Windows Server 2016 Hyper-Converged Cluster over Mellanox Ethernet Solution

Reference Deployment Guide

Rev 1.0

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Revision

Table 1: Revision

Revision	Date	Description
1.0	February 26, 2017	Initial release of this version.

Purpose

This Reference Deployment Guide provides guidelines on how to design an Hyper-Converged solution over Windows Server 2016. It also includes a reference design of a 4 nodes Storage Spaces Direct All Flash based Hyper-Converged cluster using System Center Virtual Machine Manager 2016 (SCVMM).

Scope

In this document we will demonstrate deployment procedure of Microsoft Hyper-Converged virtualization cluster based on Storage Spaces Direct connected by Mellanox end-to-end Ethernet solution, which includes the Spectrum™ switch, ConnectX-4 / ConnectX-4 Lx NICs and LinkX™ cables.

Definitions/Abbreviation

Table 2: Abbreviation

Definitions/Abbreviation	Description
RoCE	RDMA over Converged Ethernet
S2D	Storage Space Direct

Related Documentation

Table 3: Related Documentation

Document Title	Description
Hyper-converged solution using Storage Spaces Direct in Windows Server 2016	https://technet.microsoft.com/windows-server-docs/storage/storage-spaces/hyper-converged-solution-using-storage-spaces-direct
Deploy, and manage SCVMM 2016	https://technet.microsoft.com/en-us/system-center-docs/vmm/vmm

1 Introduction

This Reference Deployment Guide provides guidelines on how to design the Hyper-Converged solution over Windows Server 2016. It includes a reference design of a 4 nodes Spaces Direct All Flash Storage based Hyper-Converged cluster using System Center Virtual Machine Manager (SCVMM). This guide also includes detailed instructions on how to install and configure the components of a Hyper-Converged system using SCVMM 2016.

The act of deploying a Hyper-Converged system can be divided into three high level phases:

- Deploy Windows Server 2016
- Configure the network with SCVMM 2016
- Configure Storage Spaces Direct Cluster

For further information on what Hyper-converged cluster with Storage Space Direct is, and how to plan your infrastructure and deployment, please refer to the following link: Hyper-converged solution using Storage Spaces Direct in Windows Server 2016

Deployment of SCVMM 2016 is not described in this guide. For information of how to deploy, and manage SCVMM 2016, please refer to the following link: https://technet.microsoft.com/en-us/system-center-docs/vmm/vmm.

2 Overview

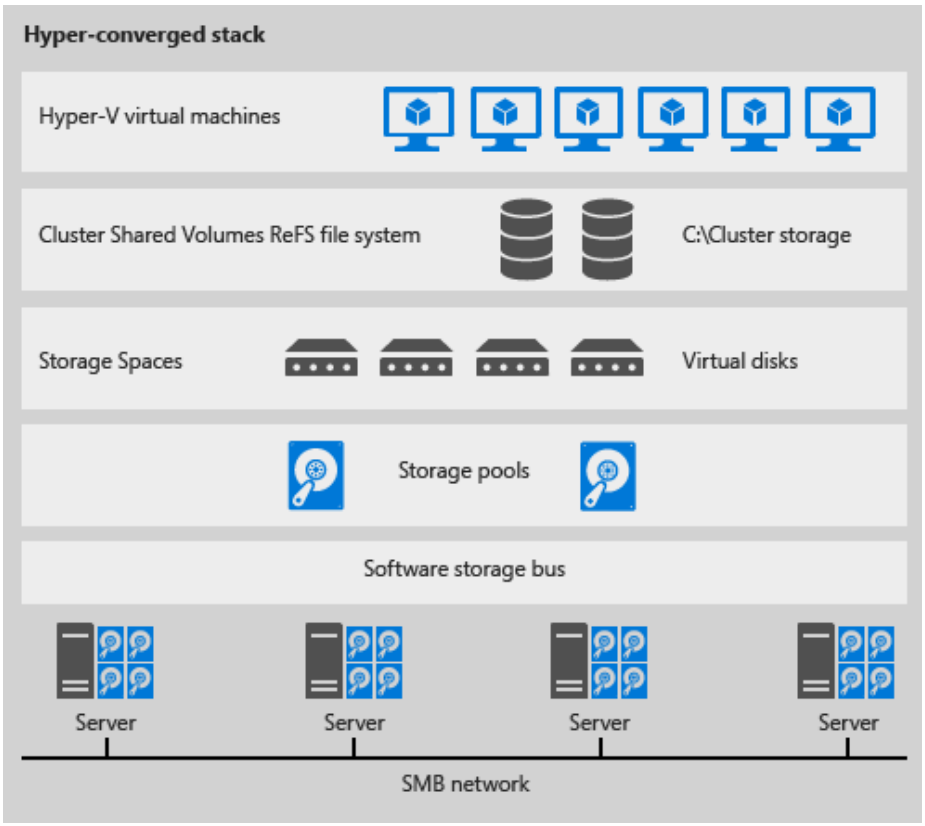
In the Hyper-Converged configuration described in this guide, Storage Spaces Direct seamlessly integrates all the functions that are needed to deploy the Windows Server Software Defined Storage (SDS) stack, including Clustered Shared Volume File System (CSVFS), Storage Spaces and Failover Clustering.

The Hyper-Converged deployment scenario includes the Hyper-V (compute) and Storage Spaces Direct (storage) components on the same cluster and the Virtual Machine files are stored on a local Cluster Share Volume (CSV). Each server includes 2 CPU sockets, 8 NVMe drives in a NUMA configuration (4 NVMe for each socket) and Mellanox's ConnectX-4 / ConnectX-4 Lx RoCE enabled NICs, all connected by Mellanox's Spectrum™ SN2700 switches and LinkX™ cables.

Mellanox ConnectX-4/ConnectX-4 Lx RDMA enabled NICs and SN2700 switches enables higher bandwidth and lower latency networking that accelerates VMs to VMs, VMs to storage and VM live migration which maximizes the overall solution efficiency.

In addition, data communication over RoCE technology, doubles the throughput, cuts the latency by 50%, and increases the CPU efficiency by more than 33% (https://www.mellanox.com/blog/2015/05/storage-spaces-direct-if-not-rdma-then-what-if-not-mellanox-then-who/)

Figure 1: Hyper-Converged Cluster Configured for Storage Spaces Direct and Virtual Machines Hosting



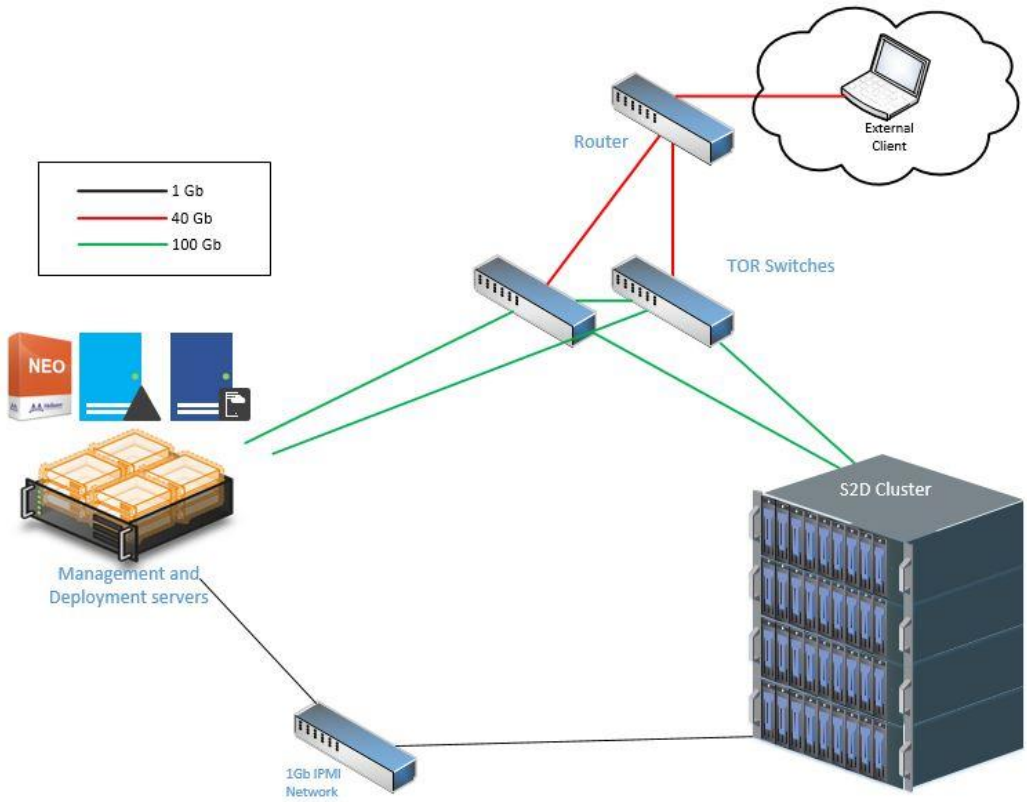
3 System Configuration

3.1 Network Components

3.1.1 Network Design

The following illustration shows an example configuration. This example does not cover the router's configuration and its connectivity to TOR switches.

Figure 2: Solution High-Level Design



Each server is connected to both SN2700 switches by Mellanox's LinkX copper cable to allow redundant network links in the event of a network port or external switch failure.

The following are the switch ports connectivity in our scenario:

- 1st port – connected to router
- 16th port – connected to Management server
- 22,24,26 and 28 ports – connected to each node in cluster
- 31 and 32 ports – IPL interconnect between two switches

Detailed switch configuration examples are provided in Appendix A:

3.1.2 Logical Networks Configuration

The table below shows the configuration of networks with VLAN ID for SN2700 switches.

Table 4: Cluster Networks

Network Name	Subnet	Mask	VLAN ID	Gateway	DNS server
Deploy	172.21.0.0	16	Native(621)	172.21.1.254	172.16.1.251
MGMT	172.16.0.0	16	616	172.16.254.253	172.16.1.251
Cluster	172.17.0.0	16	617	172.17.1.253	No
LiveMigration	172.18.0.0	16	618	172.18.1.253	No
Storage	172.19.0.0	16	619	172.19.1.253	No

3.1.3 Servers Network Configuration

The table below shows the server names and their network configuration.

Table 5: Server Names and Network Configuration

Server type	Server name	IP and NICS	
		Deploy network	MGMT network
DC (AD DS, DNS, DHCP)	clx-wrd-dc	Not part of this network	IP:1 72.16.1.251/16
			GW: 172.16.254.253
			DNS: 172.16.1.251
SCVMM	clx-wrd-vmm	Not part of this network	IP:172.16.1.250/16
			GW:172.16.254.253
			DNS: 172.16.1.251
Compute, Storage	clx-wrd-s1	By DHCP from DC	From Pool via SCVMM
Compute, Storage	clx-wrd-s2	By DHCP from DC	From Pool via SCVMM
Compute, Storage	clx-wrd-s3	By DHCP from DC	From Pool via SCVMM
Compute, Storage	clx-wrd-s4	By DHCP from DC	From Pool via SCVMM

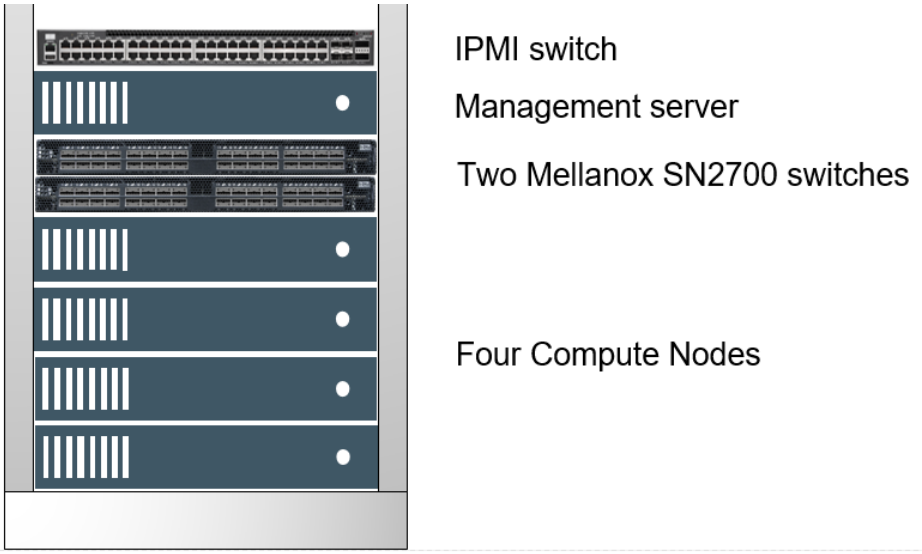
3.1.4 DHCP Service Configuration

Domain Controller (DC) will provide the DHCP service for the Deploy network. The DHCP Deploy scope should be configured according to the information below:

- IP: 172.21.1.1-100/16
- GW: 172.21.1.254
- DNS: 172.16.1.251

3.2 Rack Design and Hardware components

Figure 3: Solution Rack Configuration using Mellanox SN2700 Switch Systems



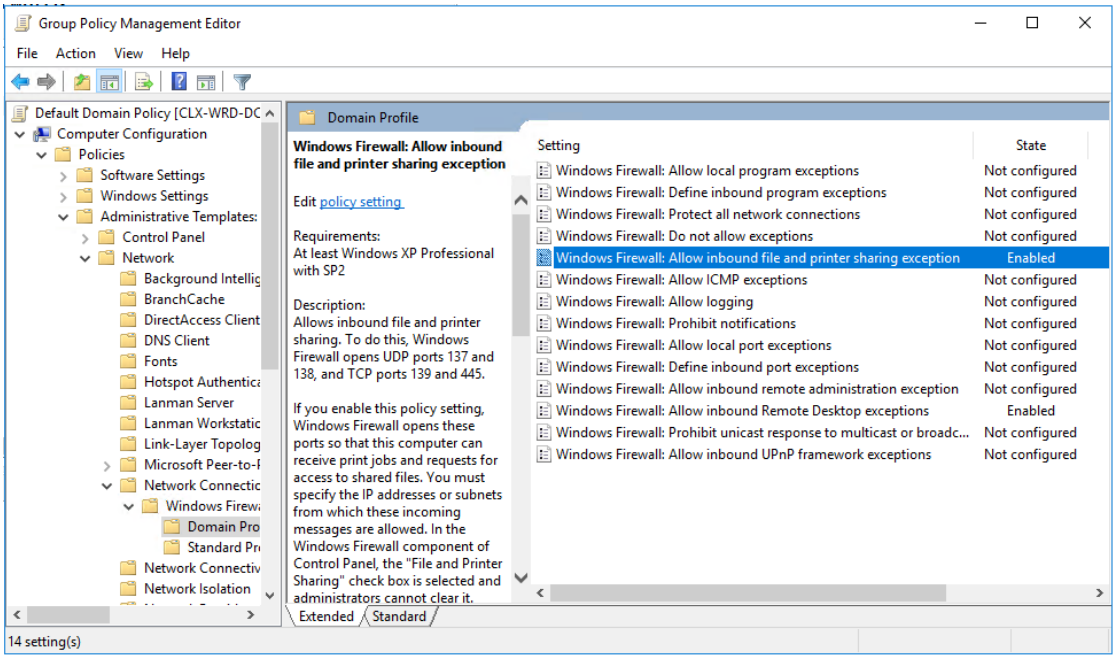
The figure above shows the rack configuration and the components of 4 nodes cluster.

- IPMI switch
- Management server: 2 socket server with 500GB local storage to host VMs
  - One Mellanox ConnectX-4 dual port adapter
  - DC VM with installed and configured AD DS, DNS and DHCP services
  - SCVMM VM in a standalone configuration
- Two Mellanox SN2700 switches with IPL interconnect
  - 32 ports 100Gbps QSFP28
- Four Compute Nodes, each containing:
  - Two Intel(R) Xeon(R) CPU E5-2660 v4 @ 2.00GHz
  - 128 GB memory
  - One Mellanox ConnectX-4 dual port adapter
  - Storage Components
    - Two SSD drives in RAID-1 for OS
    - Eight NVMe 1.2TB SSDs for S2D storage services
- Mellanox LinkX MCP1600-Cxxx series cables to connect the servers to switches.

4 System Deployment

4.1 Configuring Domain Firewall Policy

1. Open GPMC and edit Default Domain Policy (Default Domain Policy →Computer configuration → Policies → Administrative Templates → Network → Network Connection → Domain Profile) and enable "Windows Firewall: Allow inbound file and printer sharing exception".



4.2 Deploying Windows Server on the Compute Nodes

1. On each Compute Node (clx-wrd-S1, clx-wrd-S2, clx-wrd-S3 and clx-wrd-S4) install Windows Server 2016 using the Setup wizard with "Windows Server 2016 (Server with Desktop Experience)" option chosen.
2. Install the latest vendor and Mellanox WinOF-2 drivers.
3. Join all hosts to Domain (in our case – wrd.clx)
4. Install Windows features on the compute hosts from the Domain Controller by running the following PowerShell script.

```
$nodes = ("clx-wrd-S1", "clx-wrd-S2", "clx-wrd-S3", "clx-wrd-S4")
Invoke-Command $nodes {Install-WindowsFeature Data-Center-Bridging}
Invoke-Command $nodes {Install-WindowsFeature Multipath-IO}
Invoke-Command $nodes {Install-WindowsFeature Failover-Clustering -
IncludeAllSubFeature -IncludeManagementTools}
Invoke-Command $nodes {Install-WindowsFeature -Name Hyper-V -
IncludeManagementTools -Restart}
```

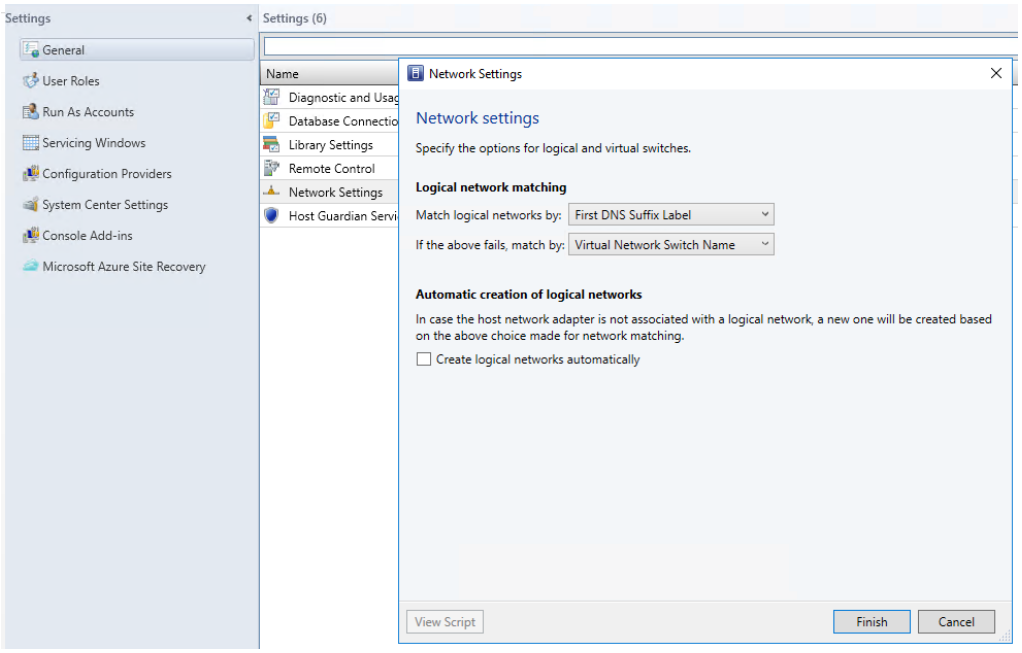
5. Enable Network Quality of Service (QoS) in the Domain Controller by running the following PowerShell script.

```
$nodes = ("clx-wrd-S1", "clx-wrd-S2", "clx-wrd-S3", "clx-wrd-S4")
Invoke-Command $nodes {Get-NetAdapter  | ? InterfaceDescription -Match
"Mellanox*" | Sort-Object number |% {$_ | Set-NetAdapterAdvancedProperty
-RegistryKeyword "*JumboPacket" -RegistryValue 9000}}
Invoke-Command $nodes {New-NetQosPolicy "SMB" –
NetDirectPortMatchCondition 445 –PriorityValue8021Action 3}
Invoke-Command $nodes {Enable-NetQosFlowControl –Priority 3}
Invoke-Command $nodes {Disable-NetQosFlowControl –Priority 0,1,2,4,5,6,7}
Invoke-Command $nodes {Get-NetAdapter | ? InterfaceDescription -Match
"Mellanox" | Enable-NetAdapterQos}
Invoke-Command $nodes {New-NetQosTrafficClass "SMB" –Priority 3 –
BandwidthPercentage 50 –Algorithm ETS}
```

4.3 Configuring the Network with SCVMM 2016

4.3.1 Setting up Network Settings in SCVMM

1. Open the SCVMM Console.
2. Go to Settings → Network Settings.
3. Uncheck "Create logical networks automatically".
4. Click Finish.



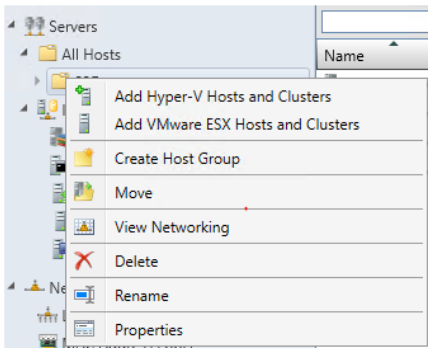
4.3.2 Setting up the Host Group

Create a dedicated host group for Hyper-V hosts in order to simplify management in future.

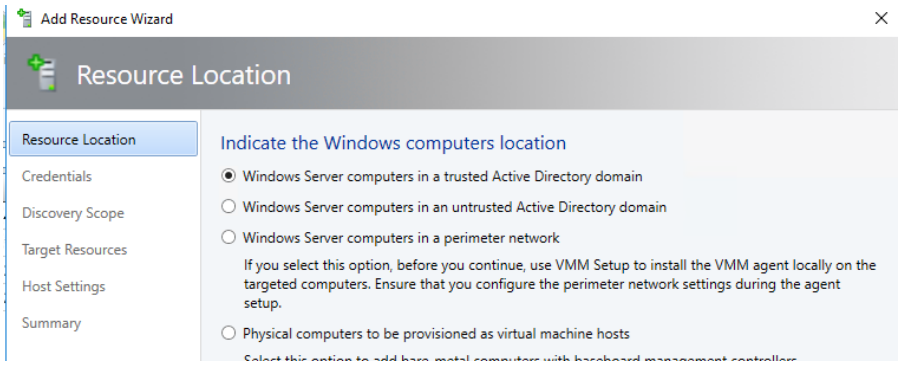
1. Open the VMM Console
2. Click "Fabric".
3. Choose the "Servers → All Hosts".
4. Right click the "All Hosts" and select "Create Host Group".
5. Type the name "S2D".

4.3.3 Adding Compute Hosts to SCVMM

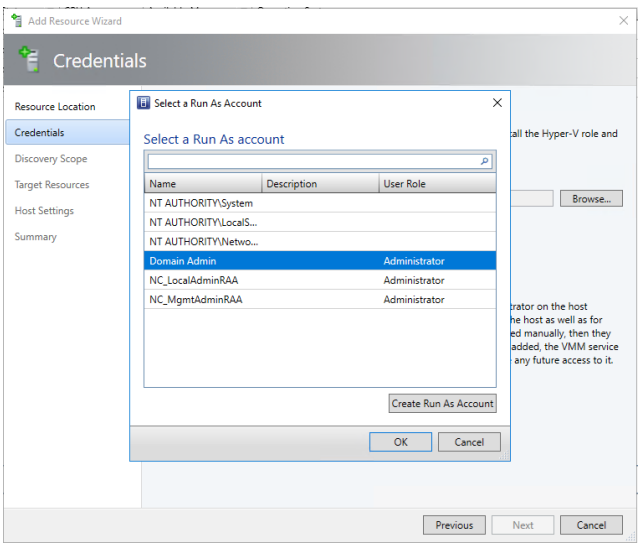
1. Right click the "All Hosts" and select "Add Hyper-V Hosts and Clusters".



2. Go to the "Add Resource Wizard".
   a. Select "Resource Location".
      i. Select "Windows Server computer in a trusted Active Directory domain".



   b. Go to the "Credentials" option.
      i. Select a user in the "Select a Run As Account".
      ii. Click on Browse and select the desired account in the "Select a Run As Account" window or click on "Create Run As Account" to create a an account with admin permission (e.g Domain Admin: WRD\Administrator).

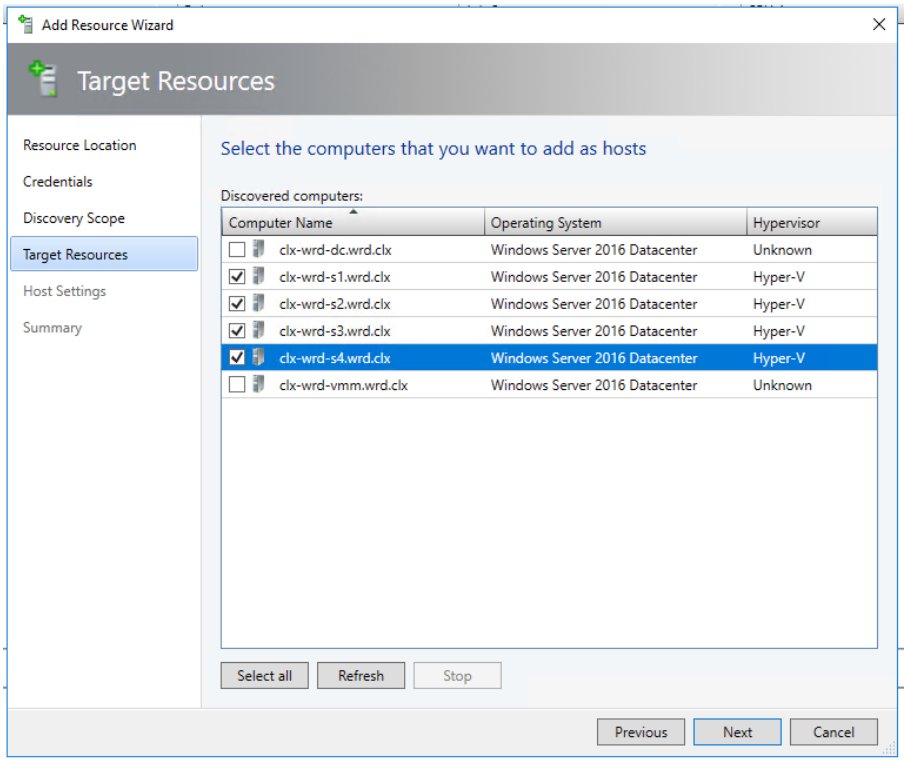


      iii. Click "OK".

c. Go to the “Target Resources” option.

i. Type “CLX” in the “Computer names” text field then press next to search for the hosts. You will see “clx-wrd-s1” to “clx-wrd-s4” displayed on the “Target Resources” page.

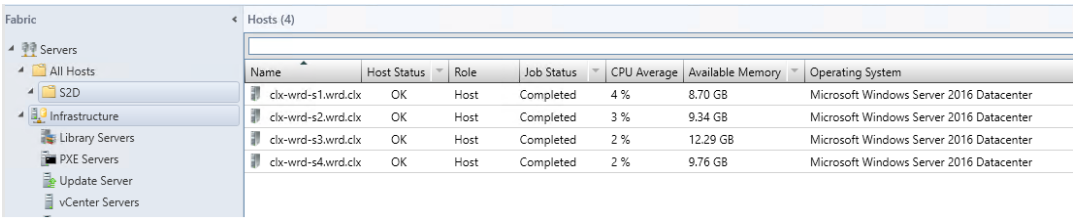
ii. Select hosts “clx-wrd-s1” to “clx-wrd-s4”.



iii. Click “Next”.

iv. On the Summary page confirm the settings and click “Finish”.

All 4 hosts will be added to the “S2D” group when the jobs are completed as the following.



4.3.4 Creating Logical Networks (MGMT, Cluster, LiveMigration and Storage)

Below we explain two ways how-to create logical networks with SCVMM server.

4.3.4.1 Automated Logical Networks Creation by PowerShell Script

Use the PowerShell script provided in Appendix B: Change the script's parameters according to your infrastructure and run it in PowerShell session from the SCVMM server.

4.3.4.2 Manual Logical Networks Creation with SCVMM GUI

Repeat the logical network and IP Address Pool creation for All Logical Networks according to the below example:

Create the Logical Network

1. Click "Fabric" → "Networking".
2. Right-click "Logical Networks" → "Create Logical Network".
3. Specify "MGMT" as a "Name" and optional "Description".
4. In "Settings" select "One Connected Network".
   All management networks need to have routing and connectivity between all hosts in that network.
5. Select "Create a VM network" with the same name to allow Virtual Machines to access this logical network directly to automatically create a VM network for your management network.
6. Click "Network Site" → Add.
7. Select the host group for the hosts that will be managed by the network controller.
8. Insert your management network IP subnet details.
   This network should already exist and be configured in your physical switch.
9. Review the Summary information and click "Finish".

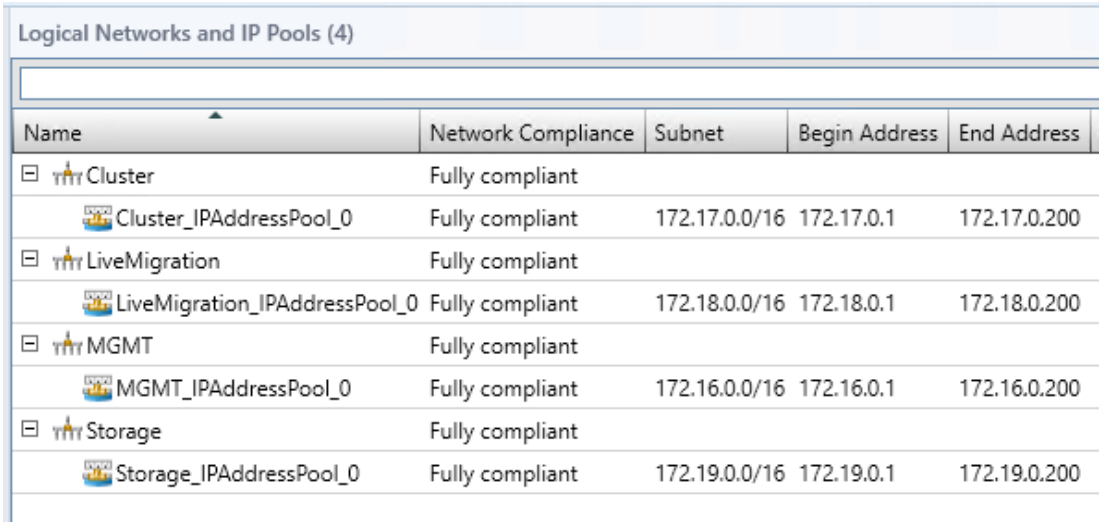
Create an IP Address Pool for Management Logical Network

In order to allocate static IP addresses to compute hosts, create an IP address pool in the management logical network. If you are using DHCP, you can skip the steps below.

1. In the VMM console, right-click the Management Logical Network in → "Create IP Pool".
2. Provide "MGMT_Pool" as a "Name" and optional "Description" for the pool and ensure that the Management Network is selected for the logical network.
3. In "Network Site" panel, select the subnet that this IP address pool will service.
4. In "IP Address Range" panel, type the starting and ending IP addresses.
5. To use an IP as Cluster IP, type one of the IP addresses from the specified range in IP addresses to be reserved for other uses box.
   Note: Do not use the first three IP addresses of your available subnet. For example, if your available subnet is from .1 to .254, start your range at .4 or greater.
6. Specify the default gateway address, DNS address and optionally configure the WINS settings.

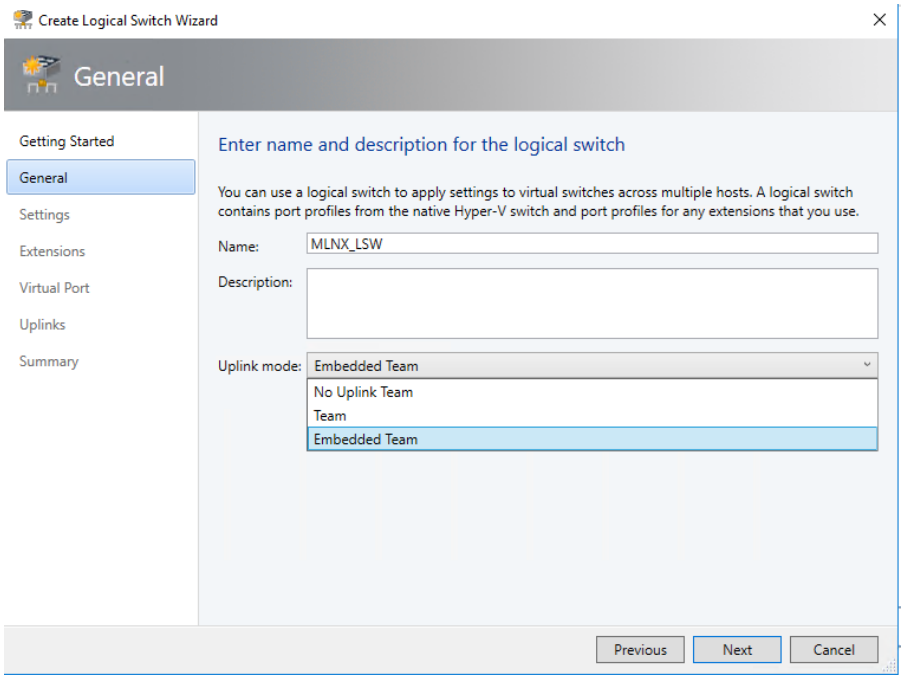
7. In the "Summary" page, review the settings and click Finish to complete the wizard.

After the completion of the logical networks and IP pools, you should see the following.

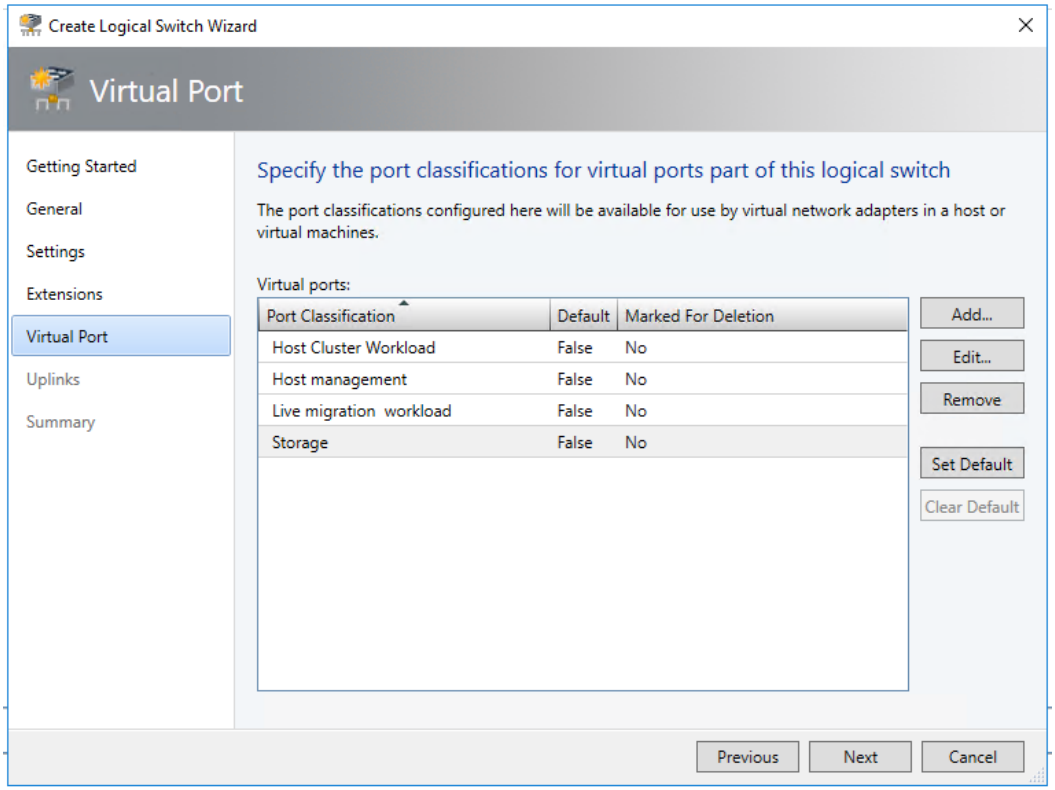


4.3.5 Creating a Logical Switch

1. Click "Create Logical Switch" on the ribbon in the VMM Console.
2. Review the "Getting Started" information and click Next.
3. Provide "MLNX-LSW" as the "Name" and optional "Description".
4. For the "Uplink mode", select "Embedded Team".
5. Click Next.



6. For "Minimum Bandwidth" mode, choose the Weight option. Click Next.
7. Uncheck all the switch extensions in the Extensions.
8. On the "Virtual Port" tab add port classifications.



9. On the "Uplinks" tab, click Add and then either create a new "Uplink Port Profile" or use an existing "Uplink Port Profile" if you already have one configured. In this document, we created a new "Uplink Port Profile".

➢ ***To create the new "Uplink Port Profile::***

   a. Use the default settings for "Load Balancing" algorithm and "Teaming Mode".

   b. Select the "Uplink Port Profile" you created and click "New virtual network adapter". This adds a host virtual network adapter (vNIC) to your logical switch and uplink port profile, so when you add the logical switch to your hosts, the vNICs are added automatically.

   c. Provide a name for the vNIC. Verify that the Management VM network is listed under the Connectivity section.

   d. Select "This network adapter will be used for host management (only for MGMT)".

   e. Select a port classification and virtual port profile.

   f. Click Next.

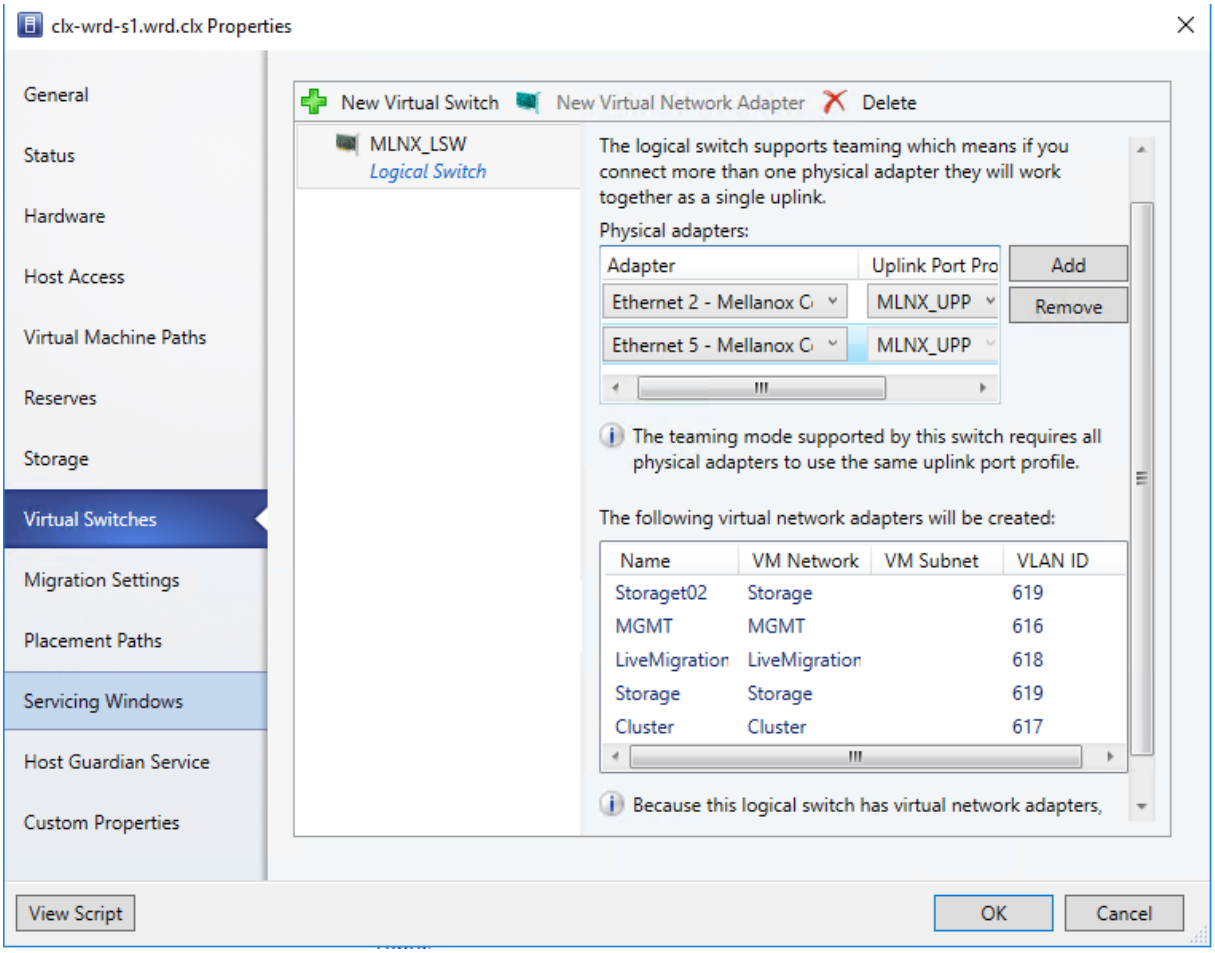
   g. Repeat steps b-f for Cluster, LiveMigration, Storage01 and Storage02 logical networks.

10. Review the Summary information and click "Finish" to complete the wizard.

In Windows Server 2016 we can add two SMB (Storage) NICs to the same network due to implementation of the new feature Simplified SMB Multichannel and Multi-NIC Cluster Networks.

4.3.6 Deploying a Logical Switch on Compute Hosts

1. Click VMs and Services on the left navigation pane in the Home screen.
2. Right click on HOST machine under "All Hosts" group and click on "Properties".
3. Click on "Virtual Switches" on the left and click on "New Virtual Switch" then choose the Logical Switch you have just created.



4. Add both Mellanox NIC ports in the "Physical Adapters" to the created Uplink Port Profile.
5. Click "OK" to start logical switch deployment after reviewing the information provided in the summary screen.
6. Repeat steps 1-5 for all hosts.

4.4 Disabling Regular Flow Control and Creating an Affinity between a Virtual NIC (vNIC) and a Physical NIC (pNIC)

After deploying the Logical switch on the all hosts, disable the regular Flow Control on the Mellanox adapters, since Priority Flow Control (PFC) and Flow Control cannot operate simultaneously on the same interface.

Creating an affinity between a vNIC and a pNIC ensures that the traffic from a given vNIC on the host (storage vNIC) uses a particular pNIC to send traffic so that it passes through the shorter path.

Please execute the following PowerShell script from the Domain controller to make all these changes quickly and consistently.

```
$nodes = ("clx-wrd-S1", "clx-wrd-S2", "clx-wrd-S3", "clx-wrd-S4")
Invoke-Command $nodes {Set-NetAdapterAdvancedProperty -InterfaceDescription
"*Mellanox*" -RegistryKeyword "*FlowControl" -RegistryValue 0}

Invoke-Command $nodes {(Get-NetAdapter -InterfaceDescription 'Mellanox
ConnectX-4 VPI Adapter').name | ? {Set-VMNetworkAdapterTeamMapping -
VMNetworkAdapterName 'Storage01' -ManagementOS -PhysicalNetAdapterName $_}}

Invoke-Command $nodes {(Get-NetAdapter -InterfaceDescription 'Mellanox
ConnectX-4 VPI Adapter #2').name | ? {Set-VMNetworkAdapterTeamMapping -
VMNetworkAdapterName 'Storage02' -ManagementOS -PhysicalNetAdapterName $ }}

Invoke-Command -ComputerName $nodes {Restart-Computer -Force}
```

4.5 Create and Configure Storage Spaces Direct Cluster

The following steps are run in PowerShell session from SCVMM with administrative permissions.

1. Run cluster validation.

```
$nodes = ("clx-wrd-S1", "clx-wrd-S2", "clx-wrd-S3", "clx-wrd-S4")
Test-Cluster -Node $nodes -Include "Storage Spaces
Direct","Inventory","Network","System Configuration"
```

2. Create a cluster

   The –NoStorage parameter is important to be added to the cmdlet, otherwise disks may be automatically added to the cluster and you will need to remove them before enabling Storage Spaces Direct otherwise they will not be included in the Storage Spaces Direct storage pool.

```
$ClusterIP = (Get-SCStaticIPAddressPool -LogicalNetworkDefinition (Get-
SCLogicalNetworkDefinition -LogicalNetwork "MGMT")).IPAddressReservedSet
New-Cluster -Name CLX-S2D -Node $nodes –NoStorage -IgnoreNetwork
172.17.0.0/16,172.19.0.0/16,172.18.0.0/16 -StaticAddress $ClusterIP
```

3. Enable Storage Spaces Direct in all-flash mode. The -CacheState Disabled parameter is important to be added to the cmdlet, because only a single tier of devices, such as an all NVMe is used.

```
Enable-ClusterStorageSpacesDirect -CacheState Disabled -AutoConfig:0 -
SkipEligibilityChecks
```

4. Show clustered disks and create pool – "S2D-Pool".

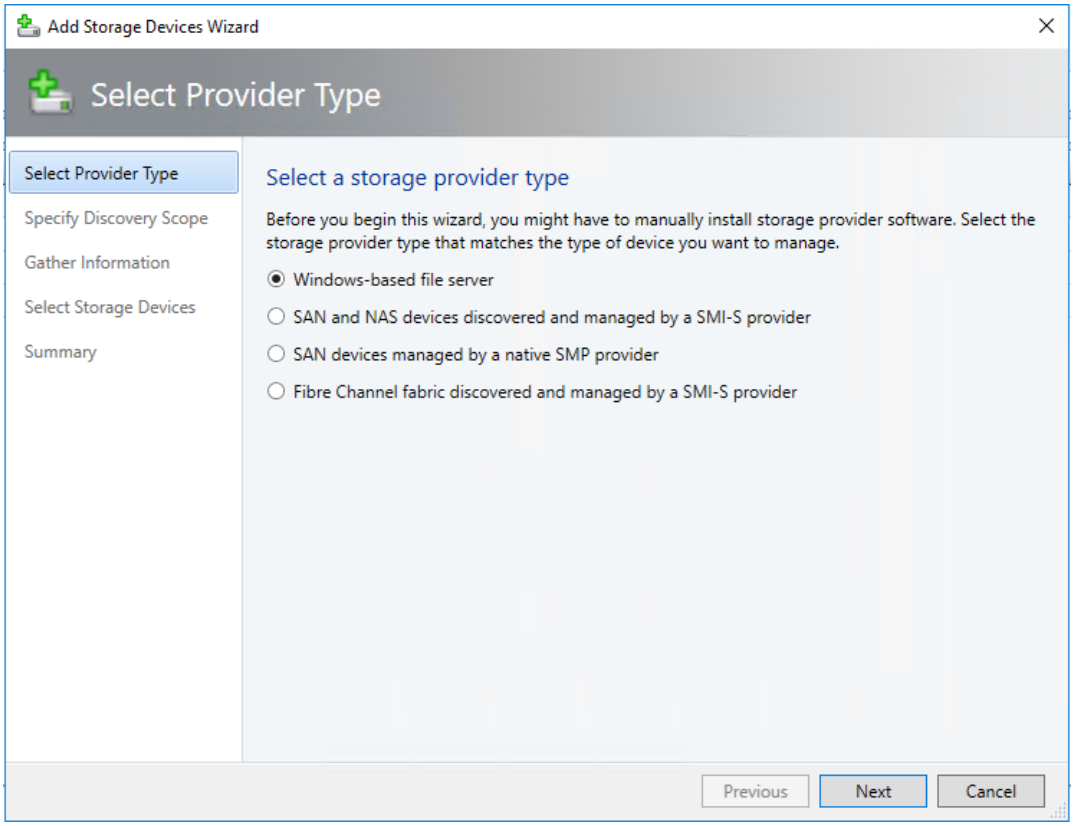
```
Get-StorageSubsystem *cluster* | Get-PhysicalDisk | ? bustype -eq NVMe
New-StoragePool -StorageSubSystemFriendlyName *Cluster* -FriendlyName
S2D-Pool -ProvisioningTypeDefault Fixed -PhysicalDisk (Get-PhysicalDisk |
? BusType -eq NVMe)
```

5. Add Storage Provider for Spaces Direct in SCVMM.

   a. Open VMM console and navigate to the Fabric workspace.

   b. Select Add Resources | Storage Devices and select Windows-based File Server as shown in the following screenshot.

   c. Click Next.



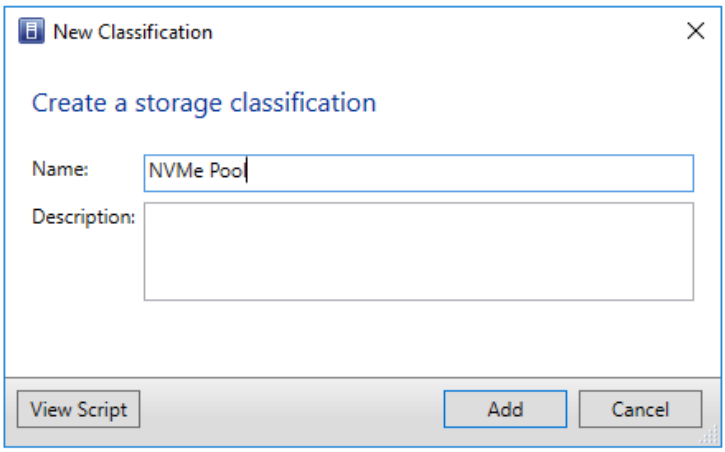
d. Provide the "IP address" or the "Cluster FQDN" and check the checkbox if the cluster is in another domain.

e. Provide the "Run As Account" and click "Next".

f. On the next screen select the "Storage Device" and click "Next".

g. Provide the "Pool Classification" to finish "Storage pool" configuration.

   To create the Pool Classification, open the SCVMM console, go to Fabric → Storage → Classification and Pools and press the icon "Create Storage Classification" on the ribbon in the "SCVMM Console".



h. Provide the New Classification's name and click "Add"

6. Specify a classification for the created pool.

a. Open the VMM console, go to Fabric → Storage →Arrays

b. Right-click the "Storage Spaces Direct Cluster" created, and then click Manage Pools.

c. Select the storage pool and click Edit.

d. Choose the "Pool classification"

e. Click OK.

7. Create a Cluster Shared Volume.

a. Right-click on the cluster that has been created.

b. Click Properties.

c. Select the Shared Volumes option.

d. Click Add and then follow the steps to create the volume.

Appendix A: Switch Configuration Examples

A.1 TOR-1 Configuration Example

```
## Hostname: swx-wrd-01
##

##
## Running-config temporary prefix mode setting
##
no cli default prefix-modes enable

##
## MLAG protocol
##
   protocol mlag

##
## Interface Ethernet configuration
##
   interface port-channel 1
   interface ethernet 1/1 speed 40000 force
   interface ethernet 1/1-1/30 mtu 9216 force
   interface ethernet 1/2 switchport mode hybrid
   interface ethernet 1/3 switchport mode hybrid
   interface ethernet 1/4 switchport mode hybrid
   interface ethernet 1/5 switchport mode hybrid
   interface ethernet 1/6 switchport mode hybrid
   interface ethernet 1/7 switchport mode hybrid
   interface ethernet 1/8 switchport mode hybrid
   interface ethernet 1/9 switchport mode hybrid
   interface ethernet 1/10 switchport mode hybrid
   interface ethernet 1/11 switchport mode hybrid
   interface ethernet 1/12 switchport mode hybrid
   interface ethernet 1/13 switchport mode hybrid
   interface ethernet 1/14 switchport mode hybrid
   interface ethernet 1/15 switchport mode hybrid
   interface ethernet 1/16 switchport mode hybrid
   interface ethernet 1/17 switchport mode hybrid
   interface ethernet 1/18 switchport mode hybrid
   interface ethernet 1/19 switchport mode hybrid
   interface ethernet 1/20 switchport mode hybrid
   interface ethernet 1/21 switchport mode hybrid
   interface ethernet 1/22 switchport mode hybrid
   interface ethernet 1/23 switchport mode hybrid
   interface ethernet 1/24 switchport mode hybrid
   interface ethernet 1/25 switchport mode hybrid
   interface ethernet 1/26 switchport mode hybrid
   interface ethernet 1/27 switchport mode hybrid
   interface ethernet 1/28 switchport mode hybrid
   interface ethernet 1/29 switchport mode hybrid
   interface ethernet 1/30 switchport mode hybrid
   interface ethernet 1/31-1/32 channel-group 1 mode active

##
## LAG configuration
##
   lacp

##
## VLAN configuration
##
   vlan 616-621
   vlan 666
   vlan 999
```

```
   vlan 616 name "MGMT"
   vlan 617 name "Cluster"
   vlan 618 name "LiveMigration"
   vlan 619 name "Storage"
   vlan 621 name "Deploy"
   interface ethernet 1/2 switchport access vlan 621
   interface ethernet 1/2 switchport hybrid allowed-vlan all
   interface ethernet 1/3 switchport access vlan 621
   interface ethernet 1/3 switchport hybrid allowed-vlan all
   interface ethernet 1/4 switchport access vlan 621
   interface ethernet 1/4 switchport hybrid allowed-vlan all
   interface ethernet 1/5 switchport access vlan 621
   interface ethernet 1/5 switchport hybrid allowed-vlan all
   interface ethernet 1/6 switchport access vlan 621
   interface ethernet 1/6 switchport hybrid allowed-vlan all
   interface ethernet 1/7 switchport access vlan 621
   interface ethernet 1/7 switchport hybrid allowed-vlan all
   interface ethernet 1/8 switchport access vlan 621
   interface ethernet 1/8 switchport hybrid allowed-vlan all
   interface ethernet 1/9 switchport access vlan 621
   interface ethernet 1/9 switchport hybrid allowed-vlan all
   interface ethernet 1/10 switchport access vlan 621
   interface ethernet 1/10 switchport hybrid allowed-vlan all
   interface ethernet 1/11 switchport access vlan 621
   interface ethernet 1/11 switchport hybrid allowed-vlan all
   interface ethernet 1/12 switchport access vlan 621
   interface ethernet 1/12 switchport hybrid allowed-vlan all
   interface ethernet 1/13 switchport access vlan 621
   interface ethernet 1/13 switchport hybrid allowed-vlan all
   interface ethernet 1/14 switchport access vlan 621
   interface ethernet 1/14 switchport hybrid allowed-vlan all
   interface ethernet 1/15 switchport access vlan 621
   interface ethernet 1/15 switchport hybrid allowed-vlan all
   interface ethernet 1/16 switchport access vlan 616
   interface ethernet 1/16 switchport hybrid allowed-vlan all
   interface ethernet 1/17 switchport access vlan 621
   interface ethernet 1/17 switchport hybrid allowed-vlan all
   interface ethernet 1/18 switchport access vlan 621
   interface ethernet 1/18 switchport hybrid allowed-vlan all
   interface ethernet 1/19 switchport access vlan 621
   interface ethernet 1/19 switchport hybrid allowed-vlan all
   interface ethernet 1/20 switchport access vlan 621
   interface ethernet 1/20 switchport hybrid allowed-vlan all
   interface ethernet 1/21 switchport access vlan 621
   interface ethernet 1/21 switchport hybrid allowed-vlan all
   interface ethernet 1/22 switchport access vlan 621
   interface ethernet 1/22 switchport hybrid allowed-vlan all
   interface ethernet 1/23 switchport access vlan 621
   interface ethernet 1/23 switchport hybrid allowed-vlan all
   interface ethernet 1/24 switchport access vlan 621
   interface ethernet 1/24 switchport hybrid allowed-vlan all
   interface ethernet 1/25 switchport access vlan 621
   interface ethernet 1/25 switchport hybrid allowed-vlan all
   interface ethernet 1/26 switchport access vlan 621
   interface ethernet 1/26 switchport hybrid allowed-vlan all
   interface ethernet 1/27 switchport access vlan 621
   interface ethernet 1/27 switchport hybrid allowed-vlan all
   interface ethernet 1/28 switchport access vlan 621
   interface ethernet 1/28 switchport hybrid allowed-vlan all
   interface ethernet 1/29 switchport access vlan 621
   interface ethernet 1/29 switchport hybrid allowed-vlan all
   interface ethernet 1/30 switchport access vlan 621
   interface ethernet 1/30 switchport hybrid allowed-vlan all

##
## STP configuration
##
```

```
no spanning-tree

##
## L3 configuration
##
   ip routing vrf default
   interface ethernet 1/1 no switchport force
   interface loopback 0
   interface vlan 616
   interface vlan 617
   interface vlan 618
   interface vlan 619
   interface vlan 621
   interface vlan 999
   interface ethernet 1/1 ip address 192.168.223.1 255.255.255.252
   interface loopback 0 ip address 172.22.0.1 255.255.255.255
   interface vlan 616 ip address 172.16.254.251 255.255.0.0
   interface vlan 617 ip address 172.17.1.251 255.255.0.0
   interface vlan 618 ip address 172.18.1.251 255.255.0.0
   interface vlan 619 ip address 172.19.1.251 255.255.0.0
   interface vlan 621 ip address 172.21.1.251 255.255.0.0
   interface vlan 999 ip address 192.168.222.1 255.255.255.252

##
## DCBX PFC configuration
##
   dcb priority-flow-control enable force
   dcb priority-flow-control priority 3 enable
   interface ethernet 1/1-1/32 dcb priority-flow-control mode on force
   interface port-channel 1 dcb priority-flow-control mode on force

##
## LLDP configuration
##
   lldp

##
## DHCP relay configuration
##
   ip dhcp relay address vrf default 172.16.1.251

##
## MAGP configuration
##
   protocol magp
   interface vlan 616 magp 16
   interface vlan 617 magp 17
   interface vlan 618 magp 18
   interface vlan 619 magp 19
   interface vlan 621 magp 21
   interface vlan 616 magp 16 ip virtual-router address 172.16.254.253
   interface vlan 617 magp 17 ip virtual-router address 172.17.1.253
   interface vlan 618 magp 18 ip virtual-router address 172.18.1.253
   interface vlan 619 magp 19 ip virtual-router address 172.19.1.253
   interface vlan 621 magp 21 ip virtual-router address 172.21.1.254
   interface vlan 616 magp 16 ip virtual-router mac-address
00:01:02:10:01:FF
   interface vlan 617 magp 17 ip virtual-router mac-address
00:01:02:11:01:FF
   interface vlan 618 magp 18 ip virtual-router mac-address
00:01:02:12:01:FF
   interface vlan 619 magp 19 ip virtual-router mac-address
00:01:02:13:01:FF
   interface vlan 621 magp 21 ip virtual-router mac-address
00:01:02:15:01:FF
```

```
##
## MLAG configurations
##
   mlag-vip neo-mlag-vip-999 ip 10.7.214.201 /24 force
   no mlag shutdown
   mlag system-mac 00:11:22:33:44:99
   interface port-channel 1 ipl 1
   interface vlan 999 ipl 1 peer-address 192.168.222.2


##
## AAA remote server configuration
##
# ldap bind-password ********
# radius-server key ********
# tacacs-server key ********

##
## SNMP configuration
##
no snmp-server host 10.7.215.46 disable
   snmp-server host 10.7.215.46 traps version 2c public

##
## Network management configuration
##
# web proxy auth basic password ********
   clock timezone Asia Middle_East Jerusalem
no ntp server 192.114.62.250 disable
   ntp server 192.114.62.250 keyID 0
no ntp server 192.114.62.250 trusted-enable
   ntp server 192.114.62.250 version 4

##
## X.509 certificates configuration
##
#
# Certificate name system-self-signed, ID
b3fbbb1d475e067acc23eb57a54a1ee34b5c1171
# (public-cert config omitted since private-key config is hidden)

##
## Persistent prefix mode setting
##
cli default prefix-modes enable
```

A.2 TOR-2 Configuration Example

```
## Hostname: swx-wrd-02
##

##
## Running-config temporary prefix mode setting
##
no cli default prefix-modes enable

##
## MLAG protocol
##
   protocol mlag

##
## Interface Ethernet configuration
##
   interface port-channel 1
   interface ethernet 1/1 speed 40000 force
   interface ethernet 1/1-1/30 mtu 9216 force
   interface ethernet 1/2 switchport mode hybrid
   interface ethernet 1/3 switchport mode hybrid
   interface ethernet 1/4 switchport mode hybrid
   interface ethernet 1/5 switchport mode hybrid
   interface ethernet 1/6 switchport mode hybrid
   interface ethernet 1/7 switchport mode hybrid
   interface ethernet 1/8 switchport mode hybrid
   interface ethernet 1/9 switchport mode hybrid
   interface ethernet 1/10 switchport mode hybrid
   interface ethernet 1/11 switchport mode hybrid
   interface ethernet 1/12 switchport mode hybrid
   interface ethernet 1/13 switchport mode hybrid
   interface ethernet 1/14 switchport mode hybrid
   interface ethernet 1/15 switchport mode hybrid
   interface ethernet 1/16 switchport mode hybrid
   interface ethernet 1/17 switchport mode hybrid
   interface ethernet 1/18 switchport mode hybrid
   interface ethernet 1/19 switchport mode hybrid
   interface ethernet 1/20 switchport mode hybrid
   interface ethernet 1/21 switchport mode hybrid
   interface ethernet 1/22 switchport mode hybrid
   interface ethernet 1/23 switchport mode hybrid
   interface ethernet 1/24 switchport mode hybrid
   interface ethernet 1/25 switchport mode hybrid
   interface ethernet 1/26 switchport mode hybrid
   interface ethernet 1/27 switchport mode hybrid
   interface ethernet 1/28 switchport mode hybrid
   interface ethernet 1/29 switchport mode hybrid
   interface ethernet 1/30 switchport mode hybrid
   interface ethernet 1/31-1/32 channel-group 1 mode active

##
## LAG configuration
##
   lacp

##
## VLAN configuration
##
   vlan 616-619
   vlan 621
   vlan 999
   vlan 616 name "MGMT"
   vlan 617 name "Cluster"
   vlan 618 name "LiveMigration"
```

```
   vlan 619 name "Storage"
   vlan 621 name "Deploy"
   interface ethernet 1/2 switchport access vlan 621
   interface ethernet 1/2 switchport hybrid allowed-vlan all
   interface ethernet 1/3 switchport access vlan 621
   interface ethernet 1/3 switchport hybrid allowed-vlan all
   interface ethernet 1/4 switchport access vlan 621
   interface ethernet 1/4 switchport hybrid allowed-vlan all
   interface ethernet 1/5 switchport access vlan 621
   interface ethernet 1/5 switchport hybrid allowed-vlan all
   interface ethernet 1/6 switchport access vlan 621
   interface ethernet 1/6 switchport hybrid allowed-vlan all
   interface ethernet 1/7 switchport access vlan 621
   interface ethernet 1/7 switchport hybrid allowed-vlan all
   interface ethernet 1/8 switchport access vlan 621
   interface ethernet 1/8 switchport hybrid allowed-vlan all
   interface ethernet 1/9 switchport access vlan 621
   interface ethernet 1/9 switchport hybrid allowed-vlan all
   interface ethernet 1/10 switchport access vlan 621
   interface ethernet 1/10 switchport hybrid allowed-vlan all
   interface ethernet 1/11 switchport access vlan 621
   interface ethernet 1/11 switchport hybrid allowed-vlan all
   interface ethernet 1/12 switchport access vlan 621
   interface ethernet 1/12 switchport hybrid allowed-vlan all
   interface ethernet 1/13 switchport access vlan 621
   interface ethernet 1/13 switchport hybrid allowed-vlan all
   interface ethernet 1/14 switchport access vlan 621
   interface ethernet 1/14 switchport hybrid allowed-vlan all
   interface ethernet 1/15 switchport access vlan 621
   interface ethernet 1/15 switchport hybrid allowed-vlan all
   interface ethernet 1/16 switchport access vlan 616
   interface ethernet 1/16 switchport hybrid allowed-vlan all
   interface ethernet 1/17 switchport access vlan 621
   interface ethernet 1/17 switchport hybrid allowed-vlan all
   interface ethernet 1/18 switchport access vlan 621
   interface ethernet 1/18 switchport hybrid allowed-vlan all
   interface ethernet 1/19 switchport access vlan 621
   interface ethernet 1/19 switchport hybrid allowed-vlan all
   interface ethernet 1/20 switchport access vlan 621
   interface ethernet 1/20 switchport hybrid allowed-vlan all
   interface ethernet 1/21 switchport access vlan 621
   interface ethernet 1/21 switchport hybrid allowed-vlan all
   interface ethernet 1/22 switchport access vlan 621
   interface ethernet 1/22 switchport hybrid allowed-vlan all
   interface ethernet 1/23 switchport access vlan 621
   interface ethernet 1/23 switchport hybrid allowed-vlan all
   interface ethernet 1/24 switchport access vlan 621
   interface ethernet 1/24 switchport hybrid allowed-vlan all
   interface ethernet 1/25 switchport access vlan 621
   interface ethernet 1/25 switchport hybrid allowed-vlan all
   interface ethernet 1/26 switchport access vlan 621
   interface ethernet 1/26 switchport hybrid allowed-vlan all
   interface ethernet 1/27 switchport access vlan 621
   interface ethernet 1/27 switchport hybrid allowed-vlan all
   interface ethernet 1/28 switchport access vlan 621
   interface ethernet 1/28 switchport hybrid allowed-vlan all
   interface ethernet 1/29 switchport access vlan 621
   interface ethernet 1/29 switchport hybrid allowed-vlan all
   interface ethernet 1/30 switchport access vlan 621
   interface ethernet 1/30 switchport hybrid allowed-vlan all

##
## STP configuration
##
no spanning-tree

##
```

```
## L3 configuration
##
   ip routing vrf default
   interface ethernet 1/1 no switchport force
   interface loopback 0
   interface vlan 616
   interface vlan 617
   interface vlan 618
   interface vlan 619
   interface vlan 621
   interface vlan 999
   interface ethernet 1/1 ip address 192.168.223.5 255.255.255.252
   interface loopback 0 ip address 172.22.0.3 255.255.255.255
   interface vlan 616 ip address 172.16.254.252 255.255.0.0
   interface vlan 617 ip address 172.17.1.252 255.255.0.0
   interface vlan 618 ip address 172.18.1.252 255.255.0.0
   interface vlan 619 ip address 172.19.1.252 255.255.0.0
   interface vlan 621 ip address 172.21.1.252 255.255.0.0
   interface vlan 999 ip address 192.168.222.2 255.255.255.252

##
## DCBX PFC configuration
##
   dcb priority-flow-control enable force
   dcb priority-flow-control priority 3 enable
   interface ethernet 1/1-1/32 dcb priority-flow-control mode on force
   interface port-channel 1 dcb priority-flow-control mode on force

##
## LLDP configuration
##
   lldp

##
## DHCP relay configuration
##
   ip dhcp relay address vrf default 172.16.1.251

##
## MAGP configuration
##
   protocol magp
   interface vlan 616 magp 16
   interface vlan 617 magp 17
   interface vlan 618 magp 18
   interface vlan 619 magp 19
   interface vlan 621 magp 21
   interface vlan 616 magp 16 ip virtual-router address 172.16.254.253
   interface vlan 617 magp 17 ip virtual-router address 172.17.1.253
   interface vlan 618 magp 18 ip virtual-router address 172.18.1.253
   interface vlan 619 magp 19 ip virtual-router address 172.19.1.253
   interface vlan 621 magp 21 ip virtual-router address 172.21.1.254
   interface vlan 616 magp 16 ip virtual-router mac-address
00:01:02:10:01:FF
   interface vlan 617 magp 17 ip virtual-router mac-address
00:01:02:11:01:FF
   interface vlan 618 magp 18 ip virtual-router mac-address
00:01:02:12:01:FF
   interface vlan 619 magp 19 ip virtual-router mac-address
00:01:02:13:01:FF
   interface vlan 621 magp 21 ip virtual-router mac-address
00:01:02:15:01:FF

##
## MLAG configurations
##
   mlag-vip neo-mlag-vip-999 ip 10.7.214.201 /24 force
```

```
   no mlag shutdown
   mlag system-mac 00:11:22:33:44:99
   interface port-channel 1 ipl 1
   interface vlan 999 ipl 1 peer-address 192.168.222.1

##
## AAA remote server configuration
##
# ldap bind-password ********
# radius-server key ********
# tacacs-server key ********

##
## SNMP configuration
##
no snmp-server host 10.7.215.46 disable
   snmp-server host 10.7.215.46 traps version 2c public

##
## Network management configuration
##
# web proxy auth basic password ********
   clock timezone Asia Middle_East Jerusalem
no ntp server 192.114.62.250 disable
   ntp server 192.114.62.250 keyID 0
no ntp server 192.114.62.250 trusted-enable
   ntp server 192.114.62.250 version 4

##
## X.509 certificates configuration
##
#
# Certificate name system-self-signed, ID
448aecb823e64c21da59133aab9e546a75bdcebc
# (public-cert config omitted since private-key config is hidden)

##
## Persistent prefix mode setting
##
cli default prefix-modes enable
```

Appendix B: PowerShell Script to Create Logical Networks in SCVMM

```
# ------------------------------------------------------------
# Script for create Logical Networks
# ------------------------------------------------------------


param(

[Parameter(Mandatory=$false)]
#Uplink Port Profile to be used in logicall switch
 $UplinkPortProfile = "MLNX_UPP", # !Must be created before script execution
[Parameter(Mandatory=$false)]
#Host Group name
 $NCHostGroupName = "S2D",        # !Must be created before script execution
[Parameter(Mandatory=$false)]
# Logical network list
 $LogicalNetworks = @(
             @{
               # Storage Network information
              Name = "Storage"
              Subnets = @(
               @{
                VLANID = 619
                AddressPrefix = "172.19.0.0/16"     #Example: "10.0.20.0/24"
                DNS = @()                           #Example: @("10.0.0.7",
"10.0.0.8")
                Gateways = "172.19.1.253"           #Example: "10.0.20.1"
                PoolStart = "172.19.0.1"            #Example: "10.0.20.5"
                PoolEnd = "172.19.0.200"            #Example: "10.0.20.100"
               }
              )
          },
          @{
              # LiveMigration Network information
              Name = "LiveMigration"
              Subnets = @(
               @{
                   VLANID = 618
AddressPrefix = "172.18.0.0/16"              #Example: "10.0.20.0/24"
                   DNS = @()                 #Example: @("10.0.0.7",
"10.0.0.8")
                   Gateways = "172.18.1.253"  #Example: "10.0.20.1"
                   PoolStart = "172.18.0.1"   #Example: "10.0.20.5"
                   PoolEnd = "172.18.0.200"   #Example: "10.0.20.100"
               }
              )
          },
          @{
              # Cluster Network information
              Name = "Cluster"
              Subnets = @(
               @{
                VLANID = 617
                AddressPrefix = "172.17.0.0/16"     #Example: "10.0.20.0/24"
                DNS = @()                           #Example: @("10.0.0.7",
"10.0.0.9")
                Gateways = "172.17.1.253"           #Example: "10.0.20.1"
                PoolStart = "172.17.0.1"            #Example: "10.0.20.5"
                PoolEnd = "172.17.0.200"           #Example: "10.0.20.100"
                  }
                 )
          },
          @{
```

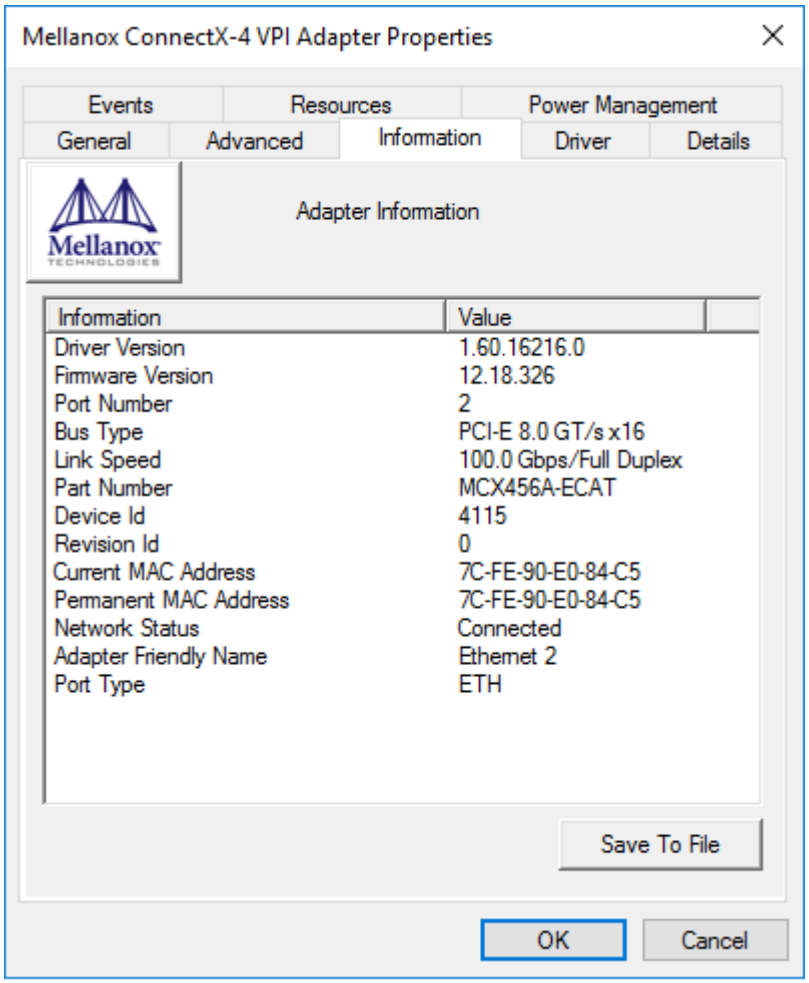
```
            # Management VM Network information.
              Name = "MGMT"
              Subnets = @(
              @{
               VLANID = 616                        #Example: 7
               AddressPrefix = "172.16.0.0/16"  #Example: "10.0.0.0/24"
               DNS = @("172.16.1.251")          #Example: @("10.0.0.7",
"10.0.0.9")
               Gateways = "172.16.254.253"      #Example: "10.0.40.1"
               PoolStart = "172.16.0.1"         #Example: "10.0.0.5"
               PoolEnd = "172.16.0.200"         #Example: "10.0.0.100"
               ReservedIPset = "172.16.0.200"   #This IP will be used for
Cluster
                 }
              )
             }
)
)

function createLogicalNetwork
{
    param([Object] $NCHostGroupName,
          [object] $ln,
          [boolean] $ManagedByNC
          )

      $LogicalNetworkCreated = New-SCLogicalNetwork -Name $ln.Name -
LogicalNetworkDefinitionIsolation $false -EnableNetworkVirtualization $false
-UseGRE $false -IsPVLAN $false

    Write-Host "Getting the Host group with Name [$NCHostGroupName]"
    $allHostGroups = @()
    $allHostGroups += Get-SCVMHostGroup -Name $NCHostGroupName

    $allSubnetVLAN = @()
    $allSubnetVLAN += New-SCSubnetVLAN -Subnet $ln.subnets[0].AddressPrefix
-VLanID $ln.subnets[0].VLANID
    $VLANId = $ln.subnets[0].VLANID

    Write-Host "Creating new Logical Network Definition"
    $LNDName = $ln.Name + "_0"
    $createdLND = New-SCLogicalNetworkDefinition -Name $LNDName -
LogicalNetwork $LogicalNetworkCreated -VMHostGroup $allHostGroups -
SubnetVLan $allSubnetVLAN

    Write-Host " create a VMNetwork with the same name as Logical Network"

    $ManagementVMNetwork = New-SCVMNetwork -Name $ln.Name -IsolationType
"NoIsolation" -LogicalNetwork $LogicalNetworkCreated

    Write-Host "Logical Network Deployment completed succssfully"

    #Create IP Pool for the created Logical Network
    $subnet = $ln.subnets[0]
    $ManagementSubnet = $subnet
    $allGateways =@()
    $allGateways += New-SCDefaultGateway -IPAddress $subnet.Gateways -
Automatic
    $IPAddressPoolName = $ln.Name + "_IPAddressPool_0"

    if($ln.Name -eq "MGMT")
    {
        if($subnet.DNS.count -eq 0)
        {
         Write-Host " DNS setttings are mandatory for MGMT Network"
         return -1
        }
```

```
        $staticIP = New-SCStaticIPAddressPool -Name $IPAddressPoolName -
LogicalNetworkDefinition $createdLND -Subnet $subnet.AddressPrefix -
IPAddressRangeStart $subnet.PoolStart -IPAddressRangeEnd $subnet.PoolEnd -
DefaultGateway $allGateways -DNSServer $subnet.DNS -IPAddressReservedSet
$subnet.ReservedIPset
    }
    else
    {
        $staticIP = New-SCStaticIPAddressPool -Name $IPAddressPoolName -
LogicalNetworkDefinition $createdLND -Subnet $subnet.AddressPrefix -
IPAddressRangeStart $subnet.PoolStart -IPAddressRangeEnd $subnet.PoolEnd -
DefaultGateway $allGateways -DNSServer $subnet.DNS
    }

    Write-Host " Created Logical Network : $LogicalNetworkCreated"
    return $LogicalNetworkCreated
}


function AssociateLogicalNetWithUPP
{
     param([string] $LogicalNetwork,
        [String] $UplinkPortProfile)

     #Get the LogicalNetwork
     $LogNet = Get-SCLogicalNetwork -Name $LogicalNetwork

    # Get the logical Network Definition
    $LogicalNetworkDefinition = Get-SCLogicalNetworkDefinition -
LogicalNetwork     $LogNet

     #Get the NC uplink port profile
     $uplink = Get-SCNativeUplinkPortProfile -Name $UplinkPortProfile

     #Set the uplink port profile
    Set-SCNativeUplinkPortProfile -NativeUplinkPortProfile $uplink -
AddLogicalNetworkDefinition $LogicalNetworkDefinition
}


#################################################################
#        Main Body to execute Network creation                  #
#################################################################

$VerbosePreference = "continue"
$ErrorActionPreference = "stop"

     try{
        if($UplinkPortProfile -eq "")
        {
         $UplinkPortProfile  = "MLNX_UPP"
        }

             # Get the VMM server. The connection to VMM server will be made
by this
        Write-Host "Getting VMM server connection with VMM server [$(gc
env:computername)]"
            $VMMServer = Get-SCVMMServer -ComputerName localhost


            ######################################################
            #        Create Logical Networks                     #
            ######################################################
            foreach ($ln in $LogicalNetworks)
                  {
                CreateLogicalNetwork $NCHostGroupName $ln $false
```

```
                AssociateLogicalNetWithUPP $ln.Name $UplinkPortProfile

                                Write-Host " Logical Network creation
succeeded -"$ln.Name
                  }
    }
      catch
      {
         Write-Host " There is some Failure. Cleaning up the system to get
in previous state..."
         #cleanup the setup
      }
```

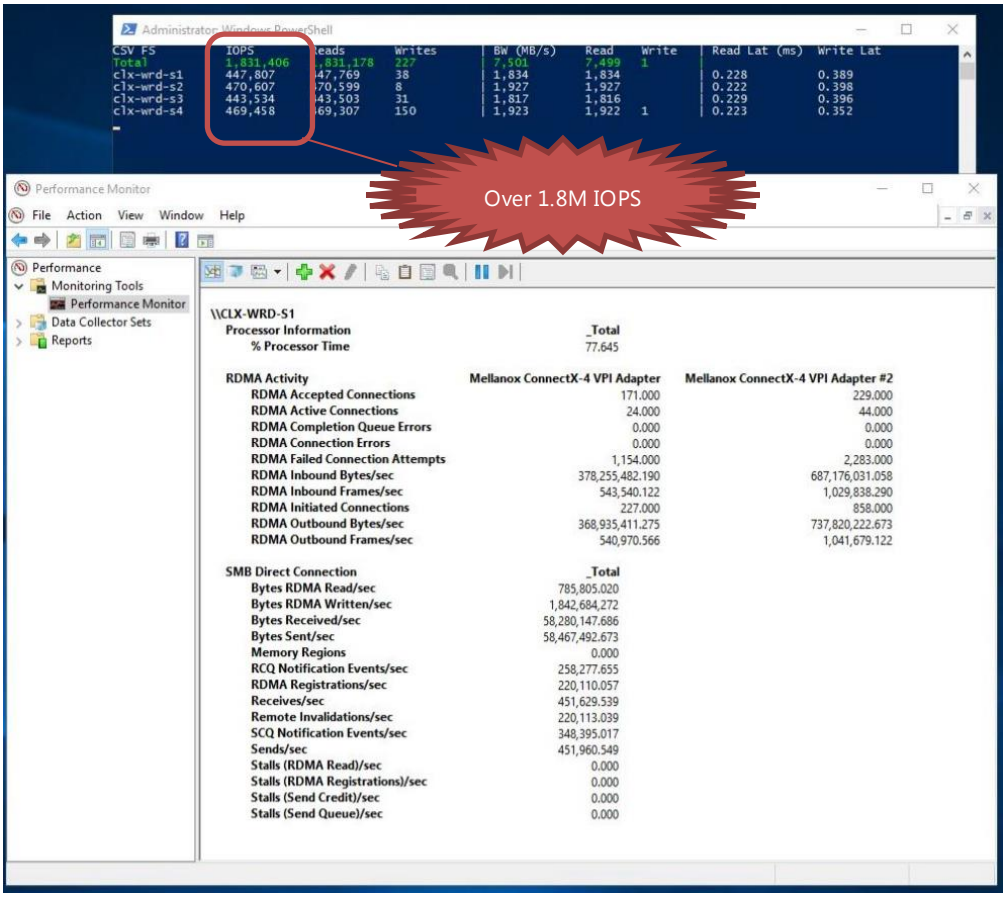
Appendix C: VM Fleet Cluster Performance Test

For the cluster performance tests the VMFleet utility is used. The results provided below are based a four node Hyper-Converged cluster where each node was equipped with Mellanox ConnectX-4 VPI 100GbE dual port adapter card. Detailed NIC information provided on screenshot below.



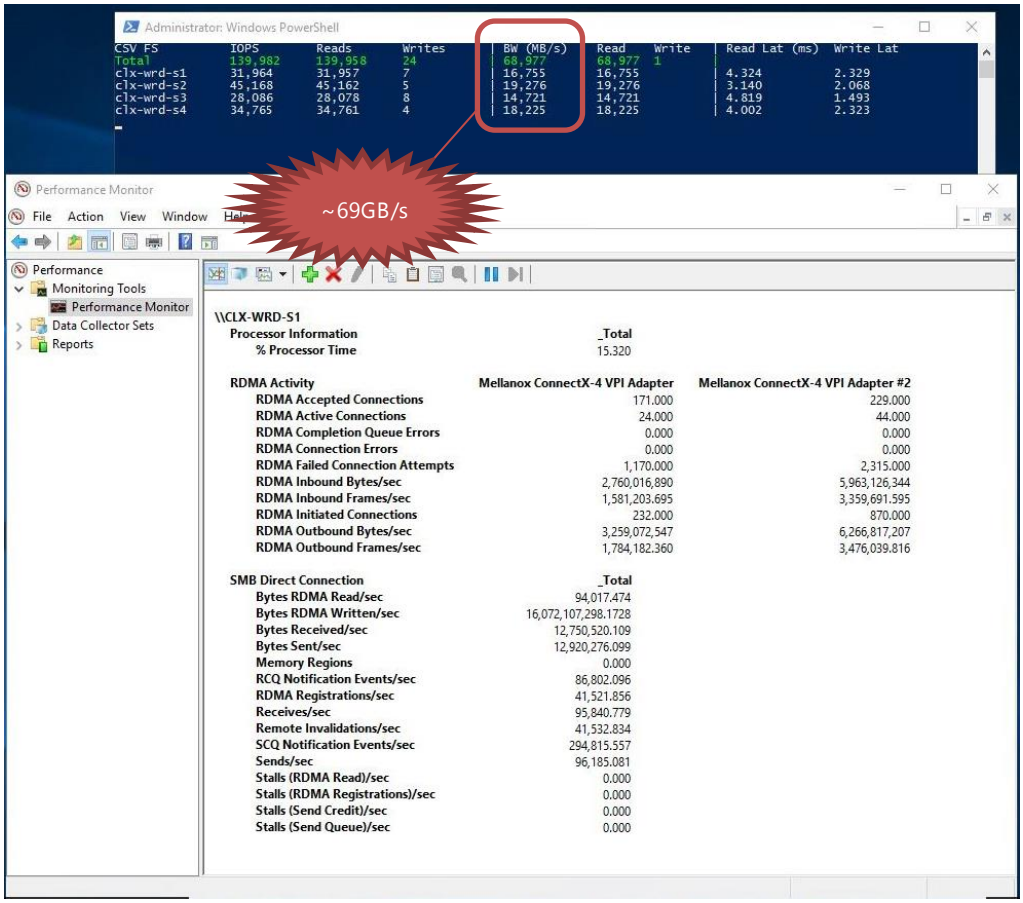
VMFleet with up to 36 virtual machines per node was used for a total of 144 Virtual Machines. Each Virtual Machine was configured with 1vCPU and 2GB RAM. Then, VMFleet was used to run DISKSPD in each of the 144 Virtual Machines for the two performance tests:

- First test - 1 thread, 4KiB sequential read with 32 outstanding IO.



This test enabled us to hit over 1.8M IOPS in aggregate throughput into the Virtual Machines.

- Second test - 1 thread, 512KiB sequential read with 4 outstanding IO.



This test enabled us to hit about 69GB/s in aggregate throughput into the Virtual Machines.