac:13:c1 00000000 B:60:0a:54:7f:ee:ac:13:c1 809e A:0000 M:0014 H:0002 F:000f
T:0000
```

Figure 18 Cisco N5K2 RPVST+ Spanning Tree Debug

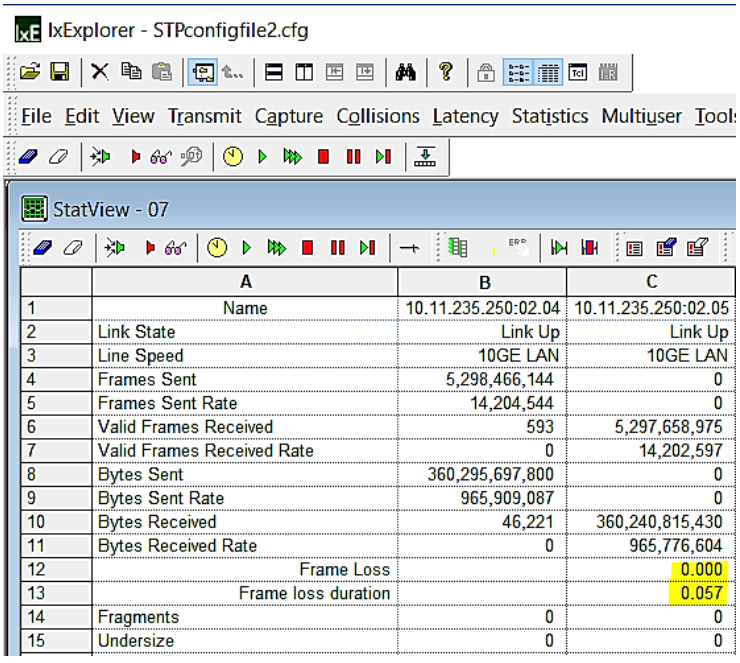
Test Steps

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



	A	B	C
1	Name	10.11.235.250:02.04	10.11.235.250:02.05
2	Link State	Link Up	Link Up
3	Line Speed	10GE LAN	10GE LAN
4	Frames Sent	5,298,466,144	0
5	Frames Sent Rate	14,204,544	0
6	Valid Frames Received	593	5,297,658,975
7	Valid Frames Received Rate	0	14,202,597
8	Bytes Sent	360,295,697,800	0
9	Bytes Sent Rate	965,909,087	0
10	Bytes Received	46,221	360,240,815,430
11	Bytes Received Rate	0	965,776,604
12	Frame Loss		0.000
13	Frame loss duration		0.057
14	Fragments	0	0
15	Undersize	0	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.

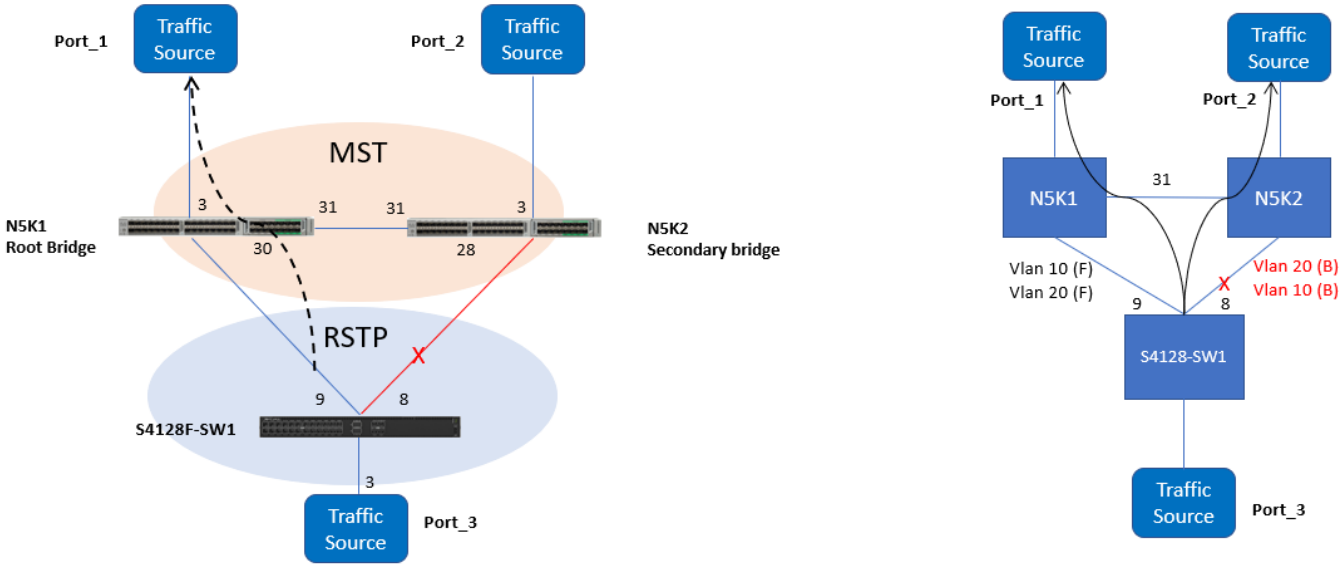


Figure 20 Physical and Logical Network Topology – RSTP (Dell EMC) and MST (Cisco)

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

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Eth1/3           Desg FWD 2000      128.131  Edge P2p
Eth1/30          Desg FWD 2000      128.158  P2p Bound(STP)
Eth1/31          Desg FWD 2000      128.159  P2p
```

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

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

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
Interface                                        Designated
Name           PortID   Prio     Cost     Sts      Cost          Bridge ID           PortID
-------------------------------------------------------------------------------------------------
ethernet1/1/3  128.524  128      2000     FWD      2000     32768  f48e.385f.3dca  128.524
ethernet1/1/8  128.544  128      2000     BLK      0        32768  002a.6a0d.a17c  128.156
ethernet1/1/9  128.548  128      2000     FWD      0        24576  547f.eeac.13c1  128.158
Interface
Name           Role    PortID   Prio     Cost     Sts      Cost     Link-type   Edge
-------------------------------------------------------------------------------------------------
ethernet1/1/3  Desg    128.524  128      2000     FWD      2000     AUTO        No
ethernet1/1/8  Altr    128.544  128      2000     BLK      0        AUTO        No
ethernet1/1/9  Root    128.548  128      2000     FWD      0        AUTO        No
```

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

```
N5K1# show spanning-tree mst 2
##### MST2    VLANs mapped:   20
Bridge        address 547f.eeac.13c1   priority      28674 (28672 sysid 2)
Root          address 002a.6a0d.a17c   priority      24578 (24576 sysid 2)
              port    Eth1/31          cost          2000      rem hops 19

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          Root   FWD 2000      128.159    P2p
```

Figure 26 N5K1 - MST2 port state

```
N5K2# show spanning-tree mst 2
##### MST2    VLANs mapped:   20
Bridge        address 002a.6a0d.a17c  priority      24578 (24576 sysid 2)
Root          this switch for MST2


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          Desg FWD   2000      128.159   P2p
```

Figure 27 N5K2 - MST2 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.

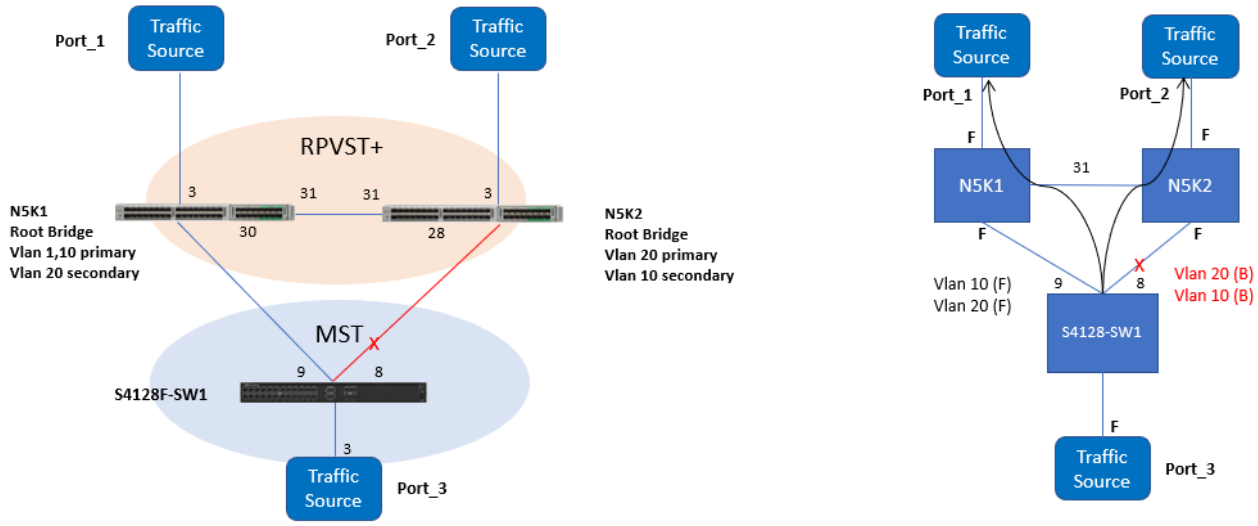


Figure 28 Physical and Logical Network Topology – MST (Dell EMC) and RPVST+(Cisco)

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

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Eth1/3           Desg FWD 2         128.131  Edge P2p
Eth1/30          Desg FWD 2         128.158  P2p
Eth1/31          Desg FWD 2         128.159  P2p
VLAN0010
  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

Interface        Role Sts Cost      Prio.Nbr    Type
---------------- ---- --- --------- -------- --------------------------------
Eth1/3           Desg FWD 2         128.131  Edge P2p
Eth1/30          Desg FWD 2         128.158  P2p
Eth1/31          Desg FWD 2         128.159  P2p
```

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 ti  me 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 P riority 32768, Address f48e.385f.3dca
CIST external path cost 2000
Interface                                        Designated
Name          PortID   Prio     Cost     Sts      Cost     Bridge ID           PortID
-------------------------------------------------------------------------------------------
ethernet1/1/3    128.524  128      2000     FWD      2000     32768   f48e.385f.3dca  128.524
ethernet1/1/8    128.544  128      2000     BLK      2        32769   002a.6a0d.a17c  128.156
ethernet1/1/9    128.548  128      2000     FWD      0        24577   547f.eeac.13c1  128.158
Interface
Name          Role     PortID   Prio     Cost     Sts      Cost     Link-type   Edge
-------------------------------------------------------------------------------------------
ethernet1/1/3    Desg  128.524  128      2000         FWD      2000     AUTO       No
ethernet1/1/8    Altr  128.544  128      2000         BLK      2        AUTO       No
ethernet1/1/9    Root  128.548  128      2000         FWD      0        AUTO       No
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
Interface                                        Designated
Name          PortID   Prio     Cost     Sts      Cost     Bridge ID           PortID
-------------------------------------------------------------------------------------------
ethernet1/1/3    128.524  128      2000     FWD      0        32768   f48e.385f.3dca  128.524
ethernet1/1/8    128.544  128      2000     BLK      0        32768   f48e.385f.3dca  128.544
ethernet1/1/9    128.548  128      2000     FWD      0        32768   f48e.385f.3dca  128.548
Interface
Name          Role     PortID   Prio     Cost     Sts      Cost     Link-type   Edge
-------------------------------------------------------------------------------------------
ethernet1/1/3    Desg  128.524  128      2000         FWD      0        AUTO       No
ethernet1/1/8    Altr  128.544  128      2000         BLK      0        AUTO       No
ethernet1/1/9    Master 128.548 128      2000         FWD      0        AUTO       No
```

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

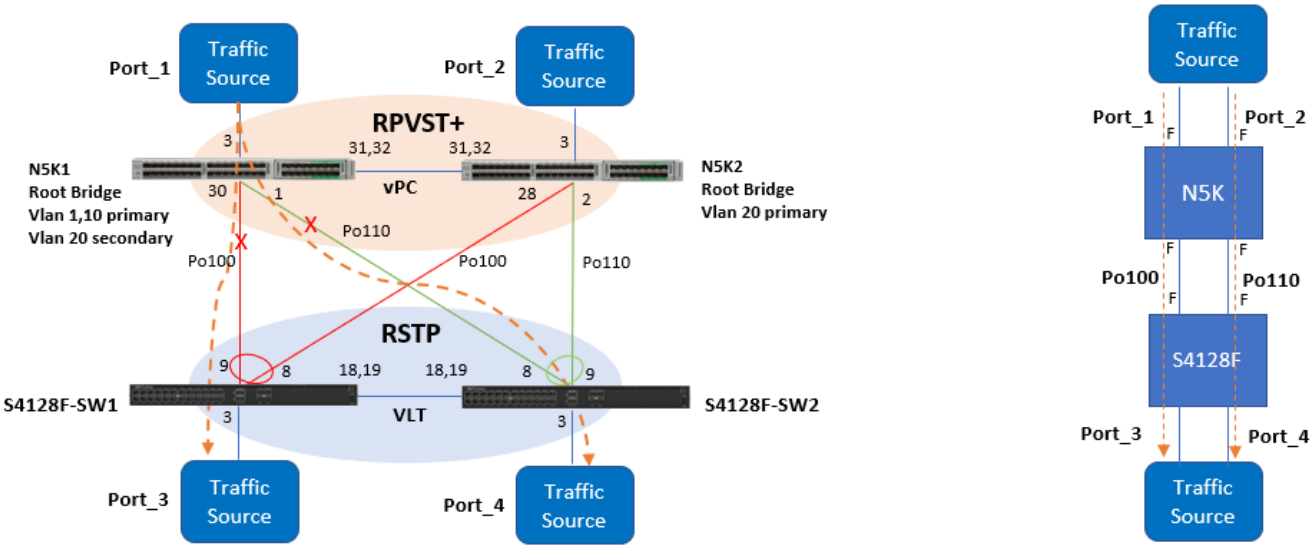


Figure 31 Physical and Logical Network Topology - RSTP (Dell EMC) and RPVST+(Cisco)

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).

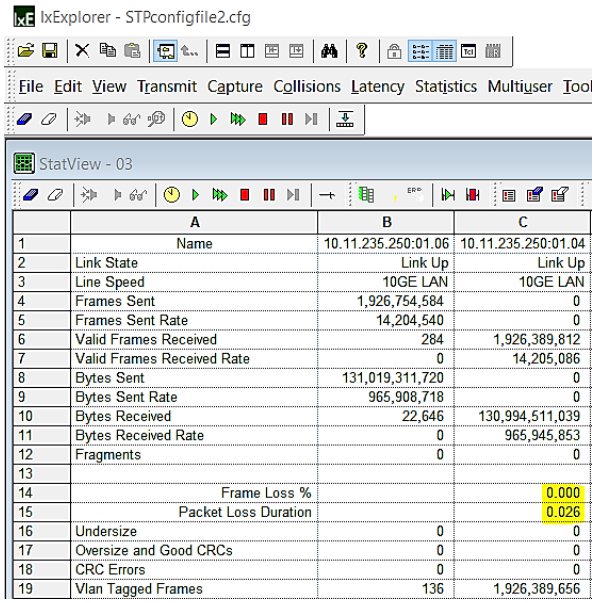
Port-channel 100 is configured on S4128-SW1 and port-channel 110 on S4128-SW2. VLANs 10 and 20 are mapped to both the port channels. The VLAN membership is shown below in Figure 32.

```
Codes: * - Default VLAN, M - Management VLAN, R - Remote Port Mirroring VLANs,
       @ - Attached to Virtual Network
Q: A - Access (Untagged), T - Tagged
    NUM    Status    Description                  Q Ports
*   1      Active                                 A Eth1/1/1-1/1/3,1/1/6-1/1/7,1/1/10-1/1/17,1/1/20-1/1/54
                                                  A Po100,1000
    10     Active                                 T Eth1/1/3
                                                  T Po100,1000
    20     Active                                 T Eth1/1/3
                                                  T Po100,1000
    4094   Active                                 T Po1000
```

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



	A	B	C
1	Name	10.11.235.250:01.06	10.11.235.250:01.04
2	Link State	Link Up	Link Up
3	Line Speed	10GE LAN	10GE LAN
4	Frames Sent	1,926,754,584	0
5	Frames Sent Rate	14,204,540	0
6	Valid Frames Received	284	1,926,389,812
7	Valid Frames Received Rate	0	14,205,086
8	Bytes Sent	131,019,311,720	0
9	Bytes Sent Rate	965,908,718	0
10	Bytes Received	22,646	130,994,511,039
11	Bytes Received Rate	0	965,945,853
12	Fragments	0	0
13			
14	Frame Loss %		0.000
15	Packet Loss Duration		0.026
16	Undersize	0	0
17	Oversize and Good CRCs	0	0
18	CRC Errors	0	0
19	Vlan Tagged Frames	136	1,926,389,656

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

S4128-SW1# **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 f48e.385f.3dca

Interface Name	PortID	Prio	Cost	Sts	Designated Cost	Bridge ID	PortID
ethernet1/1/3	128.524	128	2000	FWD	501	32768 f48e.385f.3dca	128.524
port-channel100	128.2517	128	500	FWD	1	32769 0023.04ee.be01	144.99

Interface Name	Role	PortID	Prio	Cost	Sts	Cost	Link-type	Edge
ethernet1/1/3	Desg	128.524	128	2000	FWD	501	AUTO	No
port-channel100	Root	128.2517	128	500	FWD	1	AUTO	No

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

Interface Name	PortID	Prio	Cost	Sts	Designated Cost	Bridge ID	PortID
ethernet1/1/3	128.524	128	2000	FWD	502	32768 6400.6af6.faf4	128.524
port-channel110	128.2517	128	500	FWD	502	32768 6400.6af6.faf4	128.2517

Interface Name	Role	PortID	Prio	Cost	Sts	Cost	Link-type	Edge
ethernet1/1/3	Desg	128.524	128	2000	FWD	502	AUTO	No
port-channel110	Root	128.2517	128	500	FWD	502	AUTO	No

Table 2 N5K RPVST+ link status

N5K1# **show spanning-tree brief**

VLAN0001
Spanning tree enabled protocol rstp
Root ID Priority 24577
Address 547f.eeac.13c1
This bridge is the root

Interface	Role	Sts	Cost	Prio.Nbr	Type
Po1	Desg	FWD	1	128.4096	(vPC peer-link) Network P2p
Po100	Desg	FWD	1	128.4195	(vPC) P2p
Po110	Desg	FWD	1	128.4205	(vPC) P2p
Eth1/3	Desg	FWD	2	128.131	Edge P2p

VLAN0010
Spanning tree enabled protocol rstp
Root ID Priority 24586
Address 547f.eeac.13c1
This bridge is the root

Interface	Role	Sts	Cost	Prio.Nbr	Type
Po1	Desg	FWD	1	128.4096	(vPC peer-link) Network P2p
Po100	Desg	FWD	1	128.4195	(vPC) P2p
Po110	Desg	FWD	1	128.4205	(vPC) P2p
Eth1/3	Desg	FWD	2	128.131	Edge P2p

VLAN0020
Spanning tree enabled protocol rstp
Root ID Priority 24596
Bridge ID Priority 28692 (priority 28672 sys-id-ext 20)
Address 547f.eeac.13c1

Interface	Role	Sts	Cost	Prio.Nbr	Type
Po1	Root	FWD	1	128.4096	(vPC peer-link) Network P2p
Po100	Desg	FWD	1	128.4195	(vPC) P2p
Po110	Desg	FWD	1	128.4205	(vPC) P2p
Eth1/3	Desg	FWD	2	128.131	Edge P2p

N5K2# **show spanning-tree brief**

VLAN0001
Spanning tree enabled protocol rstp
Root ID Priority 24577
Address 547f.eeac.13c1
Bridge ID Priority 32769 (priority 32768 sys-id-ext 1)
Address 002a.6a0d.a17c

Interface	Role	Sts	Cost	Prio.Nbr	Type
Po1	Root	FWD	1	128.4096	(vPC peer-link) Network P2p
Po100	Desg	FWD	1	128.4195	(vPC) P2p
Po110	Desg	FWD	1	128.4205	(vPC) P2p
Eth1/3	Desg	FWD	2	128.131	P2p

VLAN0010
Spanning tree enabled protocol rstp
Root ID Priority 24586
Address 547f.eeac.13c1
Bridge ID Priority 28682 (priority 28672 sys-id-ext 10)
Address 002a.6a0d.a17c

Interface	Role	Sts	Cost	Prio.Nbr	Type
Po1	Root	FWD	1	128.4096	(vPC peer-link) Network P2p
Po100	Desg	FWD	1	128.4195	(vPC) P2p
Po110	Desg	FWD	1	128.4205	(vPC) P2p
Eth1/3	Desg	FWD	2	128.131	P2p

VLAN0020
Spanning tree enabled protocol rstp
Root ID Priority 24596
Address 002a.6a0d.a17c
This bridge is the root

Interface	Role	Sts	Cost	Prio.Nbr	Type
Po1	Desg	FWD	1	128.4096	(vPC peer-link) Network P2p
Po100	Desg	FWD	1	128.4195	(vPC) P2p
Po110	Desg	FWD	1	128.4205	(vPC) P2p
Eth1/3	Desg	FWD	2	128.131	P2p

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.

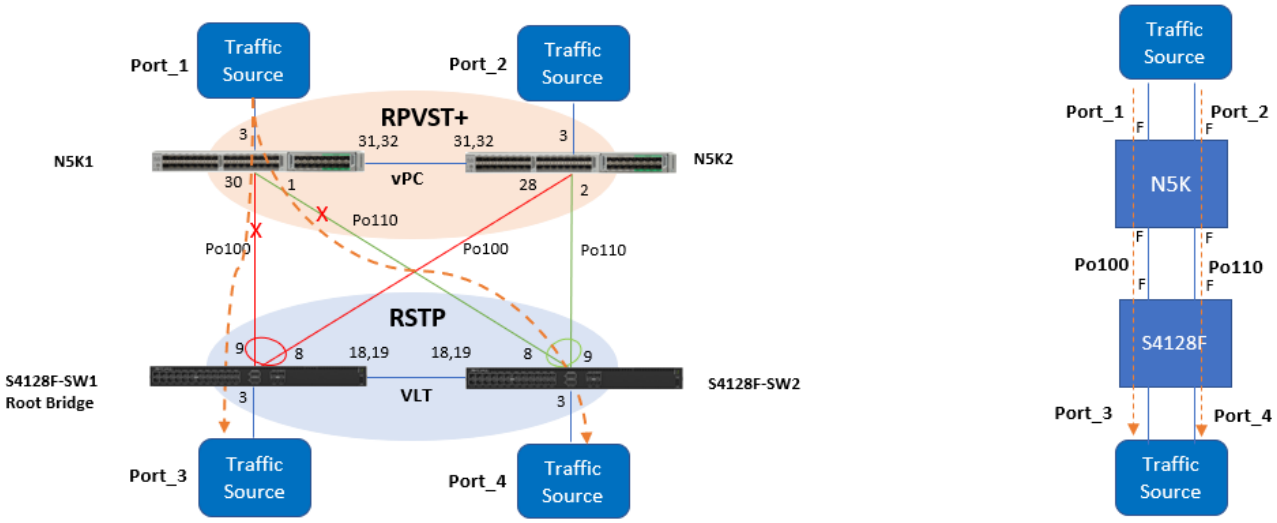


Figure 34 Physical and Logical Network Topology - RSTP (Dell EMC) and RPVST+(Cisco)

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.

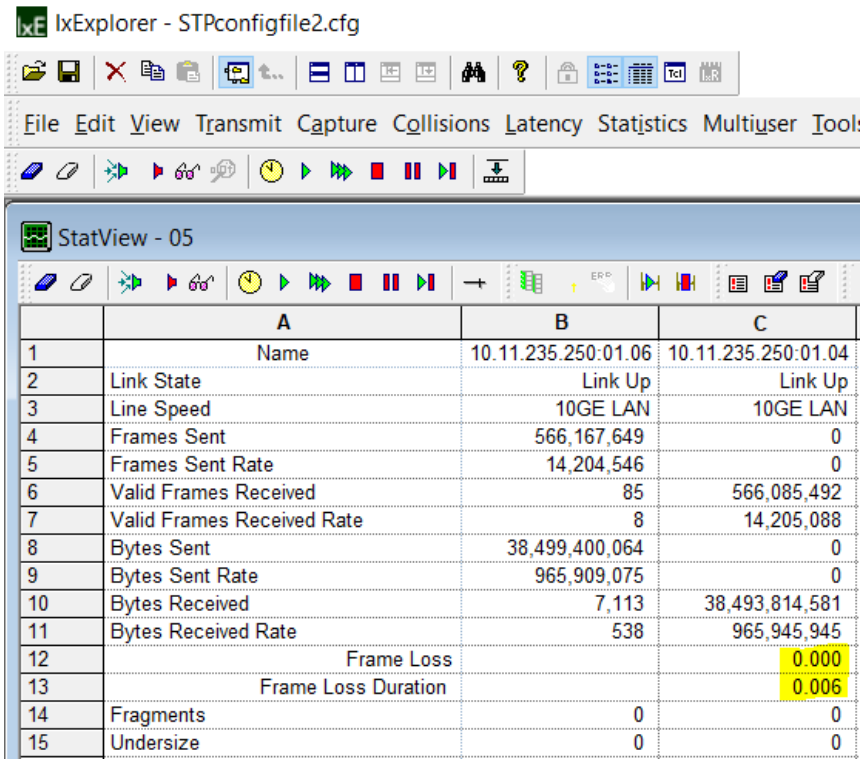
5. Recover ports 30 and 1 and check for any measurable traffic disruption.

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



	A	B	C
1	Name	10.11.235.250:01.06	10.11.235.250:01.04
2	Link State	Link Up	Link Up
3	Line Speed	10GE LAN	10GE LAN
4	Frames Sent	566,167,649	0
5	Frames Sent Rate	14,204,546	0
6	Valid Frames Received	85	566,085,492
7	Valid Frames Received Rate	8	14,205,088
8	Bytes Sent	38,499,400,064	0
9	Bytes Sent Rate	965,909,075	0
10	Bytes Received	7,113	38,493,814,581
11	Bytes Received Rate	538	965,945,945
12	Frame Loss		0.000
13	Frame Loss Duration		0.006
14	Fragments	0	0
15	Undersize	0	0

Figure 35 Traffic port statistics during fail-over

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.

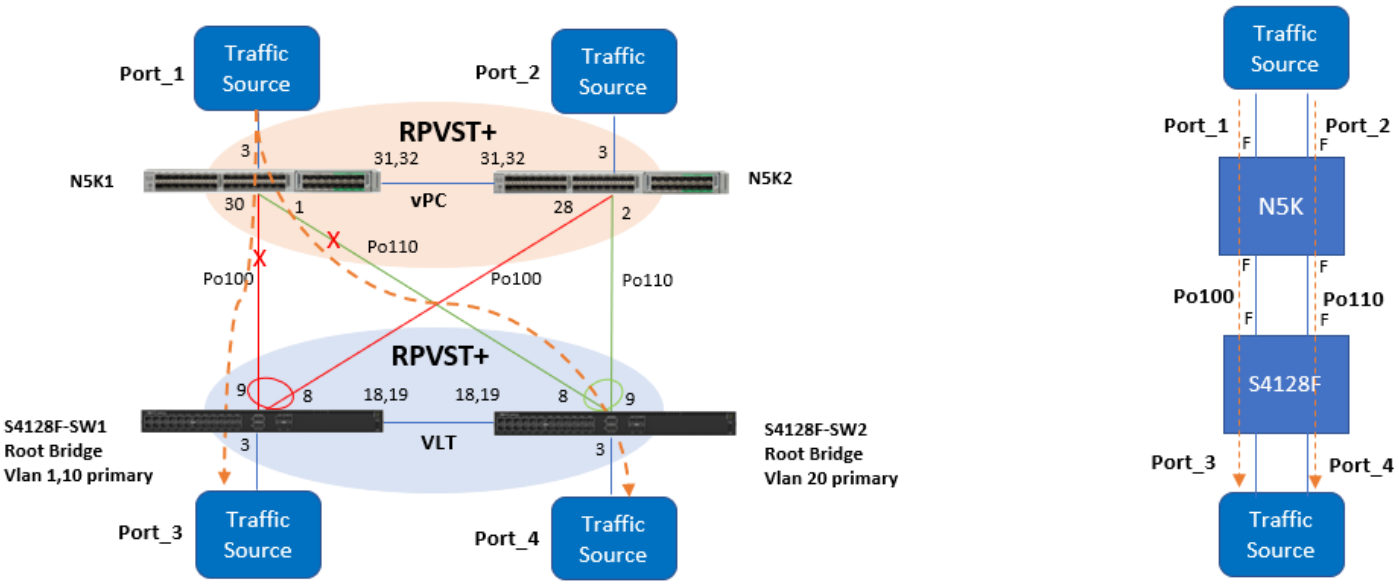
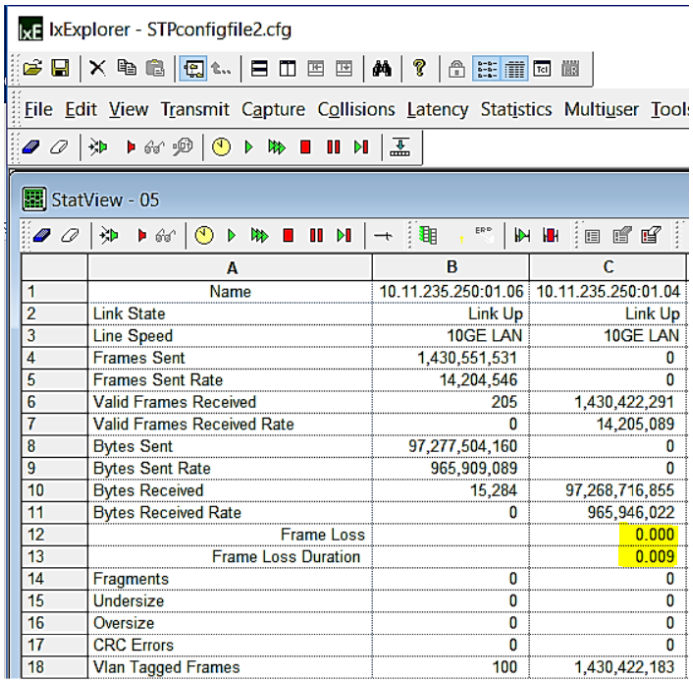


Figure 36 Physical and Logical Network Topology - RPVST+ (Dell EMC) and RPVST+ (Cisco)

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



	A	B	C
1	Name	10.11.235.250:01.06	10.11.235.250:01.04
2	Link State	Link Up	Link Up
3	Line Speed	10GE LAN	10GE LAN
4	Frames Sent	1,430,551,531	0
5	Frames Sent Rate	14,204,546	0
6	Valid Frames Received	205	1,430,422,291
7	Valid Frames Received Rate	0	14,205,089
8	Bytes Sent	97,277,504,160	0
9	Bytes Sent Rate	965,909,089	0
10	Bytes Received	15,284	97,268,716,855
11	Bytes Received Rate	0	965,946,022
12	Frame Loss		0.000
13	Frame Loss Duration		0.009
14	Fragments	0	0
15	Undersize	0	0
16	Oversize	0	0
17	CRC Errors	0	0
18	Vlan Tagged Frames	100	1,430,422,183

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.

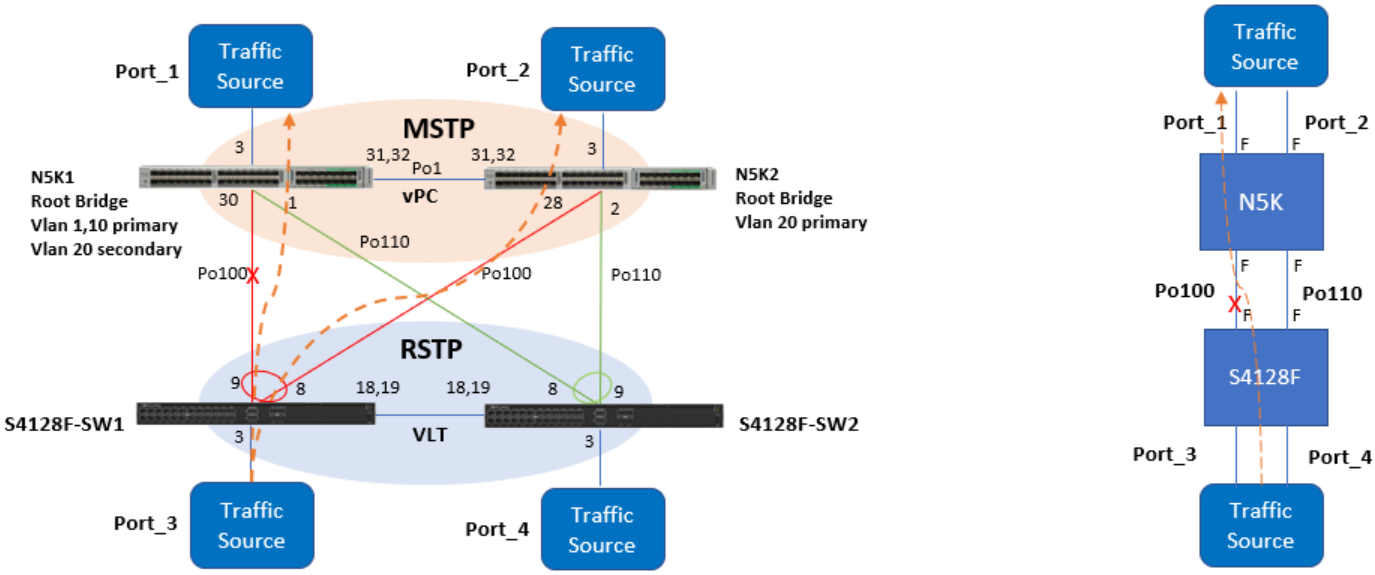


Figure 38 Physical and Logical Network Topology - RSTP (Dell EMC) and MST (Cisco)

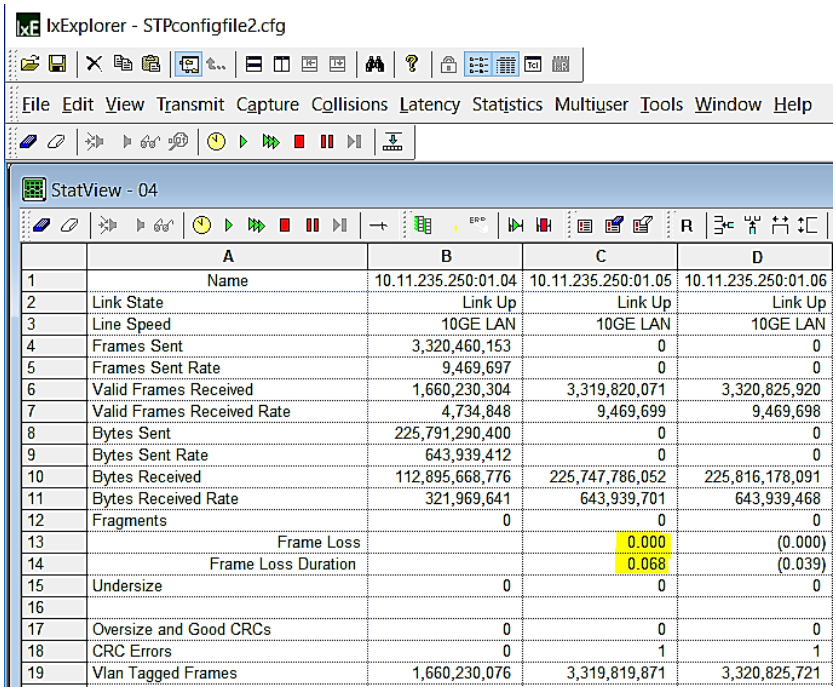
Test Steps

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



	A	B	C	D
1	Name	10.11.235.250:01.04	10.11.235.250:01.05	10.11.235.250:01.06
2	Link State	Link Up	Link Up	Link Up
3	Line Speed	10GE LAN	10GE LAN	10GE LAN
4	Frames Sent	3,320,460,153	0	0
5	Frames Sent Rate	9,469,697	0	0
6	Valid Frames Received	1,660,230,304	3,319,820,071	3,320,825,920
7	Valid Frames Received Rate	4,734,848	9,469,699	9,469,698
8	Bytes Sent	225,791,290,400	0	0
9	Bytes Sent Rate	643,939,412	0	0
10	Bytes Received	112,895,668,776	225,747,786,052	225,816,178,091
11	Bytes Received Rate	321,969,641	643,939,701	643,939,468
12	Fragments	0	0	0
13	Frame Loss		0.000	(0.000)
14	Frame Loss Duration		0.068	(0.039)
15	Undersize	0	0	0
16				
17	Oversize and Good CRCs	0	0	0
18	CRC Errors	0	1	1
19	Vlan Tagged Frames	1,660,230,076	3,319,819,871	3,320,825,721

Figure 39 Traffic port statistics during link fail-over

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

Dell EMC OS10EE	Cisco (NX_OS)	
No VLT (RPVST+)	No vPC(RPVST+)	Frame Loss % = 0 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.
No VLT (MST)	No vPC(MST)	Frame Loss % = 0 Same mode, 100% interoperable. RSTP timers will be used when a spanning tree event takes place.
No VLT (RSTP)	No vPC(RPVST+)	Frame Loss % = 50% Not a clear advantage, due to the proprietary nature of RPVST+ 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
No VLT (RSTP)	No vPC(MST)	Frame Loss % = 0 Both spanning tree versions interoperate 100% due to MST's underlying use of RSTP's convergence timers.
No VLT (MST)	No vPC(RPVST+)	Frame Loss % = 0 No clear advantage.

With VLT: RSTP	With vPC: RPVST+	Frame Loss % = 0 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.
With VLT: RPVST+	With vPC: RPVST+	Frame Loss % = 0
With VLT: RSTP	With vPC: MST	Frame Loss % = 0

4 Switch Configurations

```
N5K1# sh run

!Command: show running-config
!Time: Fri Jan 25 21:04:23 2019

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
!
support-assist
!
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 2019-01-16T07:09:26.961427+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 2019-01-16T07:09:27.096482+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-channel1000

<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-channel1000

<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-channel1000

<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
```

```
<165>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

<165>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

<165>1 2019-01-16T08:53:32.061970+00:00 S4128-SW2 dn_ifm 790 - -  Node.1-Unit.1:
PRI [event], Dell EMC (OS10) %IFM_ASTATE_UP: Interface admin state up :port-chan
nel110

<165>1 2019-01-16T08:53:32.062787+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-channel110

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

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

S4128-SW2(conf-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_OSTATE_UP:
Interface operational state is up :port-channel110

<165>1 2019-01-16T08:57:48.477119+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

<165>1 2019-01-16T08:57:48.498977+00:00 S4128-SW2 dn_app_vlt 1111 - -  Node.1-
Unit.1:PRI [event], Dell EMC (OS10) %VLT_PORT_ CHANNEL_UP: vlt-port-channel 1 is
up


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                            PortID    Prio      Cost      Sts         Cost
Bridge I                        D               PortID
--------------------------------------------------------------------------------
-----------                       -------------------------
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 |
   Unit ID    |                |   Unit ID    |                |   (Gb/s)    |
|
------------------------------------------------------------------------------
------------
1             |ethernet1/1/18  |2             |ethernet1/1/18  |10           |up
|
1             |ethernet1/1/19  |2             |ethernet1/1/19  |10           |up
|
2             |ethernet1/1/18  |1             |ethernet1/1/18  |-            |-
|
2             |ethernet1/1/19  |1             |ethernet1/1/19  |-            |-
|
```

```
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
```