DataON TracSystem S2D-5224 & Windows Server 2016 Storage Spaces Direct Solution with Mellanox Spectrum Switches

Rev 1.0

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Document Revision History

Table 1: Document Revision History

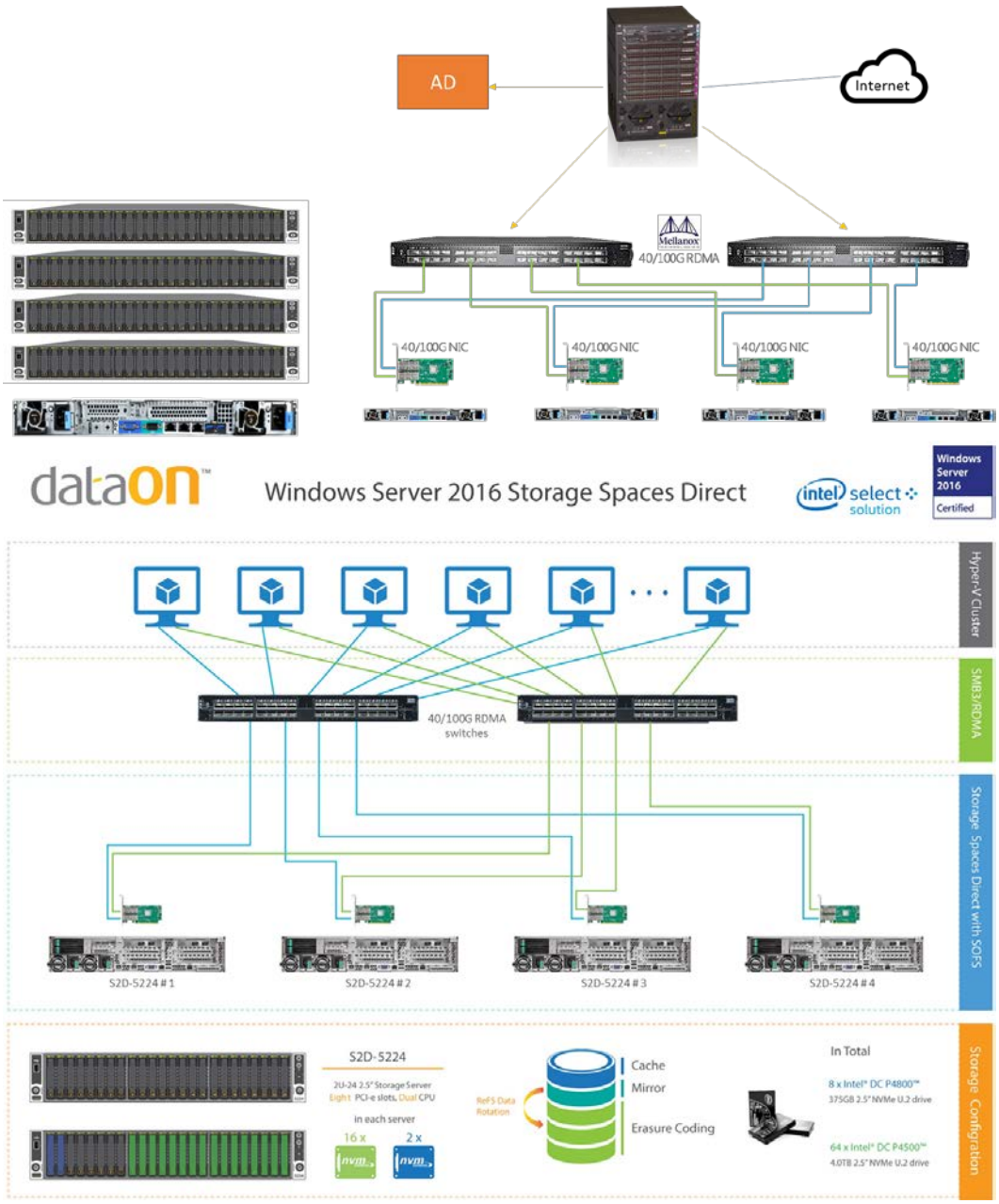
Revision	Date	Description
1.0	September 22, 2017	Updated to DataON TracSystem S2D-5224L Added DataON & Windows Server 2016 Storage Spaces Direct content

1 Setup

The setup includes two Mellanox Spectrum switches configured with VRRP and four DataON servers equipped with NVMe cards and Mellanox ConnectX®-4 network adapters dual ports for multi-path connectivity.

There are several models of Mellanox Spectrum™ switches, in this example we use the SN2700 32-port 100GbE switches.

- Servers: DataON TracSystem S2D-5224L (one node per S2D-5224 cluster, up to 16)
- Switches: Mellanox Spectrum™ SN2700
- Network adapters: Mellanox ConnectX®-4
- Mellanox Firmware Tools (WinMFT, version 4.7.0 or later) for utilities mentioned later



2 Overview

We configure this setup in 3 phases:

- IP connectivity
- RDMA QoS configuration (PFC/ECN, buffers) on the switches and servers
- Windows server configuration, core switch connectivity and other considerations

In this design, the traffic between the servers will be over RDMA (storage traffic), while traffic towards the core switches will be TCP/Management traffic and not RDMA traffic.

3 Configuration

Before you start, make sure you have the servers installed and powered up as well as the switches.

For first time MLNX-OS® installation, please refer to HowTo Get Started with Mellanox switches.

3.1 IP Connectivity

- Ports 1-28 downlinks to the servers (VLAN interface)
- Ports 29-30 uplinks towards the core switches (router ports)
- Ports 31-32 connected to the other ToR switch (port-channel)

3.1.1 VLANs

We will use the dual ports for the multi-path solution. Each server will be configured with different VLAN on each port.

In this example we will use VLANs 8 and 9:

```
switch (config) # vlan 8-9
switch (config) # vlan 8 name "Storage1"
switch (config) # vlan 9 name "Storage2"
```

3.1.2 Interface

1. Create LAG (port-channel) in trunk mode on ports 31 and 32. This link will be used for VRRP communication between switches.

```
switch (config) # interface port-channel 1
switch (config) # interface port-channel 1 description VRRP Link To other
switch
switch (config) # interface ethernet 1/31 description VRRP Link To other
switch
switch (config) # interface ethernet 1/32 description VRRP Link To other
switch
switch (config) # interface ethernet 1/31 channel-group 1 mode on
switch (config) # interface ethernet 1/32 channel-group 1 mode on
switch (config) # interface port-channel 1 switchport mode trunk
```

NOTE: All VLANs are members of trunk ports by default.

2. Configure links 1-28 (downlinks) towards the servers as trunk.

```
switch (config) # interface ethernet 1/1 switchport mode trunk
switch (config) # interface ethernet 1/2 switchport mode trunk
...
switch (config) # interface ethernet 1/28 switchport mode trunk
```

NOTE: All VLANs are members of trunk ports by default. The trunk allow only tagged traffic, if untagged traffic is needed (e.g. PXE boot) as well on those ports, set the links to hybrid and configure it to allow all VLANs.

```
switch (config) # interface Ethernet 1/28 switchport mode hybrid
switch (config) # interface Ethernet 1/28 switchport hybrid
allow-vlan all
```

Learn more about switchport on Mellanox switches in HowTo Configure Switch Port Types with MLNX-OS®.

3. Configure the uplink ports as router ports towards the core switches. Set the IP Address and subnet required on this interface.

```
switch (config) # interface ethernet 1/29 no switchport
switch (config) # interface ethernet 1/29 ip address 10.10.1.1 /24
switch (config) # interface ethernet 1/30 no switchport
switch (config) # interface ethernet 1/30 ip address 10.10.2.1 /24
```

NOTE: In this design, we assume that RDMA traffic will not pass via the core switches.

3.1.3 L3 and VRRP

We design the network to have two VLANs (multi-path). Each of the switches will be configured as VRRP master for a different VLAN, so both of the switches will be used (active-active).

1. Enable IP routing, and configure VLAN interface for each VLAN (8, 9).

NOTE: Each ToR switch should be configured with different IP addresses, this IP address will be the local IP address of each switch.

ToR 1:

```
switch (config) # ip routing vrf default
switch (config) # interface vlan 8
switch (config) # interface vlan 9
switch (config) # interface vlan 8 ip address 192.168.101.2 255.255.255.0
switch (config) # interface vlan 9 ip address 192.168.102.2 255.255.255.0
```

ToR 2:

```
switch (config) # ip routing vrf default
switch (config) # interface vlan 8
switch (config) # interface vlan 9
switch (config) # interface vlan 8 ip address 192.168.101.3 255.255.255.0
switch (config) # interface vlan 9 ip address 192.168.102.3 255.255.255.0
```

2. Enable the VRRP protocol on the switch and configure virtual IP address for each VLAN. Make sure to design the VRRP master for each VLAN to be a different port (using the priority parameter, the master priority is 255).

   ToR 1:

```
switch (config) # protocol vrrp
switch (config) # interface vlan 8 vrrp 8
switch (config) # interface vlan 8 vrrp 8 address 192.168.101.1
switch (config) # interface vlan 9 vrrp 9
switch (config) # interface vlan 9 vrrp 9 address 192.168.102.1
switch (config) # interface vlan 8 vrrp 8 priority 200
                  ToR 1 will be the VRRP Slave for this subnet
```

   ToR 2:

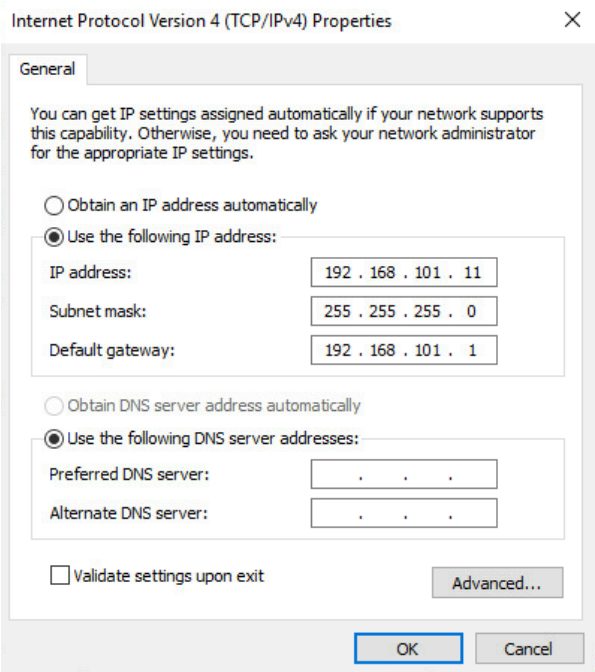
```
switch (config) # protocol vrrp
switch (config) # interface vlan 8 vrrp 8
switch (config) # interface vlan 8 vrrp 8 address 192.168.101.1
switch (config) # interface vlan 9 vrrp 9
switch (config) # interface vlan 9 vrrp 9 address 192.168.102.1
switch (config) # interface vlan 9 vrrp 9 priority 200
                  ToR 2 will be the VRRP Slave for this subnet
```

To learn more about the VRRP configuration, see HowTo Configure VRRP on Mellanox Ethernet Switches.

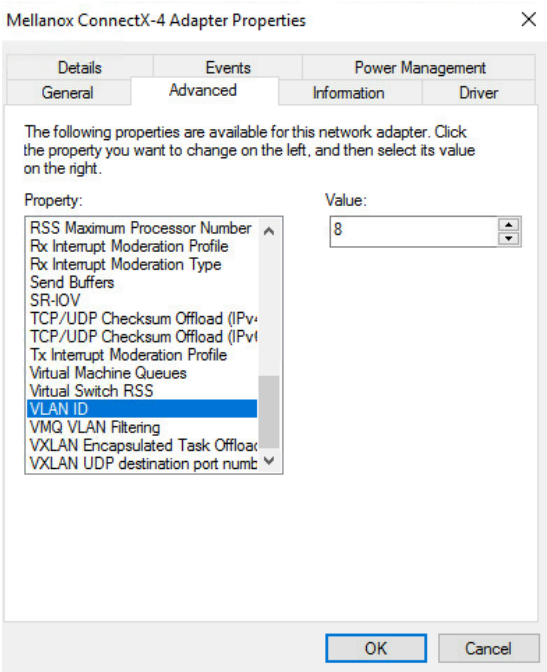
3.1.4 IP Interfaces on the Servers

1. Make sure to install Windows Server 2016 with the latest WinOF-2 driver on the servers. The servers should be equipped with ConnectX®-4 or ConnectX®-5 dual port adapters.
2. Make sure that security features, like firewalls are disabled, so ping can pass.
3. Set the IP addresses on the interfaces:
   a. Configure port 1 on the server connected to ToR 1 with VLAN 8 with the IP range of that VLAN (192.168.101.X)
   b. Configure port 2 on the server connected to ToR 2 with VLAN 9 with the IP range of that VLAN (192.168.102.X)

c. Set the IP address to suit the VRRP virtual address.



d. Set the VLAN to 8.



4. Add a route with lower metric from one network to the other network.

For example:

```
C:\> route add 192.168.101.0 192.168.102.1 METRIC 500
C:\> route add 192.168.102.0 192.168.101.1 METRIC 500
```

There are two ways now to reach the 101 network:

- via 192.168.101.11 (locally connected)
- via the other port 192.168.102.1 (the virtual router address)

So if one port is down, the traffic to that network will be sent from the second port.

NOTE: That the second route should have higher metric (510) in the example below. higher metric will be lower priority to be used. we don't want that to be used regularly.

```
IPv4 Route Table
===========================================================================
Active Routes:
Network Destination        Netmask          Gateway       Interface  Metric
          0.0.0.0          0.0.0.0    192.168.101.1   192.168.101.11     266
          0.0.0.0          0.0.0.0         10.0.0.1       10.0.1.244      25
         10.0.0.0      255.255.0.0         On-link        10.0.1.244     281
       10.0.1.244  255.255.255.255         On-link        10.0.1.244     281
     10.0.255.255  255.255.255.255         On-link        10.0.1.244     281
        127.0.0.0        255.0.0.0         On-link         127.0.0.1     331
        127.0.0.1  255.255.255.255         On-link         127.0.0.1     331
  127.255.255.255  255.255.255.255         On-link         127.0.0.1     331
    192.168.101.0    255.255.255.0         On-link    192.168.101.11     266
    192.168.101.0  255.255.255.255    192.168.102.1   192.168.102.11     510
   192.168.101.11  255.255.255.255         On-link    192.168.101.11     266
  192.168.101.255  255.255.255.255         On-link    192.168.101.11     266
    192.168.102.0    255.255.255.0         On-link    192.168.102.11     266
    192.168.102.0  255.255.255.255    192.168.101.1   192.168.101.11     510
   192.168.102.11  255.255.255.255         On-link    192.168.102.11     266
  192.168.102.255  255.255.255.255         On-link    192.168.102.11     266
        224.0.0.0        240.0.0.0         On-link         127.0.0.1     331
        224.0.0.0        240.0.0.0         On-link        10.0.1.244     281
        224.0.0.0        240.0.0.0         On-link    192.168.101.11     266
        224.0.0.0        240.0.0.0         On-link    192.168.102.11     266
  255.255.255.255  255.255.255.255         On-link         127.0.0.1     331
  255.255.255.255  255.255.255.255         On-link        10.0.1.244     281
  255.255.255.255  255.255.255.255         On-link    192.168.101.11     266
  255.255.255.255  255.255.255.255         On-link    192.168.102.11     266
===========================================================================
Persistent Routes:
  Network Address          Netmask  Gateway Address  Metric
          0.0.0.0          0.0.0.0    192.168.101.1  Default
===========================================================================
```

3.1.5 Verification

Test the L3 connectivity. Make sure ping is running (all to all).

1. Ping between the servers (all to all) make sure that traffic reaches the virtual routers and the local router interfaces on the VLANs.
2. Ping to the core switches and to external servers.
3. Disable a port, verify that the traffic goes via the second port and reach the desired network (high availability).

4 RDMA QoS Configuration

There are different ways to Setup the RDMA layer required for the Windows S2D. To learn more about RDMA and RoCE, see RDMA/RoCE Solutions page.

The Recommended Network Configuration Examples for RoCE Deployment will give you a good start with the switch configuration for a few selected profiles.

To understand more about QoS requirement for RDMA, see Understanding QoS Configuration for RoCE.

4.1 Switch Configuration

For this example, we will select Profile Follow Lossless RoCE Configuration for MLNX-OS Switches in DSCP-Based QoS Mode to configure the switches.

- Loss-less network, PFC is enabled on priority 3
- ECN is enabled on the switch for priority 3.
- Trust L3 is configured on the switch ports (classify the priority via DSCP field).
- Buffer pool configuration and priority mapping.
- CNP traffic will pass on DSCP 48.

NOTE: In the example below, we configure QoS on all ports. It is not needed to do so for the uplink ports, just for the ports that may carry RDMA traffic.

1. In order to make DCQCN congestion control to work, a user must enable ECN for RoCE traffic that run over traffic class 3:

```
switch (config) # interface ethernet 1/1-1/32 traffic-class 3 congestion-
control ecn minimum-absolute 150 maximum-absolute 1500
```

   For a fair sharing of switch buffer with other traffic classes It is recommended to configure ECN on all other traffic classes as well.

2. Buffer pool configuration.

   Allocating a buffer pool 0 for lossy traffic and pool 1 for lossless traffic.

```
switch (config) # pool ePool1 direction egress-mc size 16777000 type
dynamic
switch (config) # pool ePool0 direction egress size 5242880 type dynamic
switch (config) # pool iPool0 direction ingress size 5242880 type dynamic
switch (config) # pool iPool1 direction ingress size 5242880 type dynamic
```

3. Bind interfaces to switch-priority.

   Binding switch priorities 3 and 6 to ingress PG group 3 and 6.

```
switch (config) # interface ethernet 1/1-1/32 ingress-buffer iPort.pg6
bind switch-priority 6
switch (config) # interface ethernet 1/1-1/32 ingress-buffer iPort.pg3
bind switch-priority 3
```

4. Mapping ingress/egress interface to pool configuration.

   Allocating buffer to priority 3 and mapping it to a lossless pool and allocating buffer to priority 6 and mapping it to a lossy pool:

```
switch (config) # interface ethernet 1/1-1/32 ingress-buffer iPort.pg3
map pool iPool1 type lossless reserved 67538 xoff 18432 xon 18432 shared
alpha 2
switch (config) # interface ethernet 1/1-1/32 ingress-buffer iPort.pg6
map pool iPool0 type lossy reserved 10240 shared alpha 8
switch (config) # interface ethernet 1/1-1/32 egress-buffer ePort.tc3 map
pool ePool1 reserved 1500 shared alpha inf
```

NOTE: The reserved buffer size may be changed according to the port speed and MTU size.

5. Setting strict priority to CNPs over traffic class 6.

```
switch (config) # interface ethernet 1/1-1/32 traffic-class 6 dcb ets
strict
```

6. Set trust mode L3 (DSCP)

```
switch (config) # interface ethernet 1/1-1/32 qos trust L3
```

7. Enable PFC on priority 3 on all ports:

```
switch (config) # dcb priority-flow-control enable force
switch (config) # dcb priority-flow-control priority 3 enable
switch (config) # interface ethernet 1/1-1/32 dcb priority-flow-control
                  mode on force
```

4.2 Server Configuration

The servers should be configured with the following:

- PFC is enabled on DSCP 26
- Windows Storage Spaces Direct RDMA traffic is mapped to egress with priority 3
- ECN is enabled with priority 3
- PFC enabled with priority 3
- CNP traffic will be sent with DSCP 48.
- Trust L3 is used (priority to DSCP mapping)

1. Install Data Center Bridging Windows Feature.

```
PS C:> Install-WindowsFeature data-center-bridging

Success Restart Needed Exit Code      Feature Result
------- -------------- ---------      --------------
True    No             Success        {Data Center Bridging}
```

2. Import the PowerShell modules that are required to configure DCB.

```
PS C:\> import-module netqos
PS C:\> import-module dcbqos
PS C:\> import-module netadapter
```

3. Enable QoS on the network adapter

```
PS C:\>  Set-NetAdapterQos -Enabled 1 *
```

4. Enable Priority Flow Control (PFC) on the specific priority 3.

```
PS C:\> Enable-NetQosFlowControl -Priority 3
```

5. Locate the registry key for the Mellanox adapter, see [HowTo Locate the Windows Registry key for Mellanox Adapters].

   In this example, the registry key is:

```
{4d36e972-e325-11ce-bfc1-08002be10318}\0003
```

   You will need that for the next configuration commands.

6. Map DSCP to priority for the RDMA traffic. In this example, we are using DSCP 26 to map into a priority 3 (PriorityToDscpMappingTable_3).

```
PS C:\>  new-itemProperty -Path
HKLM:\SYSTEM\CurrentControlSet\Control\Class\"{4d36e972-e325-11ce-bfc1-
08002be10318}"\0003\ -Name "PriorityToDscpMappingTable_3" -PropertyType
"String" -Value "26" -Force
PriorityToDscpMappingTable_3 : 26
PSPath                       :
Microsoft.PowerShell.Core\Registry::HKEY_LOCAL_MACHINE\SYSTEM\CurrentCont
rolSet\Control\Class\{4d36e972-e325-11ce-bfc1-08002be10318}\0003\
PSParentPath                 :
Microsoft.PowerShell.Core\Registry::HKEY_LOCAL_MACHINE\SYSTEM\CurrentCont
rolSet\Control\Class\{4d36e972-e325-11ce-bfc1-08002be10318}
PSChildName                  : 0003
PSDrive                      : HKLM
PSProvider                   : Microsoft.PowerShell.Core\Registry
```

7. Create a Quality of Service (QoS) policy, and tag each type of traffic with the relevant priority.

   In this example we used SMB port 445 with a CoS Value 3.

```
PS c:\> New-NetQosPolicy "SMBDirect" -NetDirectPortMatchCondition 445 -
PriorityValue8021Action 3
Name           : SMBDirect
Owner          : Group Policy (Machine)
NetworkProfile : All
Precedence     : 127
JobObject      :
NetDirectPort  : 445
PriorityValue  : 3
```

   For testing, you can add another port (e.g. 50000) that will be used later by performance tests (e.g. nd_write_bw).

```
PS c:\> New-NetQosPolicy "SMBDirect" -NetDirectPortMatchCondition 50000 -
PriorityValue8021Action 3
Name           : SMBDirect_testRDMA
Owner          : Group Policy (Machine)
NetworkProfile : All
Precedence     : 127
JobObject      :
NetDirectPort  : 50000
PriorityValue  : 3
```

8. Enable ECN on priority 3, and set the DSCP value of the CNP traffic to 48.

```
PS c:\> Mlx5Cmd.exe -Qosconfig -Name RDMA1 -Dcqcn -Enable 3
The command was executed successfully
PS c:\> Mlx5Cmd.exe -Qosconfig -Name RDMA1 -Dcqcn -set -DcqcnCnpDscp 48
The command was executed successfully
PS c:\> Mlx5Cmd.exe -Qosconfig -Name RDMA2 -Dcqcn -Enable 3
The command was executed successfully
PS c:\> Mlx5Cmd.exe -Qosconfig -Name RDMA2 -Dcqcn -set -DcqcnCnpDscp 48
The command was executed successfully
```

9. In Device Manager, disable and re-enable RDMA1 and RDMA2 to make the settings active on the NICs.

4.3 Other Related Commands

The following commands are not needed in this procedure as there are VLANs, but in case of RDMA over untagged traffic, it should be used.

1. Do not add an 802.1Q tag to transmitted packets that are assigned an 802.1p priority. Note that they are not assigned a non-zero VLAN ID (for example priority-tagged). The default is 0x0 for DSCP-based PFC set to 0x1.

```
PS C:\>  new-itemProperty -Path
HKLM:\SYSTEM\CurrentControlSet\Control\Class\"{4d36e972-e325-11ce-bfc1-
08002be10318}"\0003\ -Name "TxUntagPriorityTag" -PropertyType "String" -
Value "1" -Force
```

2. Map all untagged traffic to the lossless receive queue. The default is 0x0 for DSCP-based PFC set to 0x1.

```
PS C:\> new-itemProperty -Path
HKLM:\SYSTEM\CurrentControlSet\Control\Class\"{4d36e972-e325-11ce-bfc1-
08002be10318}"\0003\ -Name "RxUntaggedMapToLossless" -PropertyType
"String" -Value "1" -Force
```

4.4 Script

This script assumes a dual-port adapter (RDMA1 and RDMA2):

```
Install-WindowsFeature data-center-bridging
import-module netqos
import-module dcbqos
import-module netadapter
Set-NetAdapterQos -Enabled 1 *
Enable-NetQosFlowControl -Priority 3
new-itemProperty -Path
HKLM:\SYSTEM\CurrentControlSet\Control\Class\"{4d36e972-e325-11ce-bfc1-
08002be10318}"\0003\ -Name "PriorityToDscpMappingTable_3" -PropertyType
"String" -Value "26" -Force
new-itemProperty -Path
HKLM:\SYSTEM\CurrentControlSet\Control\Class\"{4d36e972-e325-11ce-bfc1-
08002be10318}"\0002\ -Name "PriorityToDscpMappingTable_3" -PropertyType
"String" -Value "26" -Force
New-NetQosPolicy "SMBDirect" -NetDirectPortMatchCondition 445 -
PriorityValue8021Action 3
New-NetQosPolicy "SMBDirect_testRDMA" -NetDirectPortMatchCondition 50000 -
PriorityValue8021Action 3
Mlx5Cmd.exe -Qosconfig -Name RDMA1 -Dcqcn -Enable 3 -set -DcqcnCnpDscp 48
Mlx5Cmd.exe -Qosconfig -Name RDMA2 -Dcqcn -Enable 3 -set -DcqcnCnpDscp 48
```

4.5 Verifying RDMA QoS Configuration

1. Verify that PFC is enabled on priority 3 and that NetDirect on the required port and priority (e.g. ports 445, 50000 are mapped to priority 3).

   - Get-NetAdapterQoS

```
PS C:\> Get-NetAdapterQos

Name                        : RDMA1
Enabled                     : True
Capabilities                :                        Hardware     Current
                                                     --------     -------
                              MacSecBypass         : NotSupported
NotSupported
                              DcbxSupport          : IEEE         IEEE
                              NumTCs(Max/ETS/PFC)  : 8/8/8        8/8/8

OperationalTrafficClasses   : TC TSA    Bandwidth Priorities
                              -- ---    --------- ----------
                               0 ETS    100%      0-7
```

```
OperationalFlowControl      : Priority 3 Enabled
OperationalClassifications : Protocol  Port/Type Priority
                             --------  --------- --------
                             Default             0
                             NetDirect 50000     3
                             NetDirect 445       3

Name                        : RDMA2
Enabled                     : True
Capabilities                :                       Hardware     Current
                                                    --------     -------
                             MacSecBypass        : NotSupported
NotSupported
                             DcbxSupport         : IEEE         IEEE
                             NumTCs(Max/ETS/PFC) : 8/8/8        8/8/8

OperationalTrafficClasses   : TC TSA    Bandwidth Priorities
                              -- ---    --------- ----------
                               0 ETS    100%      0-7

OperationalFlowControl      : Priority 3 Enabled
OperationalClassifications : Protocol  Port/Type Priority
                             --------  --------- --------
                             Default             0
                             NetDirect 50000     3
                             NetDirect 445       3
```

2. Verify that PFC is enabled on priority 3.

   - Get-Net-QosFlowControl

```
PS C:\> Get-NetQosFlowControl

Priority   Enabled    PolicySet        IfIndex IfAlias
--------   -------    ---------        ------- -------
0          False      Global
1          False      Global
2          False      Global
3          True       Global
4          False      Global
5          False      Global
6          False      Global
7          False      Global
```

3. Verify that NetDirect on the required port and priority. For example, ports 445, 50000 are mapped to priority 3.

   - Get-NetQoSPolicy

```
PS C:\Users\Administrator> Get-NetQosPolicy

Name            : S2D Policy1
Owner           : Group Policy (Machine)
NetworkProfile  : All
Precedence      : 127
JobObject       :
NetDirectPort   : 50000
PriorityValue   : 3

Name            : SMB
Owner           : Group Policy (Machine)
NetworkProfile  : All
Precedence      : 127
JobObject       :
```

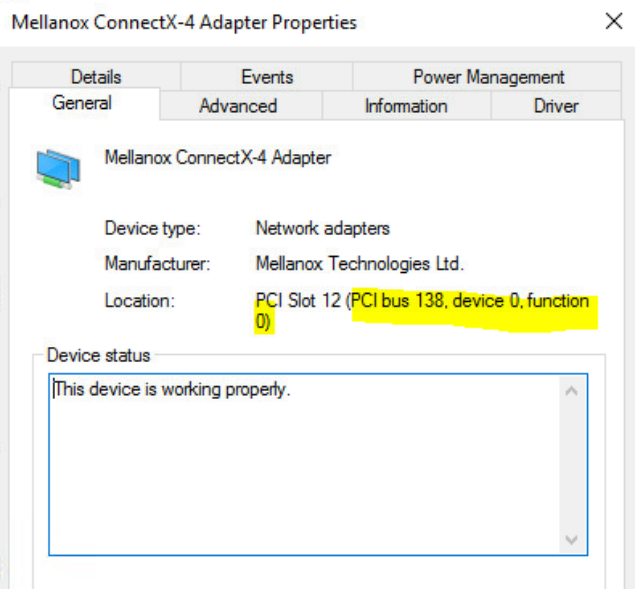
```
NetDirectPort   : 445
PriorityValue   : 3
```

4. Check DCQCN/ECN Configuration via Mlx5Cmd.exe command.
   - Check the DCQCN is enabled on priority 3 for RP and NP
   - Verify that the DSCP CNP is mapped to DSCP 48

```
PS C:\Users\Administrator> Mlx5Cmd.exe -Qosconfig -Name RDMA1 -Dcqcn -get
DCQCN RP attributes for adapter "RDMA1":
        DcqcnRPEnablePrio0: 1
        DcqcnRPEnablePrio1: 1
        DcqcnRPEnablePrio2: 1
        DcqcnRPEnablePrio3: 1
        DcqcnRPEnablePrio4: 1
        DcqcnRPEnablePrio5: 1
        DcqcnRPEnablePrio6: 1
        DcqcnRPEnablePrio7: 1
        DcqcnClampTgtRate: 0
        DcqcnClampTgtRateAfterTimeInc: 1
        DcqcnRpgTimeReset: 300
        DcqcnRpgByteReset: 32767
        DcqcnRpgThreshold: 5
        DcqcnRpgAiRate: 5
        DcqcnRpgHaiRate: 50
        DcqcnAlphaToRateShift: 11
        DcqcnRpgMinDecFac: 50
        DcqcnRpgMinRate: 1
        DcqcnRateToSetOnFirstCnp: 0
        DcqcnDceTcpG: 4
        DcqcnDceTcpRtt: 1
        DcqcnRateReduceMonitorPeriod: 4
        DcqcnInitialAlphaValue: 1023

DCQCN NP attributes for adapter "RDMA1":
        DcqcnNPEnablePrio0: 1
        DcqcnNPEnablePrio1: 1
        DcqcnNPEnablePrio2: 1
        DcqcnNPEnablePrio3: 1
        DcqcnNPEnablePrio4: 1
        DcqcnNPEnablePrio5: 1
        DcqcnNPEnablePrio6: 1
        DcqcnNPEnablePrio7: 1
        DcqcnCnpDscp: 48
        DcqcnCnpPrioMode: 1
        DcqcnCnp802pPrio: 7
The command was executed successfully
```

5. Check the Priority to DSCP mapping.
   - Get the PCI location, for example 138.0.0



6. Get the regKeys configured.
   - Verify that DSCP is mapped to 26

```
PS C:\Users\Administrator> Mlx5Cmd.exe -RegKeys -bdf 138.0.0
NIC 1:
    Adapter: Mellanox ConnectX-4 Adapter
    Location (PCI bus, device, function): (138,0,0)
        Registry Key                                    Value
Default

        *IPChecksumOffloadIPv4                          3               3
        *TCPUDPChecksumOffloadIPv4                      3               3
        *TCPUDPChecksumOffloadIPv6                      3               3
        *EncapsulatedPacketTaskOffload                  1               1
        *EncapsulatedPacketTaskOffloadNvgre             1               1
        *EncapsulatedPacketTaskOffloadVxlan             1               1
        *VxlanUDPPortNumber                             4789            4789
        *LsoV2IPv4                                      1               1
        *LsoV2IPv6                                      1               1
        *TransmitBuffers                                2048            2048
        TxIntModerationProfile                          1               1
        *RSS                                            1               1
        *ReceiveBuffers                                 512             512
        *NumRssQueues                                   8               128
        RecvCompletionMethod                            1               1
        *RscIPv4                                        1               1
        *RscIPv6                                        1               1
        RxIntModerationProfile                          1               1
        RxIntModeration                                 2               2
        *VMQ                                            1               1
        *VMQVlanFiltering                               1               1
        *Sriov                                          1               0
        *RssOnHostVPorts                                0               0
        *QOS                                            1               0
        *FlowControl                                    3               3
        DcbxMode                                        2               2
        PriorityToDscpMappingTable_3                    26              3
        *PriorityVLANTag                                3               3
```

```
        VlanId                                          8               0
        *JumboPacket                                    1514            1514
        *EncapOverhead                                  0               0
        PortType                                        1               None
        *InterruptModeration                            1               1
        *PacketDirect                                   1               0
        *NetworkDirect                                  1               1
```

4.6 Benchmark Testing (Basic)

1. Run RDMA traffic between two ports.

   For example:

   Server:

   ```
   PS C:\> nd_write_bw -D 10 -S 192.168.101.12 -p 50000
   ```

   Client

   ```
   PS C:\> nd_write_bw -D 10 -C 192.168.101.12 -p 50000
   ```

2. Open **Performance Monitoring tool** (perfmon) and add the following counter sets.
   - Mellanox WinOF-2 Congestion Control
   - Mellanox WinOF-2 Port QoS
   - RDMA Activity
3. Check performance.

4.7 Congestion Control Verification

1. Create a synthetic congestion in the network (for example, lower the speed of one port to 10G), open Performance Monitoring (perfmon) tool, and run the benchmark testing.
2. Check the Congestion Control counters are progressing on the Notification Point (NP)—receiver—and the Reaction Point (RP)—sender.

RP example:

Mellanox WinOF-2 Congestion Control	_Total
Notification Point - CNPs Sent Successfully	0.000
Notification Point - RoCEv2 ECN Marked Packets	0.000
Reaction Point - Current Number of Flows	0.000
Reaction Point - Ignored CNP Packets	0.000
Reaction Point - Successfully Handled CNP Packets	833,172.000

NP example:

Mellanox WinOF-2 Congestion Control	_Total
Notification Point - CNPs Sent Successfully	833,172.000
Notification Point - RoCEv2 ECN Marked Packets	833,172.000
Reaction Point - Current Number of Flows	0.000
Reaction Point - Ignored CNP Packets	0.000
Reaction Point - Successfully Handled CNP Packets	0.000

If you see these counters, it means that DCQCN is working fine in the network (the switch upon congestion marks the IP ToS ECN bits.

NOTE: PFC counters (pause counters) are not expected to advance.

4.8 PFC Verification

1. Disable ECN on one of the switch ports.

```
switch (config) # no interface ethernet 1/1 traffic-class 3 congestion-
                  control
```

2. Run the benchmark test, and verify that the PFC counters are progressing. The Congestion Control counters should not be progressing.

Mellanox WinOF-2 Port QoS	_Total
Bytes Received	597,635,394,054.0000
Bytes Sent	977,339,740.000
Bytes Total	598,533,981,062.0000
KBytes Received/Sec	4,786,034.392
KBytes Sent/Sec	7,313.125
KBytes Total/Sec	4,792,916.795
Packets Received	548,199,254.000
Packets Received/Sec	4,495,663.005
Packets Sent	13,817,973.000
Packets Sent/Sec	106,944.928
Packets Total	561,944,442.000
Packets Total/Sec	4,601,759.696
Rcv Pause Duration	0.000
Rcv Pause Frames	0.000
Sent Pause Duration	8,292.000
Sent Pause Frames	2,754.000

3. Enable ECN back on the switch.

```
switch (config) # interface ethernet 1/1 traffic-class 3 congestion-
                  control ecn minimum-absolute 150 maximum-absolute 1500
```

4.9 Packet Format Validation

1. Capture RDMA traffic on one of the servers, use Mlx5Cmd.exe for that. For example:

```
PS C:\> Mlx5Cmd.exe -Sniffer -name RDMA1 -start -filename
testing_rdma.pcap
```

   See also HowTo Capture RDMA traffic on mlx5 driver using mlx5cmd (Windows).

2. Run benchmark test.
3. Open the file in Wireshark.

4. Verify that the RDMA traffic is sent with DSCP 26 (as configured).
   - DSCP 26
   - ECN is not 00

```
ip.dsfield.dscp == 26

No.   Time        Source          Destination     Protoc Leng Info
3916  20.897735   192.168.101.11  192.168.101.12  UDP    1082 49214 → 4791 Len=1040
3917  20.897736   192.168.101.11  192.168.101.12  UDP    1082 49214 → 4791 Len=1040
3918  20.897737   192.168.101.11  192.168.101.12  UDP    1082 49214 → 4791 Len=1040
3919  20.897737   192.168.101.11  192.168.101.12  UDP    1082 49214 → 4791 Len=1040
3920  20.897737   192.168.101.11  192.168.101.12  UDP    1082 49214 → 4791 Len=1040
3921  20.897743   192.168.101.12  192.168.101.11  UDP      62 49214 → 4791 Len=20
3922  20.897743   192.168.101.11  192.168.101.12  UDP    1082 49214 → 4791 Len=1040
3923  20.897743   192.168.101.11  192.168.101.12  UDP    1082 49214 → 4791 Len=1040
3924  20.897743   192.168.101.11  192.168.101.12  UDP    1082 49214 → 4791 Len=1040
3926  20.897744   192.168.101.12  192.168.101.11  UDP      62 49214 → 4791 Len=20

> Frame 3922: 1082 bytes on wire (8656 bits), 1082 bytes captured (8656 bits)
v Ethernet II, Src: Mellanox_23:74:fe (7c:fe:90:23:74:fe), Dst: Mellanox_23:74:6a (7c:fe:90:23:74:6a)
  > Destination: Mellanox_23:74:6a (7c:fe:90:23:74:6a)
  > Source: Mellanox_23:74:fe (7c:fe:90:23:74:fe)
    Type: IPv4 (0x0800)
v Internet Protocol Version 4, Src: 192.168.101.11, Dst: 192.168.101.12
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  v Differentiated Services Field: 0x69 (DSCP: AF31, ECN: ECT(1))
      0110 10.. = Differentiated Services Codepoint: Assured Forwarding 31 (26)
      .... ..01 = Explicit Congestion Notification: ECN-Capable Transport codepoint '01' (1)
    Total Length: 1068
    Identification: 0x15a8 (5544)
  > Flags: 0x02 (Don't Fragment)
    Fragment offset: 0
    Time to live: 128
    Protocol: UDP (17)
    Header checksum: 0x9547 [validation disabled]
    [Header checksum status: Unverified]
    Source: 192.168.101.11
    Destination: 192.168.101.12
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
> User Datagram Protocol, Src Port: 49214, Dst Port: 4791
v Data (1040 bytes)
    Data: 0740ffff0000011c00312c030000000000000000000000000...
    [Length: 1040]
```

5. Verify that the CNP traffic is send with DSCP 48 (as configured)
   - DSCP 48
   - RDMA OpCode is 0x81

```
ip.dsfield.dscp == 48

No.   Time        Source          Destination     Protoc Leng Info
2512  20.896349   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
2516  20.896366   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
3799  20.897667   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
3892  20.897723   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
3895  20.897724   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
3908  20.897732   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
3911  20.897733   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
3925  20.897744   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
3927  20.897748   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32
3928  20.897749   192.168.101.12  192.168.101.11  UDP      74 0 → 4791 Len=32

> Frame 3928: 74 bytes on wire (592 bits), 74 bytes captured (592 bits)
v Ethernet II, Src: Mellanox_23:74:6a (7c:fe:90:23:74:6a), Dst: Mellanox_23:74:fe (7c:fe:90:23:74:fe)
  > Destination: Mellanox_23:74:fe (7c:fe:90:23:74:fe)
  > Source: Mellanox_23:74:6a (7c:fe:90:23:74:6a)
    Type: IPv4 (0x0800)
v Internet Protocol Version 4, Src: 192.168.101.12, Dst: 192.168.101.11
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  v Differentiated Services Field: 0xc1 (DSCP: CS6, ECN: ECT(1))
      1100 00.. = Differentiated Services Codepoint: Class Selector 6 (48)
      .... ..01 = Explicit Congestion Notification: ECN-Capable Transport codepoint '01' (1)
    Total Length: 60
    Identification: 0xe733 (59187)
  > Flags: 0x02 (Don't Fragment)
    Fragment offset: 0
    Time to live: 128
    Protocol: UDP (17)
    Header checksum: 0xc753 [validation disabled]
    [Header checksum status: Unverified]
    Source: 192.168.101.12
    Destination: 192.168.101.11
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
> User Datagram Protocol, Src Port: 0, Dst Port: 4791
v Data (32 bytes)
    Data: 8100ffff40000122000000000000000000000000000000...
    [Length: 32]
```

Read more on CNP packet format in [RoCEv2 CNP Packet Format Example](#).

5 DataON & Windows Server 2016 Storage Spaces Direct Configuration, Deployment and Testing

In this sample deployment, we use a DataON TracSystem S2D-5224L Hyper-Converged Infrastructure. The S2D-5224L is built to optimize the full stack of Microsoft Server 2016 Storage Spaces Direct in a hyper-converged platform. It is designed with integrated compute, network and storage infrastructure with near-linear scalability to simplify and maximize the deployment of Microsoft applications, virtualization, data protection and hybrid cloud services.

The TracSystem S2D-5224L utilizes Mellanox 40/100GbE switches that support low-latency RDMA networking for a loss-less network with no packet loss.

- **Hyper-V virtualization** – supports more than 40 Hyper-V virtual machines per node
- **Storage and networking with SMB3 over RDMA** – increases CPU efficiency while delivering the highest throughput and lowest latency.
- **Hyper-converged scalability** – delivers incremental compute, networking and storage resources while providing near-linear scalability. The HCI cluster can also be expanded via 12GB/s SAS JBODs.
- **Managed by MUST** – DataON's exclusive MUST software provides visibility, monitoring and management for Windows Server 2016 environments.

5.1 DataON S2D Solution

The following is DataON TracSystem S2D-5224L HCI for Windows Server Storage Spaces Direct configuration with 4 nodes and Mellanox network fabric optimized for IOPS & performance for Windows Server 2016 Storage Spaces Direct.

Form Factor	2U 24-bay 2.5"
Appliance Node	2U Server cluster - 4 Nodes
Windows Server 2016 Hyper-Converged Infrastructure	Intel® Xeon® Scalable Processor with Intel C620 Chipsets 24x Intel SSD Data Center Family with NVMe Intel Optane SSDs
Hyper-V Deployment	100-300 VMs (scale to 224 physical cores and 24 DIMMs per CPU)
Storage Pool Allocated Capacity	20-150TB (3-way mirror [33%] or RS 2+2 [47% efficiency] MRV erasure coding).
Performance	3M IOPS (100% read); 1.5M IOPS (70/30 read-write)
Networking Fabric	SMB3 over RDMA; 40/100G RDMA NIC
Memory Slot	24x DDR4 DRIMMs per node
Expansion Slot	7x PCIe 3.0 x8 per node
Management	DataON MUST visibility, monitoring and management tool

DataON S2D Test Configuration and Result – (4) x DataON 5224 Node Cluster with Mellanox Network Fabric

Hardware Details per Node	
CPU	Intel Gold 6148 2.4GHz x 2
Memory	384 GB
Cache	INTEL Optane P4800X 375GB NVMe SSD x 2
Data	INTEL DC P4500 4TB NVMe SSD x 16

Figure 1 - NVME and SSD (3-way Mirror) Configuration

Volume	Filesystem	Capacity	Used	Resiliency	Size (Mirror)	Size (Parity)	Footprint	Efficiency
arizona-n1	ReFS	18TB	3%	3-Way Mirror	18TB	0	54TB	33%
arizona-n2	ReFS	18TB	3%	3-Way Mirror	18TB	0	54TB	33%
arizona-n3	ReFS	18TB	3%	3-Way Mirror	18TB	0	54TB	33%
arizona-n4	ReFS	18TB	3%	3-Way Mirror	18TB	0	54TB	33%
collect	ReFS	56GB	38%	3-Way Mirror	56GB	0	169GB	33%

36 Virtual Machines created on each (144 Virtual Machines in total).

VMFleet results:

```
Block size 4Kb, 8 Threads, 8 Outstanding I/O, (100% Read / 0% write), Random
```

CSV FS	IOPS	Reads	Writes	BW (MB/s)	Read	Write	Read Lat (ms)	Write Lat
Total	3,052,082	3,051,873	209	12,507	12,502	4		
arizona-n1	748,843	748,803	39	3,068	3,068		0.316	1.652
arizona-n2	774,780	774,735	45	3,176	3,174	2	0.237	1.260
arizona-n3	752,625	752,534	91	3,083	3,083	1	0.571	3.285
arizona-n4	775,834	775,801	33	3,179	3,178		0.544	2.593

SYS	CPU (%)
Total	317
arizona-n1	78
arizona-n2	83
arizona-n3	79
arizona-n4	77

5.2 Hardware Configuration and Deployment Tips

Here are some basic configuration and deployment tips to help you get started.

Hardware – Windows Server 2016 Server and Storage Certifications	• Make sure your system is certified for Microsoft Server, Microsoft Software-Defined Data Center, and Window Server Software-Defined, for the most optimized infrastructure, operational visibility and reliability for their Windows Server 2016 based software-defined data center. • Check that all the S2D hardware components are certified for Microsoft Windows Server 2016. • Intel Processor selection – Keep in mind the CPU clock speed or frequency and cache has a direct impact on the performance of workloads like SQL and VDI. • Make sure you have enough memory for each node/system because it will impact application memory allocation to application workloads such as SQL. • For the Windows Server Storage Spaces Direct storage bus cache tier selection, select high endurance and make sure you have enough storage capacity (see Intel Data Center SSDs). • For the Windows Server Storage Spaces Direct storage bus performance tier selection, you should mirror to match at least your

	most demanding workload. You should also make sure you have enough storage capacity (see Intel data center SSDs). • For the Windows Server Storage Spaces Direct storage bus capacity tier selection, you can select mirror or RS 2+2 with multi-resilient volume or erasure coding to meeting your storage capacity needs (see HGST HDDs). • Deploy SMB3 over RDMA networking with DCB enabled switches.
SMB3 over RDMA Networking Fabric	• With S2D storage, use SMB3 multi-channel RDMA networking for consistent performance and low latency. • Make sure your DCB switch supports RDMA, as well as supports priority flow control (PFC). • Make sure you setup your DCB switch with the right parameters. Determine if either lowest latency or highest bandwidth is your priority, which will affect some settings such as jumbo frame size. • In choosing a 1-port RDMA NIC versus a 2-port RDMA NIC, consider your bandwidth saturation and need for dedicated data paths for PCIe 3.0 lanes • For best performance, use a 40G or 100G end-to-end network • Using a 40GbE to 10GbE splitter is not advised. • Need to develop customized S2D network deployment charts with subnet, gateways, and VLAN ID for your SMB fabric, host, cluster, live migration and others (refer to the DataON S2D deployment checklist).
DataON S2D Storage Setup	• Make sure the VHDX files for the VMs are configured with 4096 physical sector size bytes (instead of 512) to ensure good performance and low write latency. • Make sure you understand your workloads' requirements before configuring S2D storage. For example, SQL databases require low latency writes so you should place tempdb and log files on 3-way mirror volumes. Read-heavy loads can be placed on MRV volumes. • Evaluate the endurance of each tier for daily writes. Microsoft's Cosmos Darwin has a great blog to help you understand SSD endurance for Storage Spaces Direct. • Make sure you use the DataON S2D platform checklist to ensure proper system configuration. • Make sure you have our customized deployment guide and S2D installation PowerShell script for your S2D deployment with correct IP for the infrastructure.

With any DataON S2D appliance, we provide a detailed deployment guide, customized PowerShell scripts, and a driver pack to help you get you running with Storage Spaces Direct.

The configuration checklist includes:

- Cabling diagram
- Switch configuration
- DataON S2D application configuration
  - System
  - Networking

- Windows features installation
  - Hyper-V
  - Failover Clustering
  - File Services
  - Data Center Bridging
- Quality of Service setup
- Virtual switches setup
- Virtual networking setup
- Cluster creation & validation
- Storage Spaces Direct configuration
- Performance testing
  - VM Fleet setup
  - Task examples
- DataON MUST visibility and management tool
  - Installation
  - Configuration
- Testing
  - Testing failover
  - Validate volumes failover
  - Using MUST to test resiliency
  - Simulate drive failures
  - Simulate node failures

The driver pack can be found on the C: drive includes the latest drivers for:

- Intel NVMe SSD
- Intel Data Center Tool
- Intel Onboard Chipset
- Intel Onboard 1G
- Mellanox ConnectX-4

The customized PowerShell scripts can also be found on the C: drive.

5.3 Benchmark & Testing Tips

DataON S2D Testing & Validation	• Use Microsoft's Diskspd utility for testing and benchmarking. Use the cluster health PowerShell command line to validate your cluster setup (at the system and virtual disk levels). • Use VM Fleet for performance tuning

<table>
<tr><td></td><td>• DataON MUST is the ideal tool for real-time diagnostics</td></tr>
<tr><td>Measure Latency From the Application Perspective</td><td>
• On the servers using Storage Spaces Direct, open the Resource Monitor (go to Task Manager and click on Resource Monitor).
• Setup steps
  • Open Task Manager
  • Click Resource Monitor at the bottom of the screen
  • Click Disk tab at the top of the screen
  • Expand Disk Activity
  • Click Total (B/sec) to sort from highest to lowest
• Testing
  • See latency in the “Response Time” column for the processes that are the highest total bytes/sec AND “normal” I/O priority.
• Real World Results
  • Before, Youth Villages was seeing 30-150ms consistently for latency on tempdb, normal log files and database.
  • After implementing Storage Spaces Direct, Youth Villages is consistently seeing 1ms latency.
  • Before Youth Villages saw that disk queuing (also through Performance Monitor) would consistently reach 100-400. After implementing Storage Spaces Direct, disk queuing stays below 2 consistently.
</td></tr>
<tr><td>Measure Performance Outside of the Application, from the Server Perspective</td><td>
• Download and extract diskspd (current version is 2.0.17)
• Open an elevated command prompt:
  • run D:\Diskspd-v2.0.17\amd64fre\diskspd -b64k -d15 -h -L -o8 -t8 -r -w100 -c50M T:io.dat
  • Where:
<table>
<tr><td>d:</td><td>Drive installed the application diskspd is installed.</td></tr>
<tr><td>-b64k</td><td>Testing with 64K blocks (use only numbers divisible by 4).</td></tr>
<tr><td>-d15</td><td>Test for 15 seconds.</td></tr>
<tr><td>-h</td><td>Disable software caching and set write-through I/O (to force the storage to use the disks and not just pull from cache).</td></tr>
<tr><td>-L</td><td>Measure latency statistics.</td></tr>
<tr><td>-o8</td><td>Defines 8 outstanding I/O requests per target per thread (if monitoring disk queueing on performance monitoring, you will see the disk queue average around 8x the number of threads.</td></tr>
<tr><td>-t8</td><td>Defines 8 threads per target. In this case, disk queuing will be around 64, if looking at performance monitoring under the Disk tab/Storage/Disk Queue Length column.</td></tr>
<tr><td>-r</td><td>Specifies random I/O.</td></tr>
</table>
</td></tr>
</table>

-w100	Determines how much of the workload is writes. In this case, looking to see 100% of writes, which is admittedly the hardest load to put on the storage.
-c50M	Create a test file that is 50 Mbytes.
t:io.dat	Tells diskspd what drive needs to be tested. This can be a drive letter or a UNC path. If testing the host, use the UNC path pointing to the SOFS share. If testing the VM, use the drive letter that is encapsulated by the VHDX.

5.4 Management by MUST™

All DataON TracSystem solutions are pre-configured with DataON MUST (Management Utility Software Tool) infrastructure visibility, monitoring and management software. Fully integrated with the Windows Storage Health Service API (SM-API), it provides advanced cluster monitoring, performance metrics, system health statistics, and automated system alerts for Windows Server 2016 Storage Spaces Direct.

MUST delivers SAN-like storage monitoring features through a single pane of glass, providing real-time dashboard level metrics for IOPS, latency, throughput on cluster nodes and volumes. With system alerts based on Windows Health Service faults and SAN-like call home services, systems administrators can be automatically notified of hardware failures, configuration issues and resource saturation.

DataON is the first to market with a tool that provides visibility, monitoring and management of your Windows Server 2016 deployments.

5.5 The DataON Difference

DataON is exclusively focused on customers who have made the “Microsoft choice” to deploy a Windows Server-based storage solution. Our team of Microsoft experts know how to design, deploy and support Windows Server storage and will work with you to performance tune your workloads with benchmarks. DataON solutions are:

- Customer-proven with over 600 enterprise deployments and greater than 100PB of DataON Storage Spaces Direct storage deployments.
- Optimized by our team of Microsoft experts to ensure successful deployments into your IT environment, tuned to your workloads.
- Certified for Windows Server 2012, 2012R2 and 2016.
- Certified for Windows Server 2016 Server Software-Defined Data Center (SDDC) Premium and Standard editions.
- Certified for the Windows Server Software-Defined (WSSD) Program.

DataON has a proud history of supporting Windows Server environments, including:

- The FIRST certified enterprise JBODs for Windows Server 2012 R2.
- The FIRST Cluster-in-a-Box (CiB) appliances for small business and enterprise deployments with Hyper-V support

5.6 About DataON

DataON is the industry-leading provider of hyper-converged cluster appliances (HCCA) and storage systems optimized for Microsoft Windows Server environments. Our solutions are built with the single purpose of rapidly and seamlessly deploying Microsoft applications, virtualization, data protection and hybrid cloud services. Our company is exclusively focused on customers who have made the "Microsoft choice" and we provide the ultimate platform for the Microsoft software-defined data center (SDDC). DataON is a division of Area Electronics. For more information, go to www.dataonstorage.com or call +1 (714) 441-8820.