OPEN COMPOSABLE COMPATIBILITY LAB

Solution Brief

StarWind NVMe-oF™ Initiator Reference Architecture with OpenFlex® Data24 4200

StarWind by DataCore

Abstract

This reference architecture describes StarWind NVMe-oF Initiator (RDMA and TCP) based configuration on Western Digital's OpenFlex Data24 4200 Platform while also defining the deployment, installation, configuration, tuning guidelines, and performance details for the overall solution.

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Introduction

When it comes to underlying storage performance, NVMe is the true king of the hill. However, extending PCIe/NVMe SSD performance efficiently over the network has traditionally been challenging. Legacy SCSI-based storage protocols were designed for spinning disks and introduce protocol translation, limited parallelism, and unnecessary CPU overhead, which prevents flash devices from reaching their full potential. StarWind's implementation of NVMe over Fabrics (NVMe-oF) allows solving the issues of traditional protocol overlay, lack of parallelism support, and ineffective CPU usage. A typical storage system consists of a variety of considerations, including file system choices, file system tuning, disk drives, storage controllers, IO cards, network cards, and switch strategies. Configuring these components for the best performance, manageability, and future scalability requires a great deal of planning and organization.

As organizations modernize their infrastructure to support latency sensitive and data intensive workloads, NVMe-oF over RDMA and TCP has emerged as a compelling alternative to traditional block storage protocols. By combining StarWind's software defined NVMe-oF Initiator with OpenFlex Data24's composable NVMe storage architecture, this solution enables efficient utilization of NVMe performance while maintaining operational simplicity and broad compatibility. With up to 1474TB[1] of low latency Dual Port SSDs in a 2U 24-bay platform, Western Digital's OpenFlex Data24 4000 series NVMe-oF storage platform extends the high performance of NVMe™ flash to shared storage. OpenFlex Data24 4000 series uses Western Digital's RapidFlex™ A2000 Fabric Bridge devices to provide 12-ports of 100GbE which can connect to RDMA and/or TCP configured host ports.

The reference architecture outlines an end to end design in which the StarWind NVMe-oF Initiator provides seamless host side access to remote NVMe namespaces exported by OpenFlex Data24 over RDAM and TCP. This approach eliminates the need for specialized networking hardware, allowing deployments to leverage existing Ethernet infrastructure while achieving predictable performance, scalability, and resilience. This architecture is not an endorsement of StarWind by Western Digital, and no warranty of the product is either expressed or implied.

Highlights

- High performance and low latency - comparable to direct attached NVMe, enabled through the NVMe-oF protocol.
- Operational simplicity - using RDMA/TCP based transport without reliance on any specific configurations.
- Scalability and flexibility - through composable storage and software defined components.
- Enterprise readiness - supporting POC validation, certification, and future production deployment.

This reference architecture serves as a blueprint for organizations evaluating NVMe-oF over RDMA and TCP as part of a proof of concept or pre production initiative. It documents deployment considerations, integration points, and best practices to ensure a consistent and repeatable implementation.

By leveraging StarWind NVMe-oF Initiator with OpenFlex Data24, enterprises can adopt a future ready storage architecture that balances performance, cost efficiency, and ease of deployment—positioning their infrastructure to meet evolving application and business demands.

This document presents a reference architecture for deploying the StarWind NVMe-oF Initiator with the OpenFlex Data24 platform, delivering a high performance, low latency, and scalable storage solution over standard Ethernet networks.

Problem Statement

Modern data center workloads increasingly demand higher throughput, lower latency, and greater scalability than what traditional block storage protocols and architectures can efficiently deliver. Legacy solutions such as iSCSI and direct attached storage often struggle to keep pace with NVMe drive capabilities, introduce performance bottlenecks, or require complex infrastructure and specialized networking to scale effectively. Additionally, organizations seek architectures that balance performance with operational simplicity, cost efficiency, and flexibility—without locking into proprietary hardware or transport technologies.

The combination of the StarWind NVMe-oF Initiator with OpenFlex Data24 addresses these challenges by enabling high performance, software defined access to composable NVMe storage over standard Ethernet using TCP. OpenFlex Data24 provides disaggregated, scalable NVMe storage alongside integrated compute and networking capabilities, while the StarWind NVMe-oF Initiator delivers seamless host side connectivity and efficient I/O processing. Together, they unlock near native NVMe performance across the network without the complexity of RDMA and TCP based fabrics, allowing organizations to modernize their storage infrastructure with a flexible, scalable, and enterprise ready NVMe-oF solution.

[1] One terabyte (TB) is equal to one trillion bytes and one petabyte (PB) is equal to 1,000 TB. Actual user capacity may be less due to operating environment.

Solution Highlights

The combined solution of OpenFlex Data24 and the StarWind NVMe-oF Initiator delivers a powerful, disaggregated storage architecture that enables Windows® based workloads to fully exploit shared NVMe performance over standard Ethernet. OpenFlex Data24 provides dense, scalable pools of high performance NVMe storage exposed over NVMe over Fabrics, while the StarWind NVMe-oF Initiator bridges the traditional Windows gap by offering native NVMe-oF connectivity with low latency and minimal CPU overhead. Together, they allow enterprises to decouple compute and storage, eliminate the performance limitations of legacy protocols like iSCSI, and achieve near local NVMe throughput for databases, analytics, and data intensive workloads—without relying on Fibre Channel or proprietary hardware.

Technology Overview

OpenFlex Data24 4000 Series Storage Platform

The OpenFlex Data24 4000 series NVMe-oF storage platform extends the high performance of NVMe flash to shared storage. The 4000 series provide low-latency sharing of NVMe SSDs over a high-performance Ethernet fabric to deliver similar performance to locally attached NVMe SSDs. Western Digital RapidFlex NVMe-oF controllers, allows up to six dual pathed hosts to be attached without a switch.

The OpenFlex Data24 4000 series uses three of Western Digital's RapidFlex A2000 Fabric Bridge Adapters per IOM to provide up to 12 ports of 100GbE which can connect to RDMA and/or RDMA configured host ports.

NVMe-oF is a networked storage protocol that allows storage to be disaggregated from compute to make that storage widely available to multiple applications and servers. By enabling applications to share a common pool of storage capacity, data can be easily shared between applications or needed capacity can be allocated to an application to respond to application needs. OpenFlex Data24 4200 series NVMe-oF storage platform can also be used as a disaggregated storage resource in an open composable infrastructure environment using the Open Composable API. OpenFlex Data24 4200 series is built to deliver high availability and enterprise-class reliability. The entire platform, including SSDs, is backed with a 5-year limited warranty.

Specification	Value
Form Factor	2U
Front Drive bays	Up to 24 x U.2 NVMe SSDs
Power Supply	2x 800W Titanium 100-240VAC, CRPS, Hot Plug
Max raw data storage capacity	1474 TB (24 x 15.36TB NVMe SSDs)
Fabric Adapter Slots	12x 100 GbE ports
Fabric Adapter(s)	Western Digital RapidFlex A2000 NVMe-oF Fabric Bridge ASICs
Cabling Passive	Cabling Passive (1 - 5m) and Active Optical (5m - 20m)
HA Redundancy	Dual IOMs, PSUs, and N+2 fans

StarWind NVMe-oF Initiator

StarWind NVMe-oF Initiator is the first software-only solution bringing high-performance NVMe-oF connectivity using TCP and RoCEv2 to Windows applications without needing specialized hardware. Certified for Windows Server, it enables near-native, low-latency storage access for SQL and virtualization workloads. StarWind NVMe-oF Initiator for Windows ensures customers get not only the best performance and lowest latency for their mission-critical applications, but also end-to-end enterprise support from the storage, initiator, and OS vendor.

NVMe-oF Initiator from StarWind also works on Windows 10, Windows 10 Pro, Windows 11, Windows Server 2016, Windows Server 2019 , Windows Server 2022 and Windows Server 2025.

StarWind NVMe-oF Initiator with OpenFlex Data24 4000

This document presents a reference architecture for deploying the StarWind NVMe over Fabrics (NVMe-oF) Initiator with the OpenFlex Data24 platform, delivering a high performance, low latency, and scalable storage solution over RDMA/TCP.

By following this guide, users will be able to successfully create RDMA (RoCEv2/TCP) connections using the StarWind NVMe-oF Initiator. The configuration will consist of Windows Server nodes configured for high performance, connected to StarWind NVMe-oF target using OpenFlex Data24. This setup provides fast, reliable, and scalable shared storage over NVMe over Fabrics.

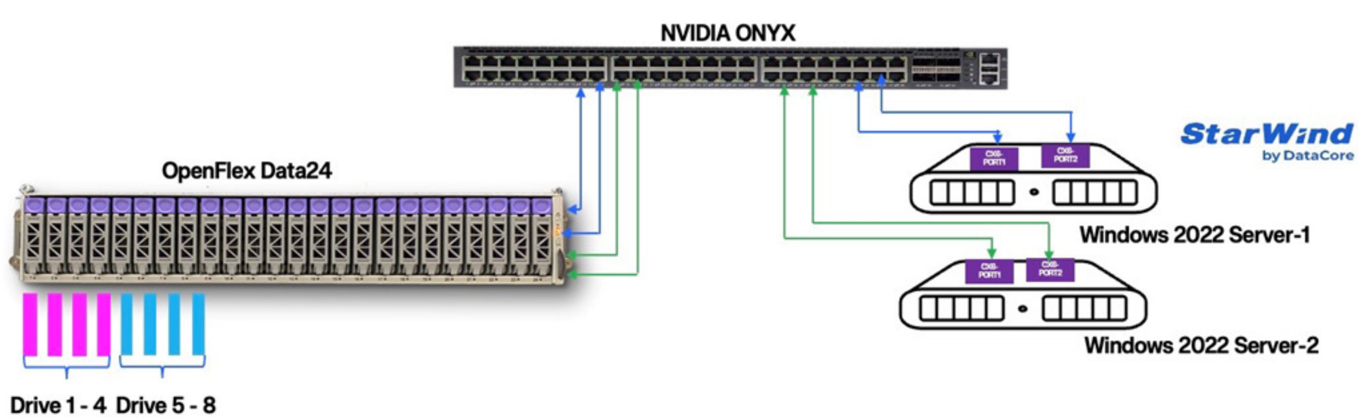
Hardware Requirements

Metrics	Details
Storage Product	OpenFlex Data24 4200
Storage Interface	12 x QSFP28 Interface (12 x 100Gbps per port)
Host OS	Windows Server 2022
Host NIC	CX6
Firmware Version	20.43.2566
Drive Version	3.10.25798.0
CPU	Intel® Xeon® Gold 5318Y CPU @ 2.10GHz or Higher CPU Configuration
CPU Core Details	Dual socket server with 24 core CPU each. 96 logical cores in total with HT enabled
Memory	256 GB
Switch Details	NVIDIA Onyx® 3700
Drive Details	Sandisk ®SN655 (15.36TB), WUS5EA1A1ESP7E3, RC610008
Tool	FIO 3.36

The following is the detailed configuration used for this deployment:

- 1x OpenFlex Data24 4200 JBOF enclosure.
- 8x 15.36 TB Sandisk SN655 NVMe disks. One namespace configured on each of the 8 drives.
- 2x Storage servers, and 2 x CX6-Gen4 cards per server are used to test the RDMA (RoCEV2) performance.
- 4x Storage servers, and 2 x CX6-Gen4 cards per server are used to test TCP performance.
- 1x NVIDIA Onyx MSN3700 – 32-port switch.

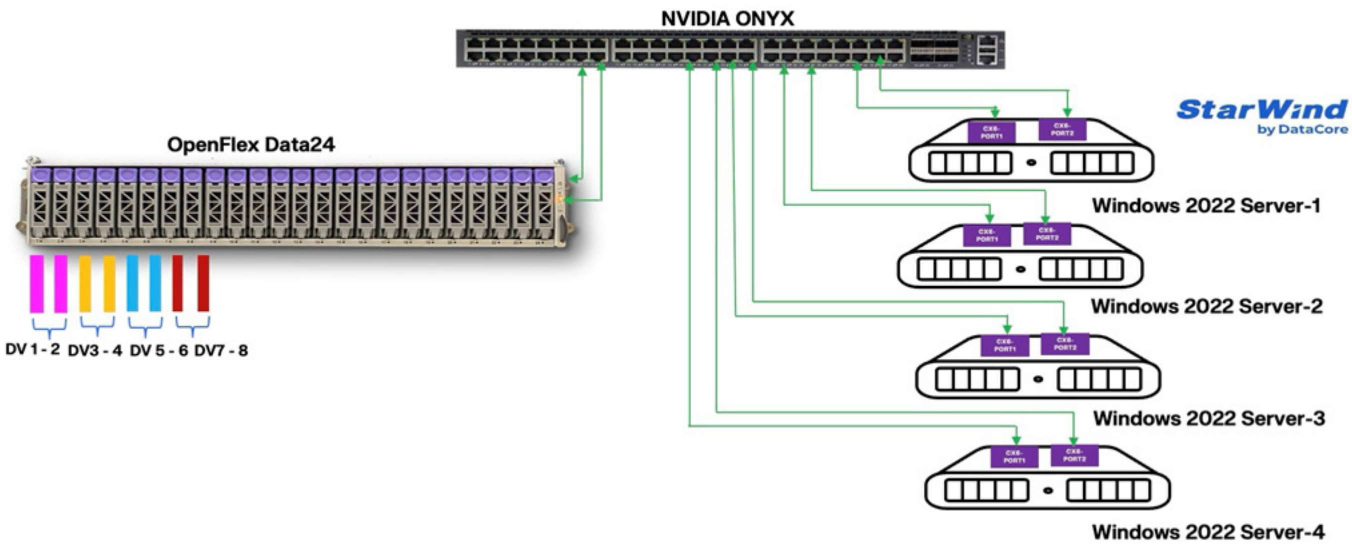
OpenFlex Data24 with StarWind NVMe-oF RDMA Configuration



The following is the detailed configuration used for the RDMA-RoCEv2 setup:

- 8x drives total from OpenFlex are used to test performance in this test.
- 4x RFX ports of OpenFlex Data24 are used in the above Topology.
- Server 1 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 4x drives (1-4) are mapped as part of server1 with RoCEv2 configuration.
- Server 2 is connected to IOMA-Port4 and IOM-B Port4 with Multipath configuration.
- 4x drives (5-8) are mapped as part of server1 with RoCEv2 configuration.

OpenFlex Data24 with StarWind NVMe-oF TCP Configuration



The following is the detailed configuration used for the TCP setup:

- 8x drives total from OpenFlex are used to test performance in this test.
- 2x RFX ports of OpenFlex Data 24 are used in the above Topology.
- Server 1 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 2x drives (1-2) are mapped as part of server1 with TCP configuration.
- Server 2 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 2x drives (3-4) are mapped as part of server1 with RoCEv2 configuration.
- Server 3 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 2x drives (5-6) are mapped as part of server1 with RoCEv2 configuration.
- Server 4 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 2x drives (7-8) are mapped as part of server1 with RoCEv2 configuration.

Pre-requisites on all Servers

BIOS Settings:

These BIOS settings are applicable for Dell R550 servers only. Based on the server the BIOS settings need to be updated.

1. Processor Settings:

- Virtualization technology - Enabled
- MADT Core Enumeration - Round Robin
- Directory Mode - Enabled

2. System Profile Settings:

- System Profile - Performance Per Watt
- Turbo Boost - Enabled
- Energy Efficient Policy - Balanced Performance

Windows System Settings:

1. Configure NTP on all servers and sync the servers.

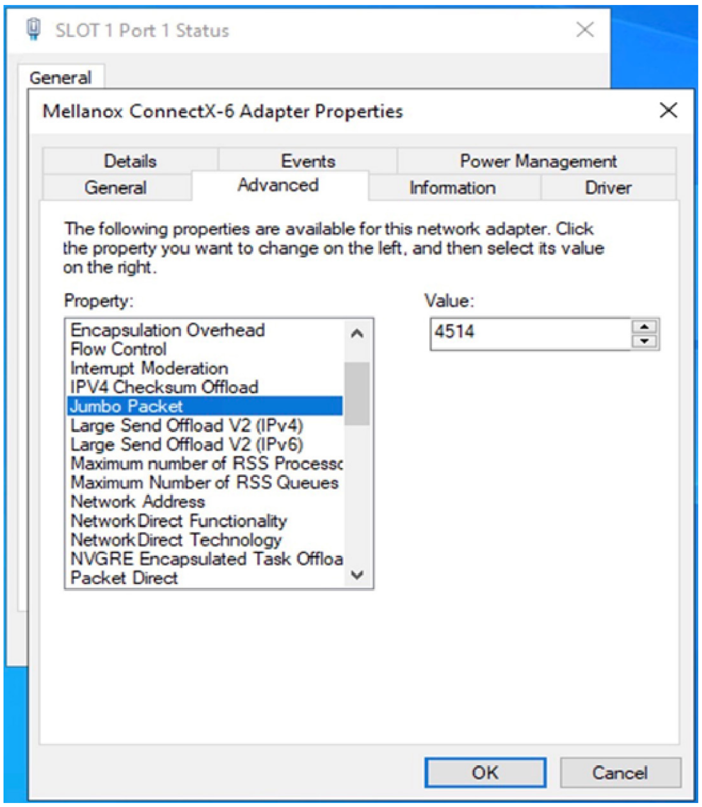
2. Ensure the Windows Server nodes are equipped with Mellanox ConnectX-6 adapters.

3. Windows Server 2022 should have the latest Mellanox drivers installed, which is available here:

   https://www.mellanox.com/products/adapter-software/ethernet/windows/winof-2

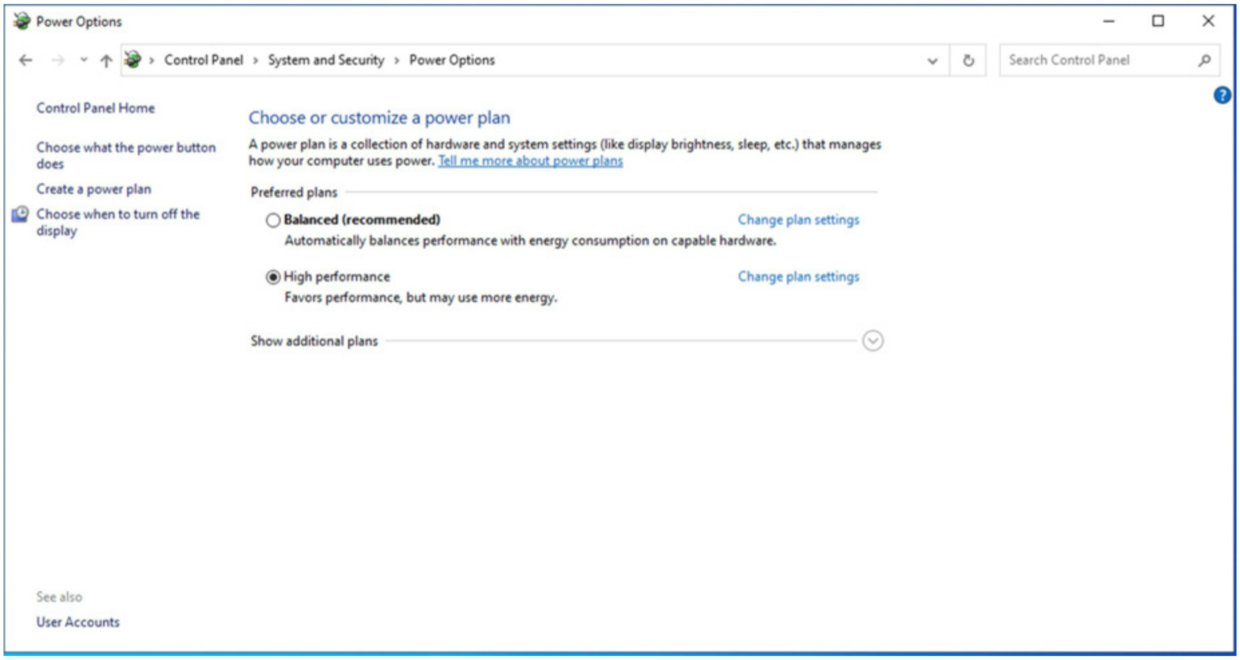
4. Install NVDIA OFED Mellanox® firmware. Check that firmware details installed as per the versions specified in the hardware configuration.

5. Set MTU/Jumbo frames as 4514 for the Mellanox ports in the Windows Server.



6. Verify the MTU/Jumbo frame details for the Mellanox ports using “netsh interface ipv4 show subinterfaces”.

7. Set the Windows server in High Performance Mode using Control Panel. Reboot the server.



Setup OpenFlex System

Refer to Openflex-Data24-NVMe-oF-Storage-Platform for more details. To set up the OpenFlex Data24 4000, use the information detailed in the OpenFlex Data24 4000 User Guide. For more details regarding installation and lossless configuration on OpenFlex Data24 contact, WD Support at: https://businessportal.westerndigital.com/.

1. Set up persistent connection to map the volumes and lossless settings on all the servers. Lossless settings need to be done on the switch, servers and OpenFlex Data24. For details regarding lossless configuration contact WD Support.

2. Connect nvme device using nqn to storage server.

3. Create nvme namespace on the nvme device.

4. Create one namespace each on all the 24 drives. So, in total create 24 namespaces out of 24 drives on OpenFlex Data24.

5. For current tests 8 drives are used from the OpenFlex Data24. Each drive contains one namespace.

6. Set the MTU as 4500 for the OpenFlex RFX ports and on the switch ports.

Note: OpenFlex Data24 can be set as RoCEv2/TCP mode. Only one mode is supported for all ports at a single point in time.

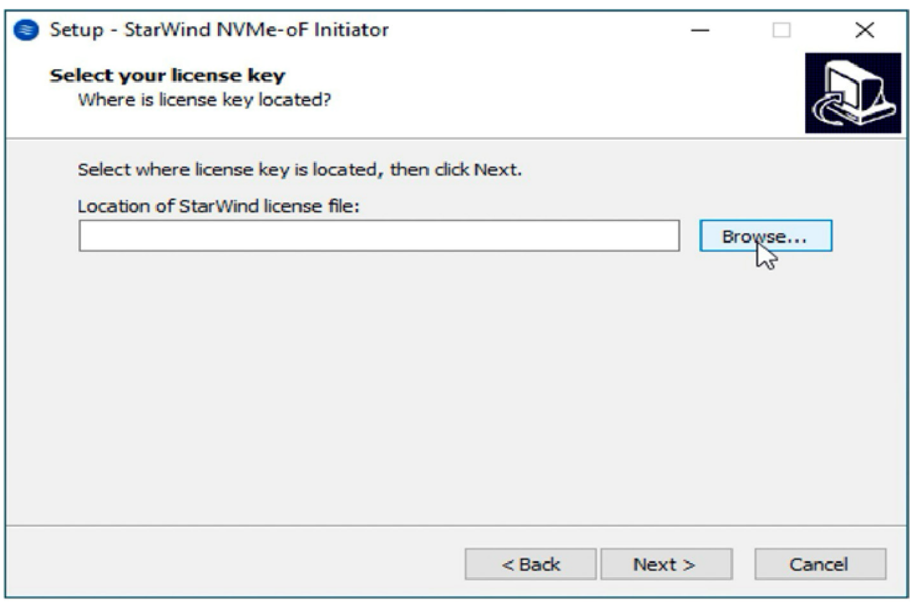
Setup StarWind NVMe-oF Initiator

1. Download StarWind NVMe-oF from the StarWind website at: https://www.starwindsoftware.com/starwind-nvme-of-initiator#download.

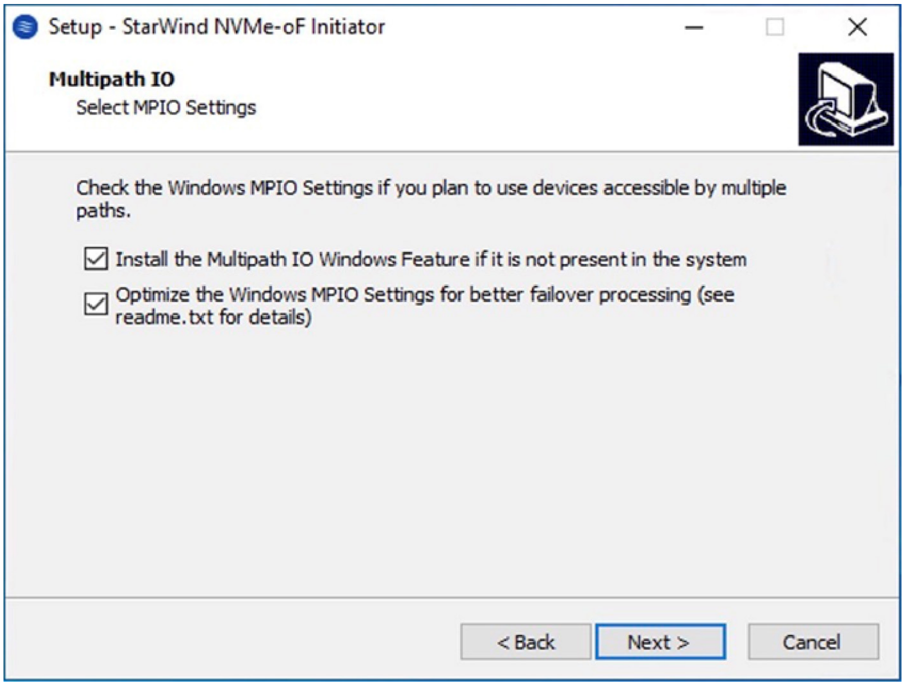
2. Execute the starwind-nvmeof.exe to install StarWind NVMe-oF Initiator and follow the steps in the wizard.

Note: StarWind NVMe-oF Initiator GUI requires .NET Desktop runtime to operate. For using StarWind NVMe-oF Initiator cmdlet and PowerShell no additional components are required.

3. Apply the license key to activate the product.

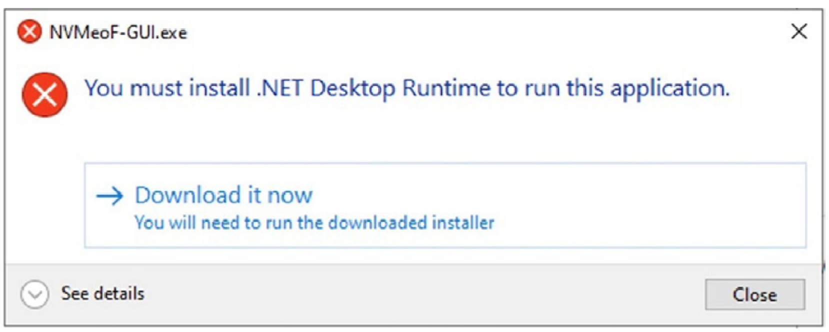


4. Select the Install the Multipath IO Windows feature and optimize its settings.

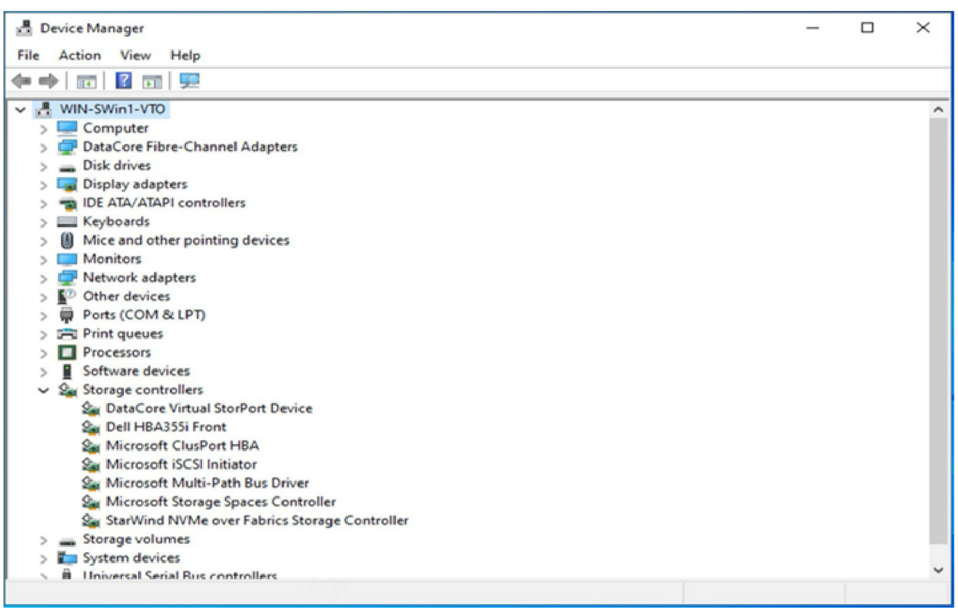


5. Once the installation is done, restart the server.

6. Install .NET Desktop Runtime to run StarWind NVMe-oF Initiator GUI application. Click Download it now to get the software and install the software.



7. Open Device Manager to check that StarWind NVMe-oF Initiator is installed on the system.



Managing Connection with StarWind NVMe-oF Initiator

The StarWind NVMe-oF Initiator provides three methods for establishing and managing connections between the target and initiator hosts.

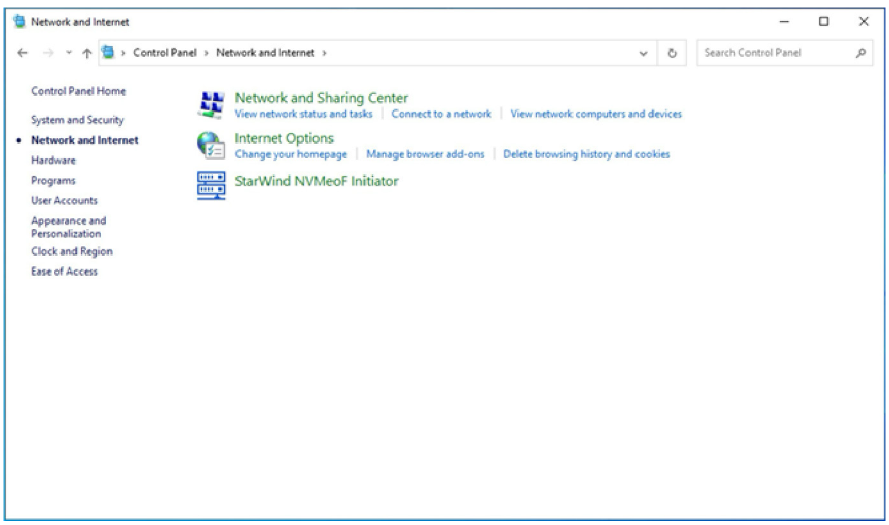
- StarWind NVMe-oF Initiator GUI - A user-friendly graphical interface for discovering, connecting, and managing NVMe-oF targets with minimal configuration effort.
- StarNVMeoF_Ctrl Command-Line Utility - A powerful command-line tool offering full control over connection setup, ideal for advanced users and script-based automation.
- PowerShell Cmdlets - Enables seamless integration with Windows PowerShell, allowing for automated workflows and complex configuration scenarios.

Choose any of these methods to establish an NVMe-oF connection between the target and the initiator hosts.

StarWind NVME-oF Initiator GUI

Discovering Targets

1. Launch StarWind NVMe-oF Initiator: Start -> Control Panel -> Network and Internet ->StarWind NVMe-oF Initiator.

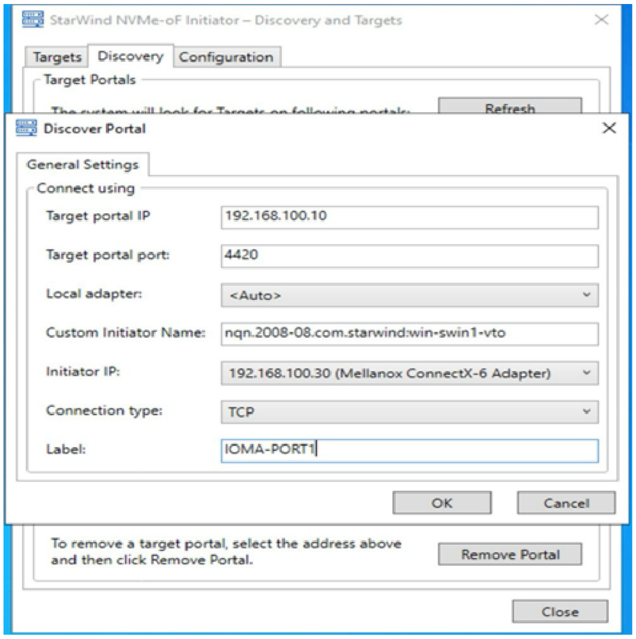


2. Navigate to the Discovery Tab.

3. In the Discover Target Portal dialog enter the IP address of the NVMe-oF target server to connect to the provisioned targets, along with the appropriate port number.

Note: To discover Volumes from OpenFlex Data24 target use port 4420 for NVMe-oF/TCP and NVMe-oF/RDMA.

4. Specify a Custom Initiator Name. Use this option if you need the client connection to use a name other than the default hostname. This allows for more flexible identification of the initiator in the target server configuration. Complete the following in the Discovery Portal window:

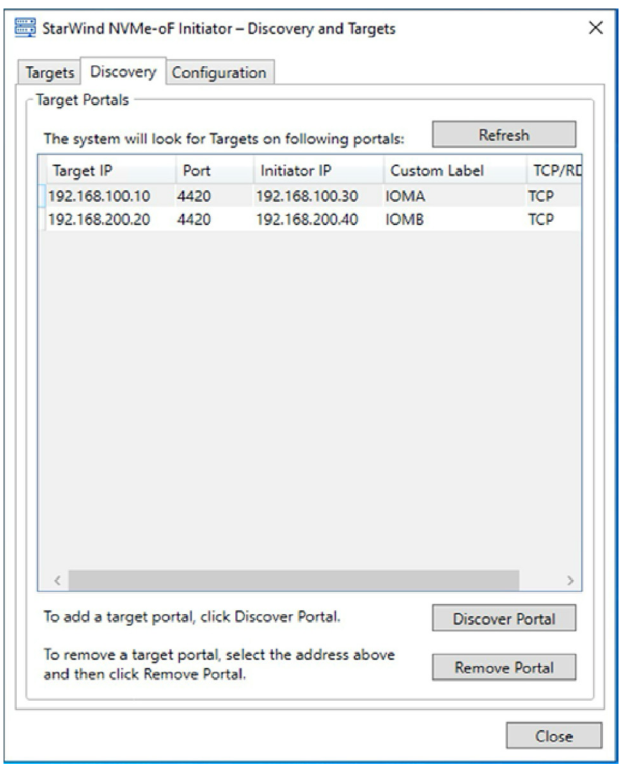


a. Select Initiator IP.

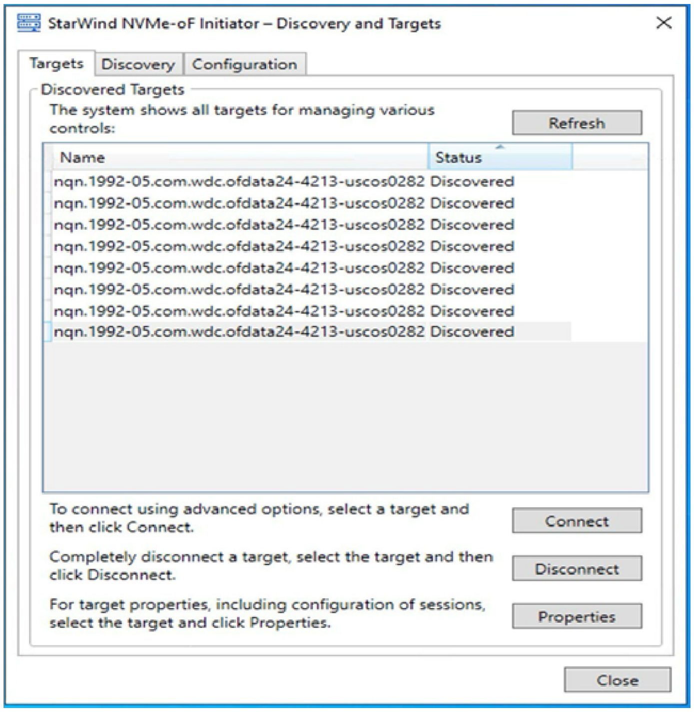
b. Specify Connection Type.

c. Add a Label for the Target Connection (Optional).

d. To start Discovery, click OK.

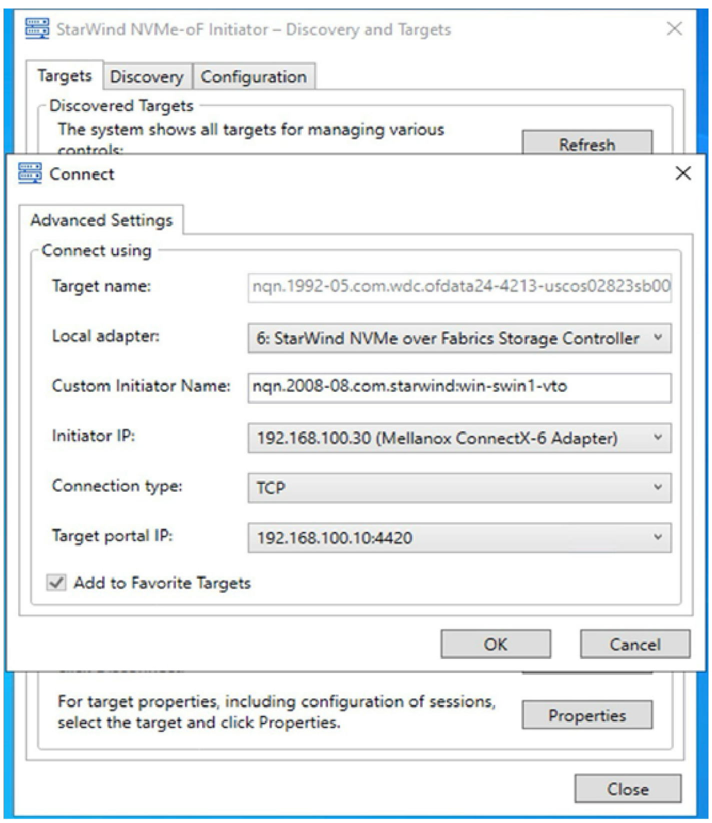


5. Once the Target Portal is Discovered, select to the Targets tab.



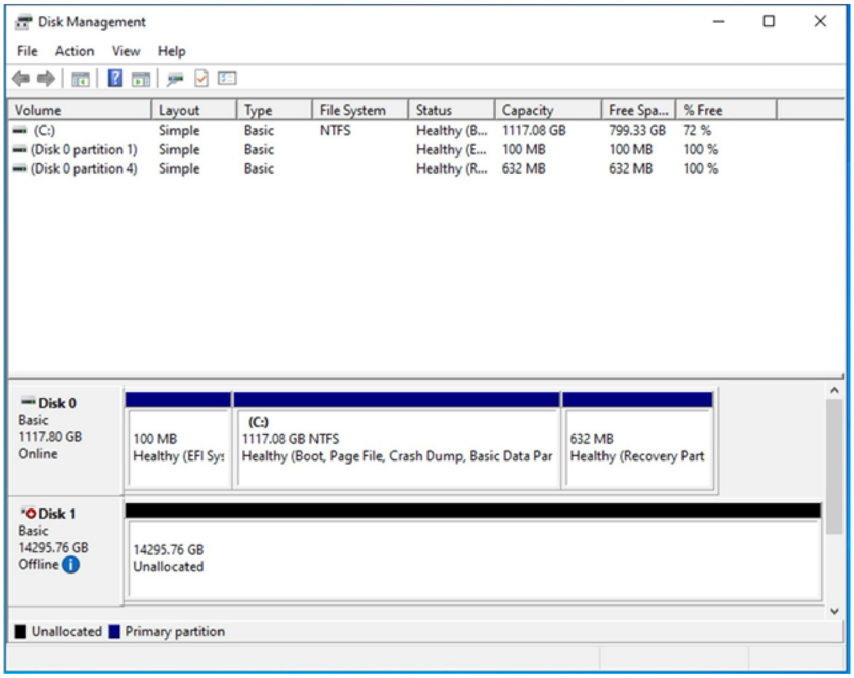
6. Select the Target Name from the Target Portals and click Connect.

7. Type the Target Portal IP address to establish the connection.



8. To verify the Connection, click OK. Once the target shows the status “has sessions,” it is connected. Repeat the previous steps to establish additional connections to other NVMe-oF targets utilizing different Target Portal IP addresses (Network adapter ports) as neccessary.

9. Open the Disk Management and verify that the connected disk(s) appear, unallocated and offline.



10. Bring the disks online by right-clicking on them and selecting the Online menu option.

Disconnecting Targets

To disconnect the NVMe-oF target choose the specified target from the Discovered Targets list and press the Disconnect button.

Note: Make sure that LUNs are not used by other applications at the moment of disconnection, as removing LUNs with active file operations may lead to data corruption.

StarWind NVMe-oF Command-Line Utility

Use the StarNVMeoF_Ctrl.exe command-line utility to make required connection from the OpenFlex Data24 target.

```
Administrator: Command Prompt
C:\Program Files\StarWind Software\StarNVMeoF>StarNVMeoF_Ctrl.exe

StarNVMeoF Controller Application v 2.0.0.702
Usage: StarNVMeoF_Ctrl.exe [switches] command [parameters]
 Switches:
  -t<rdma|tcp|hv> -- transport to access the target (rdma is default)
  -a<N> -- use ScsiPortN instead of the first found one (use 'adapters' cmd to list all available)
  -j  -- use JSON format for output data instead of plain text
 Commands and parameters:
  adapters -- list of existing StarNVMeoF adapters
  discovery <target_addr[:port]> <local_addr> [<HostNQN> [<queueDepth>]] -- discovery controllers
  insert <target_addr[:port]> <local_addr> <SubNQN> [<HostNQN> [<numIoQueues> [<ioQueueDepth> [<numaNode> [<firstCore>]]
]]] -- connect to a controller
  insert_all <target_addr[:port]> <local_addr> [<HostNQN> [<queueDepth>]] -- discovery and connect to all found controll
ers
  list [<mode={0-3}> [<start> [<count>]]] -- show all attached controllers
  remove <controllerId> -- disconnect and remove a controller by its id
  remove_all [<controllerNQN>] -- disconnect and remove all controllers (or all controllers connected to <controllerNQN>
)
  status -- query status and information about the driver
 Examples:
  StarNVMeoF_Ctrl.exe discovery 10.0.0.1:4420 10.0.0.2 -- discovery NVMeoF controllers via RDMA with IPv4
  StarNVMeoF_Ctrl.exe -ttcp discovery [2001:db8:100:3::2]:4444 [2001:db8:100:3::12] -- discovery NVMeoF controllers via
TCP with IPv6
  StarNVMeoF_Ctrl.exe -ttcp insert 10.0.0.1:4444 10.0.0.2 nqn.2020-02.com.sample.target:1 -- connect to a TCP controller

  StarNVMeoF_Ctrl.exe -j list 3 -- list all existing controllers in JSON format
  StarNVMeoF_Ctrl.exe -trdma remove_all -- disconnect and remove all connected RDMA controllers

C:\Program Files\StarWind Software\StarNVMeoF>_
```

Discovering Targets

Launch StarWind NVMe-oF Initiator: Start -> Control Panel -> Network and Internet ->StarWind NVMe-oF Initiator.

```
StarNVMeoF_Ctrl.exe <discovery|discovery_tcp> <target_ip_addr:[port]> <local_ip_addr> by specifying the protocol, target host IP address, and port number.
```

RDMA example:

```
StarNVMeoF_Ctrl.exe discovery 192.168.100.10:4420 192.168.100.30

TCP example: StarNVMeoF_Ctrl.exe discovery_tcp 192.168.100.10:4420 192.168.100.30

Here <192.168.100.10:4420> – NVMe-oF target IP and <192.168.100.30> – initiator host IP.
```

```
C:\Program Files\StarWind Software\StarNVMeoF>StarNVMeoF_Ctrl.exe discovery_tcp 192.168.100.10:4420 192.168.100.30

StarNVMeoF Controller Application v 2.0.0.702
Our Miniport #6 (ver 2.0.702, lic:1)
Discovering of TCP addr 192.168.100.10:4420 from 192.168.100.30...
        NET_LUID:       0x6008005000000
Discovery returned: gen 0, numrec 8
1) subnqn nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.1
        NVMe: port 0x2, cntlid 0xffff, trtype TCP, addr 192.168.100.10:4420, adrfam IPv4, asqsz 32
2) subnqn nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.2
        NVMe: port 0x2, cntlid 0xffff, trtype TCP, addr 192.168.100.10:4420, adrfam IPv4, asqsz 32
3) subnqn nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.3
        NVMe: port 0x2, cntlid 0xffff, trtype TCP, addr 192.168.100.10:4420, adrfam IPv4, asqsz 32
4) subnqn nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.4
        NVMe: port 0x2, cntlid 0xffff, trtype TCP, addr 192.168.100.10:4420, adrfam IPv4, asqsz 32
5) subnqn nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.5
        NVMe: port 0x2, cntlid 0xffff, trtype TCP, addr 192.168.100.10:4420, adrfam IPv4, asqsz 32
6) subnqn nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.6
        NVMe: port 0x2, cntlid 0xffff, trtype TCP, addr 192.168.100.10:4420, adrfam IPv4, asqsz 32
7) subnqn nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.7
        NVMe: port 0x2, cntlid 0xffff, trtype TCP, addr 192.168.100.10:4420, adrfam IPv4, asqsz 32
8) subnqn nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.8
        NVMe: port 0x2, cntlid 0xffff, trtype TCP, addr 192.168.100.10:4420, adrfam IPv4, asqsz 32

C:\Program Files\StarWind Software\StarNVMeoF>_
```

Connecting Targets

1. To connect the target, run the following command:

```
StarNVMeoF_Ctrl.exe <insert|insert_tcp> <target_ip_addr[:port]> <local_ip_addr> <SubNQN> <HostNQN> [<num_io_queues><io_queue_depth> <first_core>]
```

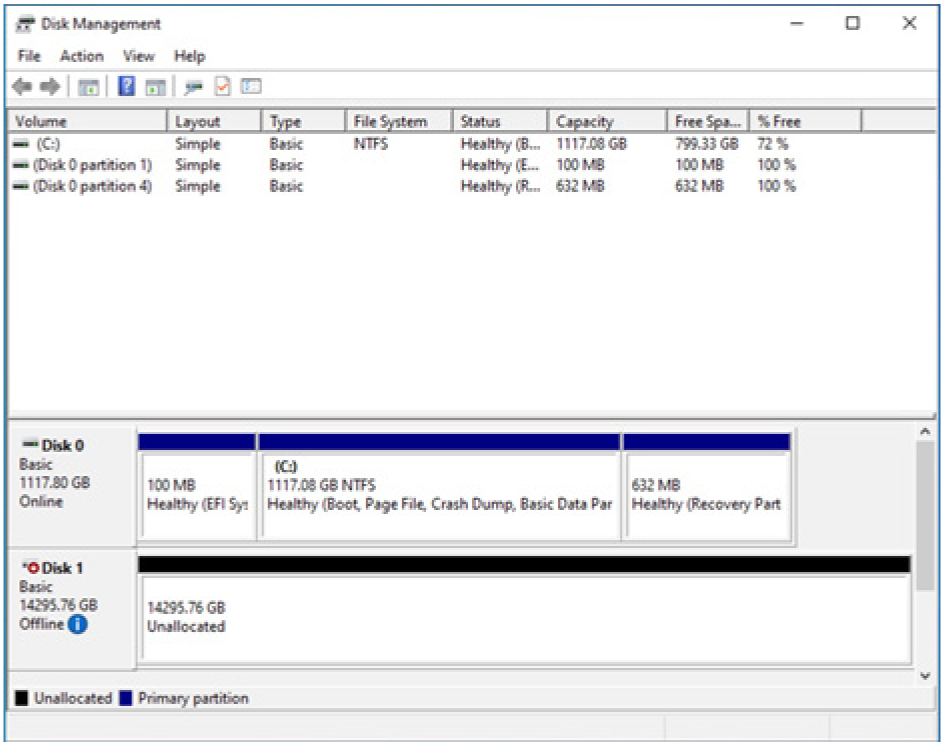
RDMA example:

```
StarNVMeoF_Ctrl.exe insert "192.168.100.10:4420"  "192.168.100.30" "nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.1" "nqn.2008-08.com.starwind:win-swin1-vto" 8

TCP example: StarNVMeoF_Ctrl.exe -ttcp insert "192.168.100.10:4420"  "192.168.100.30" "nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.1" "nqn.2008-08.com.starwind:win-swin1-vto" 8
```

Here:

```
<192.168.100.10:4420 > – OpenFlex target IP and port details.

<192.168.10.30> – Initiator host IP.

< nqn.1992-05.com.wdc.ofdata24-4213-uscos02823sb0008:nvme.1> – SubNQN of the OpenFlex target

< nqn.2008-08.com.starwind:win-swin1-vto > – local HostNQN.

<8> – quantity of connections to the target.

<16> – queue depth.

<0> – number of the initial core.
```

2. To show the list of connected NVMe-oF controllers, run the “StarNVMeoF_Ctrl.exe list” command.



Getting Information About Targets

To show the list of connected NVMe-oF controllers, run the “StarNVMeoF_Ctrl.exe list” command.

```
C:\Program Files\StarWind Software\StarNVMeoF>StarNVMeoF_Ctrl.exe list

StarNVMeoF Controller Application v 2.0.0.702
Our Miniport #6 (ver 2.0.702, lic:1)
Listing Controllers (mode 0, start 0, count 0)...
Attached Controllers: 1 of 1
  0
```

Disconnecting Targets

To disconnect LUNs from the system, run the following controller disconnect command:

`StarNVMeoF _ Ctrl.exe remove <controllerId>`

Example:

`StarNVMeoF _ Ctrl.exe remove 0`

Here:

`<1> – controller Id`

```
C:\Program Files\StarWind Software\StarNVMeoF>StarNVMeoF_Ctrl.exe remove 0

StarNVMeoF Controller Application v 2.0.0.702
Our Miniport #6 (ver 2.0.702, lic:1)
Disconnecting ControllerId 0...
Controller disconnected: [0]
```

Note: Make sure that LUNs are not used by other applications at the moment of disconnection, as removing LUNs with active file operations may lead to data corruption.

Performance Test with FIO

FIO tool is used here to measure performance. FIO spawns a number of threads or processes doing a particular type of I/O action as specified by the user. Fio takes a number of global parameters, each inherited by the thread unless otherwise parameters given to them overriding that setting is given. The typical use of fio is to write a job file matching the I/O load one wants to simulate.

The measured performance numbers are specific for the current configuration of StarWind NVMe-OF Initiator with OpenFlex Data24 topology in conjunction with the uses of 8 volumes in Multipath connection over RoCEv2 and TCP. The performance test is run using FIO, simultaneously running tests from all the Windows clients. Different test parameters are used to check the overall system performance.

Performance Results with RDMA-RoCEv2 configuration

RoCEv2 - Two Host with 4Drives per Host using Multipath connection	
Profile Details	Performance Details
Sequential Read (Block Size=128K)	45.5 GBps
Sequential Write (Block Size=128K)	29.9 GBps
Random Read (Block Size=4K)	2093 K IOPS
Random Write (Block Size=4K)	2880 K IOPS

Configuration Details

- 2x Windows Server 2022 with one CX6 card per server.
- 4x RFX ports of OpenFlex Data 24 4200.
- 1x NVIDIA Onyx Management 3700 switch.
- 8x SN655 (15.36TB) – Model: WUS5EA1A1ESP7E3 - FW: RC610008).
- Server 1 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 4x drives (1-4) are mapped as part of server1 with RoCEv2 configuration.
- Server 2 is connected to IOMA-Port4 and IOM-B Port4 with Multipath configuration.
- 4x drives (5-8) are mapped as part of server1 with RoCEv2 configuration.

Performance Results with TCP Configuration

TCP - Host with 4Drives per Host using Multipath connection	
Profile Details	Performance Details
Sequential Read (Block Size=128K)	21.74 GBps
Sequential Write (Block Size=128K)	20 GBps
Random Read (Block Size=4K)	1638 K IOPS
Random Write (Block Size=4K)	1271 K IOPS

Configuration Details

- 4x Windows Server 2022 with one CX6 card.
- 2x RFX ports of OpenFlex Data 24 4200.
- 1x NVIDIA Onyx Management 3700 switch.
- 8x SN655 (15.36TB) – Model: WUS5EA1A1ESP7E3 - FW: RC610008).
- Server 1 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 2x drives (1-2) are mapped as part of server1 with TCP configuration.
- Server 2 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 2x drives (3-4) are mapped as part of server1 with RoCEv2 configuration.
- Server 3 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 2x drives (5-6) are mapped as part of server1 with RoCEv2 configuration.
- Server 4 is connected to IOMA-Port1 and IOM-B Port1 with Multipath configuration.
- 2x drives (7-8) are mapped as part of server1 with RoCEv2 configuration.

Note: The performance results are captured after running multiple iterations with different data sizes (block size, queue depth, number of jobs, CPU parameters, Max Transfer length and Max IO queues). The Performance will improve by increasing the number of NVMe-oF initiator hosts, utilizing all available RFX ports, and ensuring that all 24 drives from the OpenFlex Data 24 4200 are in use.

Disclaimer: All the performance data are subject to change depending on the Drive model, capacity, workloads, servers, CPU, tunings, and HA topology that are being used.

Advantages

With advanced NVMe-oF and composable infrastructure technologies and StarWind NVMe-oF Initiator, organizations can achieve:

Scaling and Efficiency

With OpenFlex Data24 Composable disaggregation, it is easy to scale servers, protocol bandwidth, and storage enclosures independently on Windows Environment. Compared to legacy FC and iSCSI, NVMe-oF offers a much lower CPU cost on the IOPS delivered to the applications with StarWind NVMe-oF initiator, which means less of the CPU is wasted on storage processing and more of it is available to your applications.

Performance

NVMe over Fabrics delivers 100% of the underlying storage performance and close to 100% of the original NVMe latency. Moreover, it offers unrivalled parallelism that enables this performance to all of the applications working with the storage.

Cost Savings

More efficient CPU usage unlocks the ability to scale down the CPUs in the application servers and save on the core-bound OS licensing. The ability to use existing TCP or RoCEv2 instead of upgrading to FC or proprietary RNICs in every server is also a huge source of savings.

Conclusion

The deployment of StarWind NVMe-oF Initiator with OpenFlex Data24 represents a modern, future-ready approach to high-performance storage for Windows environments. By pairing OpenFlex Data24's disaggregated, scalable NVMe storage with StarWind's Windows-native NVMe-oF connectivity, organizations break free from legacy storage protocols and architectures.

The result: near-local NVMe performance over standard Ethernet, dramatically reduced CPU overhead, and true separation of compute and storage. Enterprises can confidently run data-intensive workloads: databases, analytics, media processing, and virtualization - with the flexibility, efficiency, and scalability required for next-generation data centers.

Overall, the benchmark of StarWind NVMe-oF Initiator with OpenFlex Data24 has proven that NVMe-oF technology can be effectively used to share fast storage over a network, practically, without the performance decrease. The solution for OpenFlex Data24 with StarWind NVMe-oF Initiator on Windows has proven that despite complexities caused by certain platform specifics it handles big blocks and long I/O queues perfectly well, still being the only efficient option to successfully share NVMe storage across the Windows network.

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