Emulex® NVMe over Fibre Channel on VMware ESXi 7.0

User Guide
Release 12.6

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Chapter 1: Overview

This user guide provides instructions for installing and configuring the NVMe over FC driver for VMware ESXi 7.0 on Emulex® LPe31000-series, LPe32000-series, and LPe35000-series adapters in initiator and target systems.

NVMe over FC is a relatively new protocol for solid-state storage devices built with nonvolatile memory technologies. NVMe provides substantially lower latency for storage I/O operations and significantly higher IOPs per device. NVMe scales up the number of devices it can address by adopting NVMe over fabric technology. LPe31000-series, LPe32000-series, and LPe35000-series HBAs are enabled for NVMe over fabrics. NVMe-enabled HBAs support NVMe over fabrics and SCSI concurrently, allowing data centers to transition to all-flash storage at their own pace.

You will need a basic understanding of NVMe over FC before configuring it. You can use a search engine to find various websites and books that describe NVMe over FC. In particular, you will need to understand the concept of *namespaces* (the NVMe equivalent of SCSI LUNs) and NVMe *subsystems* (containers of SCSI LUN equivalents).

A link to the NVMe driver for ESXi 7.0 is available on the VMware website. Install the driver as instructed in the VMware documentation.

This document describes how to perform the following procedures:

- Configure NVMe on a NetApp target system.
- Configure NVMe on an initiator system.

In addition, basic troubleshooting information is provided.

1.1 Abbreviations

Acronym/Abbreviation	Description
DID	device ID
FCP	Fibre Channel Protocol
GA	general availability
GB	gigabyte
GPT	GUID partition table
GUID	globally unique identifier
I/O	input/output
ID	identifier
LIF	logical interface
LIP	Loop Initiatialization Primitive
NPIV	N_Port ID virtualization
NQN	NVMe qualified name
RDM	raw device mapping
VMID	Virtual Machine Identifier
VMFS	virtual machine file system
XRI	Extensible Resource Indicator

Chapter 2: Installing and Configuring NVMe over FC

This chapter describes how to install and configure NVMe over FC.

2.1 Installing NVMe over FC

Install the ESXi 7.0 GA operating system on the server, following the instructions provided with the operating system. Installing the operating system automatically installs inbox NVMe drivers. You can also install out-of-box drivers by following the instructions provided with the operating system.

The operating system includes commands that are used for NVMe over FC targets (`esxcli nvme`). Refer to the VMware documentation for more information

After the operating system is installed on the initiator system, follow the instructions in the next sections to configure NVMe over FC.

2.2 Configuring NVMe over FC on a NetApp Target

This section describes how to configure NVMe over FC on a NetApp target. For instructions on configuring NVMe over FC on other targets, contact the target vendor.

The following variables are used in the commands provided in this section:

- *<vserver_name>* is the name of the virtual server.
- *<lif1_name>* is the name of LIF 1.
- *<node_name>* is name of the LIF home node.
- *<home_port>* is the home port of the LIF.
- *<volume_name>* is the name you want to assign to the volume.
- *<aggregate_name>* is an aggregate identified in the Aggregate column.
- *<aggregate_size>* is the size of the aggregate.
- *<namespace_path>* is the path of the namespace.
- *<namespace_size>* is the namespace size. You can specify the size in bytes, KB, MB, GB, TB, or PB. For example, a 4-GB namespace can be indicated as `4GB`.
- *<subsystem_name>* is the name of the subsystem.
- *<host_nqn>* is the NQN information that identifies the host.

To configure NVMe over FC on a NetApp target, perform the following steps:

1. Create a virtual server by typing the following command:
   `vserver create -vserver <vserver_name>`
2. Display the available protocols by typing the following command:
   `vserver show-protocols -vserver <vserver_name>`
   Information similar to the following is displayed:
   ```
   Vserver: <vserver_name>
   Protocols: nfs, cifs, fcp, iscsi, ndmp, nvme
   ```
3. Remove all protocols except FCP and NVMe by typing the following command:
   `vserver remove protocols -vserver <vserver_name> protocols nfs, cifs, iscsi, ndmp`

4. Create the NVMe service for the virtual server by typing the following command:
   `vserver nvme create -vserver <vserver_name>`
5. Create an LIF on the virtual server by typing the following command:
   `network interface create -vserver <vserver_name> -lif <lif1_name> -data-protocol fc-nvme -role data -home-node <node_name> -home-port <home_port> -status-admin up`
   Repeat this command for each LIF you want to create.
6. After all desired LIFs are created, you can verify the LIFs by typing the following command:
   `network interface show -vserver <vserver_name>`
   Information similar to the following is displayed.

```
             Logical      Status       Network                    Current      Current      Is
Vserver      Interface    Admin/Oper   Address/Mask               Node         Port         Home
------------ ---------- ----------- ------------------------   ----------  ----------- -----
vserver_name lif1_name    up/up        20:9e:00:a0:98:5e:3c:86    node1_name  home_port1   true
             lif2_name    up/up        20:43:00:a0:98:5e:3c:86    node2_name  home_port1   true
             lif3_name    up/up        22:e3:00:a0:98:5e:3c:86    node1_name  home_port2   true
             lif4_name    up/up        22:e4:00:a0:98:5e:3c:86    node2_name  home_port2   true
```

7. Display aggregate information by typing the following command:
   `aggr show`
   Information similar to the following is displayed.

```
Aggregate    Size       Available    Used%     State      #Vols     Nodes         RAID Status
----------   --------   ----------   -------   ---------  -------   -----------   -----------
aggr1        349.0GB    16.03GB      95%       online     1         node_name1    normal
aggr2        349.0GB    16.43GB      95%       online     1         node_name2    normal
aggr3        4.66TB     1.64TB       65%       online     131       node_name1    normal
aggr4        1.43TB     345.7GB      76%       online     67        node_name1    normal
aggr5        2.15TB     294.6GB      87%       online     136       node_name2    normal
5 entries were displayed
```

8. Using the information displayed by the `aggr show` command in Step 7, create volumes on the nodes by typing the following command:
   `volume create -vserver <vserver_name> -volume <volume_name> -aggregate <aggregate_name> -size <aggregate_size> -state online`
9. Verify the sizes of the created volumes by typing the following command:
   `volume show -vserver <vserver_name>`
   Information similar to the following is displayed.

```
Vserver         Volume       Aggregate    State        Type    Size    Available    Used%
-------------   ----------   ----------   ----------   -----   -----   ----------   -------
vserver_name    vol_name1    aggr1        online       RW      5GB     4.75GB       0%
vserver_name    vol_name2    aggr2        online       RW      5GB     4.75GB       0%
vserver_name    vol_name3    aggr3        online       RW      1GB     972.5MB      0%
3 entries were displayed
```

10. Create a namespace on each of the volumes you created in Step 8 by typing the following command:
    `vserver nvme namespace create -vserver <vserver_name> -path <namespace_path> -size <namespace_size> -ostype vmware -block-size 512B`
    The namespace size must be smaller than the volume on which the namespace was created. Refer to the output obtained in Step 9 for the available space on each volume. For best results, configure a namespace size of 4 GB or more.
11. Create a subsystem by typing the following command:
    `vserver nvme subsystem create -vserver <vserver_name> -subsystem <subsystem_name> -ostype vmware`
    Repeat this command for each subsytem you want to create.
12. Obtain the host NQN by typing the following command:
    `esxcli nvme info get`
    Information similar to the following is displayed:
    `Host NQN: nqn.2014-08.net.broadcom.dhcp:nvme:dhcp-10-123-178-157`
13. Add a host to each subsystem you created by typing the following command:
    `vserver nvme subsystem host add -vserver <vserver_name> -subsystem <subsystem_name> -host-nqn <host_nqn>`
14. Verify the subsystem information on the virtual server by typing the following command:
    `vserver nvme subsystem show -vserver <vserver_name>`
    Information similar to the following is displayed:

```
Vserver Subsystem   Target NQN
------- ------------ ----------------------------------------------------------
nvme_test
   nvme_ss1         nqn.1992-08.com.netapp:sn.1f86d926a7cf11e9bb0e00a0985e3c87:subsystem.nvme_ss1
   nvme_ss2         nqn.1992-08.com.netapp:sn.1f86d926a7cf11e9bb0e00a0985e3c87:subsystem.nvme_ss2
2 entries were displayed.
```

NOTE: To obtain the host NQN for ESXi 7.0, type the following command:
`esxcli nvme info get`
Information similar to the following is displayed:
`Host NQN: nqn.2014-08.net.broadcom.dhcp:nvme:dhcp-10-123-178-157`

15. Map each namespace to its subsystem by typing the following command:
    `vserver nvme subsystem map add -vserver <vserver_name> -subsystem <subsystem_name> -path <namespace_path>`
16. Verify the mapping by typing the following command:
    `vserver nvme subsystem map show -vserver <vserver_name>`
    Information similar to the following is displayed:

```
Vserver    Subsystem  NSID Namespace Path
---------------------------------------------------------------------------
nvme_test
           nvme_ss1   00000001h /vol/nvme_vol/nvme_ns
           nvme_ss2   00000001h /vol/nvme_vol2/nvme_ns2
2 entries were displayed.
```

NVMe over FC is configured on the Netapp target. You can now configure NVMe over FC on an initiator system.

2.3 Configuring NVMe over FC on an Initiator System

The following variables are used in the commands provided in this section:

- <*wwpn*> is the WWPN of the HBA.
- <*firmware_filename*> is the name of the firmware file.

To configure NVMe over FC on an initiator system, perform the following steps after the operating system and drivers are installed. For information about updating ESXi drivers, refer to the *Emulex Drivers for VMware ESXi User Guide*. The NVMe driver file-name format is `Broadcom-ELX-brcmnvmefc_<driver_version>-<OS_version>_<VMware_info>.zip`.

1. Install all applicable VMware components, such as the `elxmgmt` utility.
2. On LPe32000-series and LPe31000-series HBAs, you must enable the `lpfc_enable_fc4_type` parameter. Refer to the FC driver parameters documentation in the *Emulex Drivers for VMware ESXi User Guide* for more information.

NOTE: The `lpfc_enable_fc4_type` parameter is enabled by default on LPe35000-series adapters.

3. Download the latest firmware for the HBA from the Broadcom® website at www.broadcom.com.
4. Install the firmware on the HBA by typing the following command:
   `esxcli elxmgmt hba firmware download -w <wwpn> -f <firmware_filename>`
5. Reboot the server.
6. After the server restarts, verify that NVMe adapters were created by typing the following command:
   `esxcfg-scsidevs -a`
   Information similar to the following is displayed:
   ```
   vmhba7 lpfc link-up fc.20000090faf0948f:10000090faf0948f (0000:05:00.0) Emulex Corporation
   Emulex LightPulse LPe32000 PCIe Fibre Channel Adapter
   vmhba66 brcmnvmefc link-up fc.20000090faf0948f:10000090faf0948f (0000:05:00.0) Emulex
   Corporation Emulex LightPulse LPe32000 PCIe Fibre
   ```
7. Verify the connected controller list by typing the following command:
   `esxcli nvme controller list`
   Information similar to the following is displayed:

```
                                                                  Con-                Trans
                                                                  troller             -port Is
Name                                                              Number  Adapter     Type  Online
----------------------------------------------------------------  ------  ----------  ----  ------
nqn.1992-                                                         262     vmhba64     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba64#203c00a0986e4449:203e00a0986e4449
nqn.1992-                                                         264     vmhba66     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba66#203c00a0986e4449:203e00a0986e4449
nqn.1992-                                                         265     vmhba67     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba67#203c00a0986e4449:203e00a0986e4449
nqn.1992-                                                         263     vmhba65     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba65#203c00a0986e4449:203e00a0986e4449
```

```
nqn.1992-                                                                392      vmhba64  FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba64#203c00a0986e4449:206600a0986e4449
nqn.1992-                                                                391      vmhba66  FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba66#203c00a0986e4449:206600a0986e4449
nqn.1992-                                                                393      vmhba65  FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba65#203c00a0986e4449:206600a0986e4449
nqn.1992-                                                                394      vmhba67  FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba67#203c00a0986e4449:206600a0986e4449
```

8. You can see the connected namespaces by typing the following command:
   `esxcli nvme namespace list`
   Information similar to the following is displayed:

```
Name                                  Controller Number  Namespace ID  Block Size  Capacity in MB
------------------------------------  -----------------  ------------  ----------  --------------
uuid.cfb11df2e43a49779293f41319de4fb0  259                1            512         5120
uuid.cfb11df2e43a49779293f41319de4fb1  259                2            512         5120
uuid.cfb11df2e43a49779293f41319de4fb2  259                3            512         5120
uuid.cfb11df2e43a49779293f41319de4fb3  259                4            512         5120
uuid.cfb11df2e43a49779293f41319de4fb4  259                5            512         5120
uuid.cfb11df2e43a49779293f41319de4fb5  259                6            512         5120
uuid.cfb11df2e43a49779293f41319de4fb6  259                7            512         5120
uuid.cfb11df2e43a49779293f41319de4fb7  261                1            512         5120
uuid.cfb11df2e43a49779293f41319de4fb8  259                8            512         102400
uuid.cfb11df2e43a49779293f41319de4fb9  261                2            512         5120
uuid.cfb11df2e43a49779293f41319de4fba  261                3            512         5120
uuid.cfb11df2e43a49779293f41319de4fdb  259                9            512         5120
```

NOTE: RDM mapping is not supported by NVMe over FC on ESXi 7.0.

You must now create datastores on the NVMe namespaces. To create datastores using the `partedUtil` and `vmkfstools` CLI commands, follow the instructions in Section 2.3.1, Creating Datastores Using CLI Commands. To create datastores using the vSphere Client GUI, go to Section 2.3.2, Creating Datastores Using the vSphere Client GUI.

2.3.1 Creating Datastores Using CLI Commands

The following variables are used in the commands provided in this section:

- <*namespace_name*> is the name of the namespace on which you are creating a datastore, such as `uuid.cfb11df2e43a49779293f41319de4fb0`.
- <*partition_number*> is the number of the partition you are creating.
- <*start_sector*> is the sector at which the partition begins.
- <*end_sector*> is the sector at which the partition ends.

- `<partition_attribute>` identifies the partition properties. This value is usually `0`. Refer to the VMware documentation for more information.
- `<datastore_name>` is the name of the datastore you are creating.

To create datastores on the NVMe namespaces using CLI commands, perform the following steps:

1. Label the existing partition table as a GPT by typing the following command:
   `partedUtil mklabel /vmfs/devices/disks/<namespace_name> gpt`
2. Determine the number of usable sectors that are available for the new partition table by typing the following command:
   `partedUtil getUsableSectors /vmfs/devices/disks/<namespace_name>`
   Information similar to the following is displayed:
   `34 10485726`
3. Create a new partition table on the disk by typing the following command:
   `partedUtil setptbl /vmfs/devices/disks/<namespace_name> gpt "<partition_number> <start_sector> <end_sector> AA31E02A400F11DB9590000C2911D1B8 <partition_attribute>"`

NOTE: Use the second value displayed in Step 2 (`10485726`) as the `<end_sector>` value. `AA31E02A400F11DB9590000C2911D1B8` is the VMFS datastore partition type in GUID format.

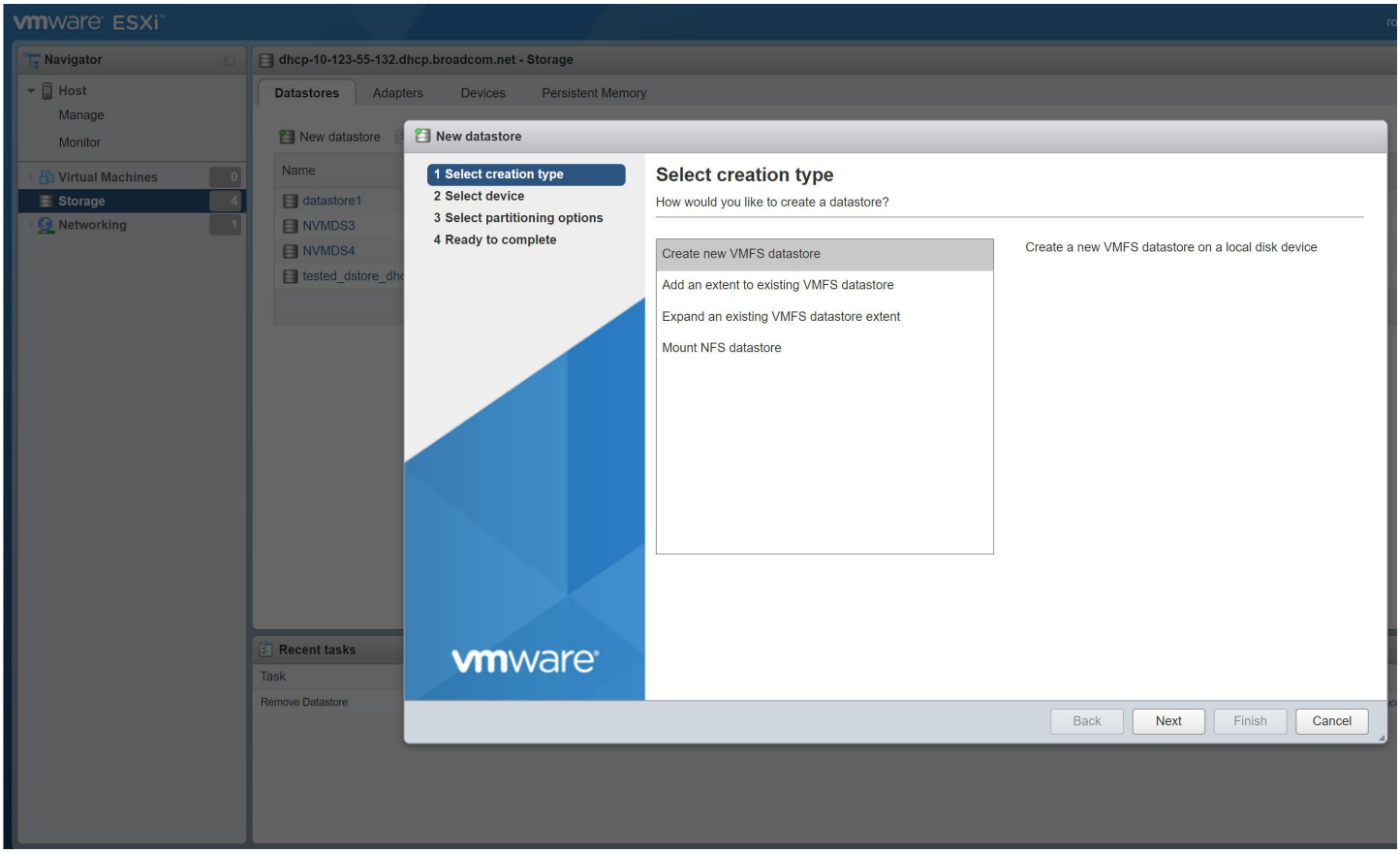
4. Create a VMFS volume and assign a name to the datastore by typing the following command:
   `vmkfstools -C vmfs6 -b 1M -S <datastore_name> /vmfs/devices/disks/<namespace_name>`

Repeat these steps for each namespace on your server, and then proceed to Section 2.3.3, Completing the Initiator Configuration.

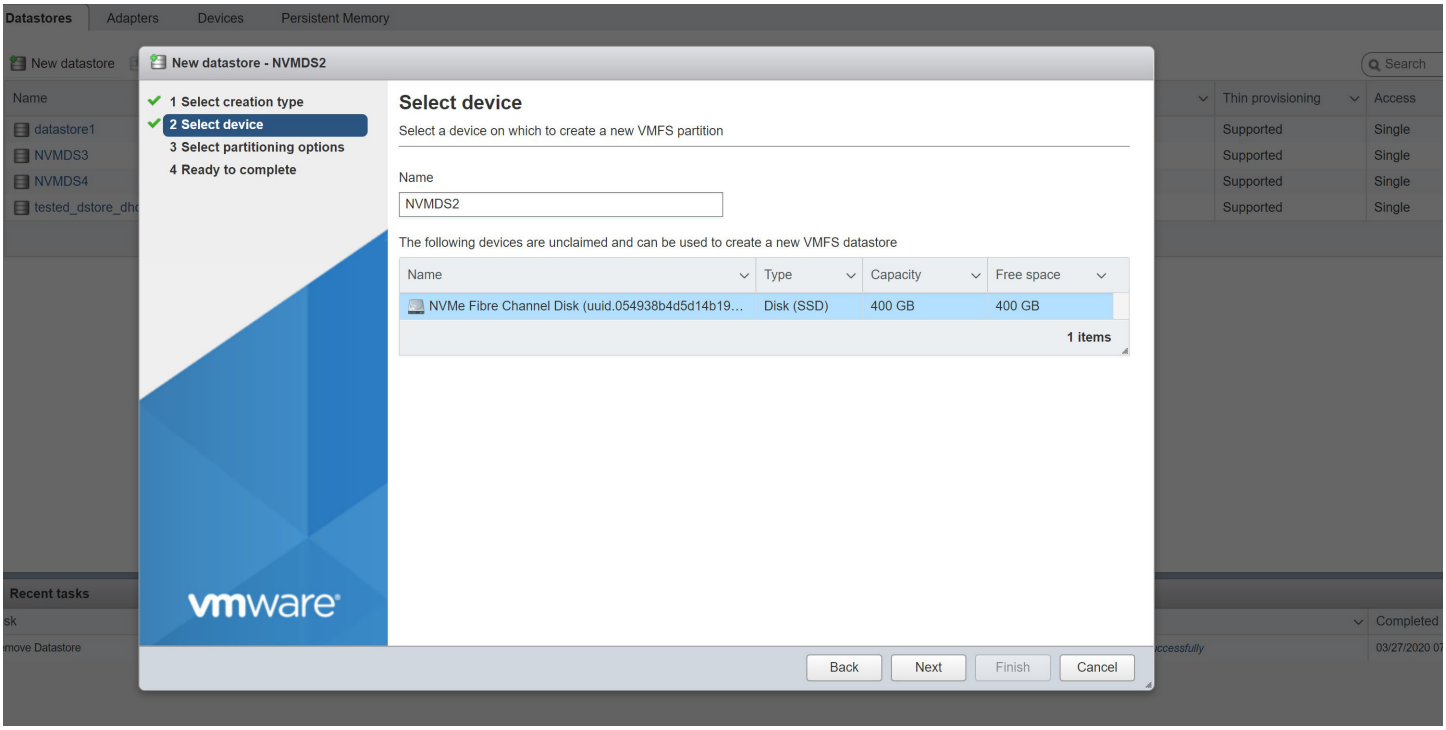
2.3.2 Creating Datastores Using the vSphere Client GUI

To create datastores on the NVMe namespaces using the vSphere Client GUI, perform the following steps:

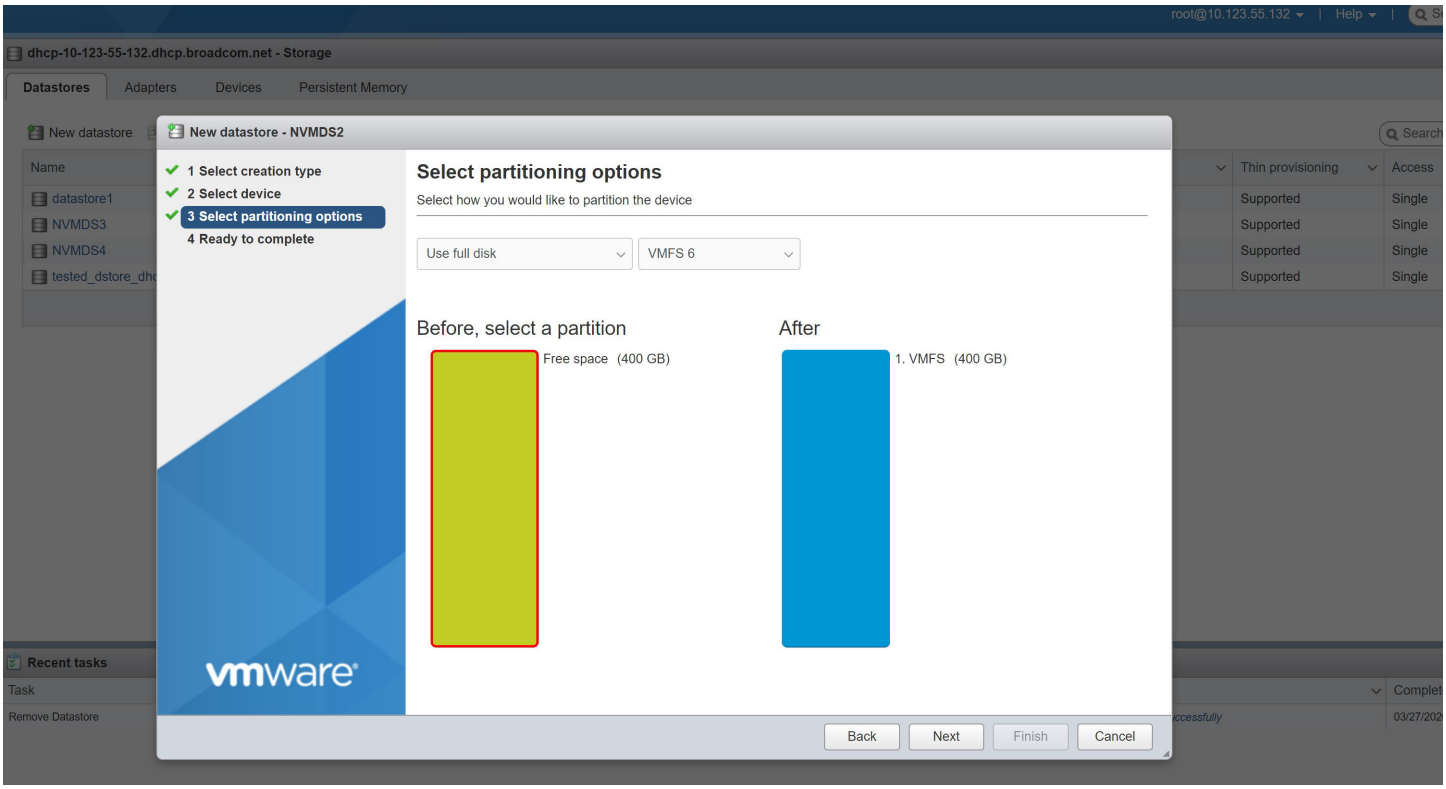
1. Create a new VMFS by navigating to **Datastores** and clicking **New datastore**. The **Select creation type** dialog of the **New datastore** window appears.



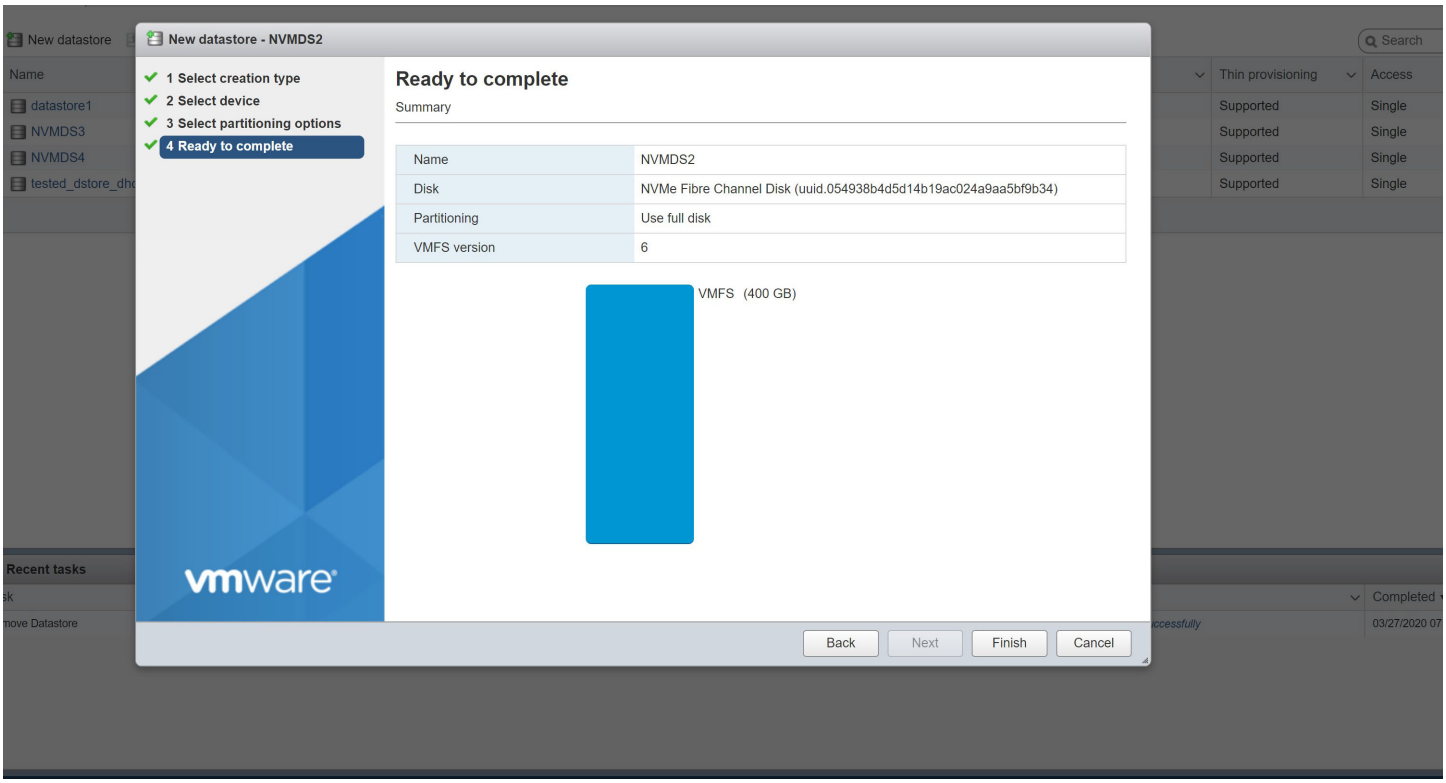
2. Select **Create new VMFS datastore** and click **Next**. The **Select device** dialog appears.



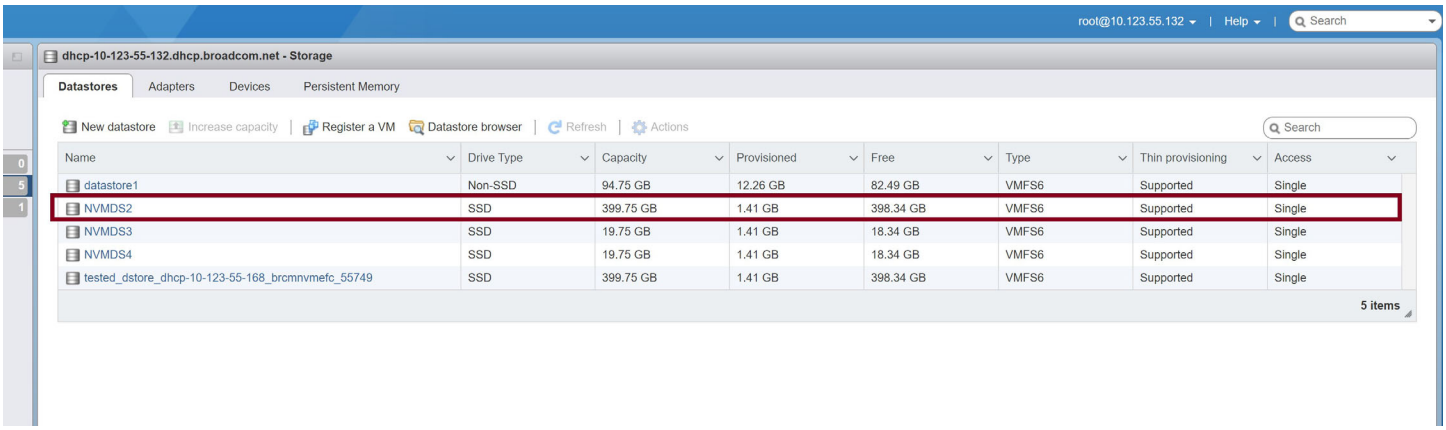
3. In the **Name** field type the name of the datastore you want to create. Select an unused namespace on which to create the datastore. Click **Next**. The **Select partitioning options** dialog appears.



4. Select the desired partitioning options and click **Next**. The **Ready to complete** dialog displays information about the selections you have made.



5. Click **Finish**. The **Datastores** tab appears.



Repeat this procedure for each namespace on your server, and then proceed to Section 2.3.3, Completing the Initiator Configuration.

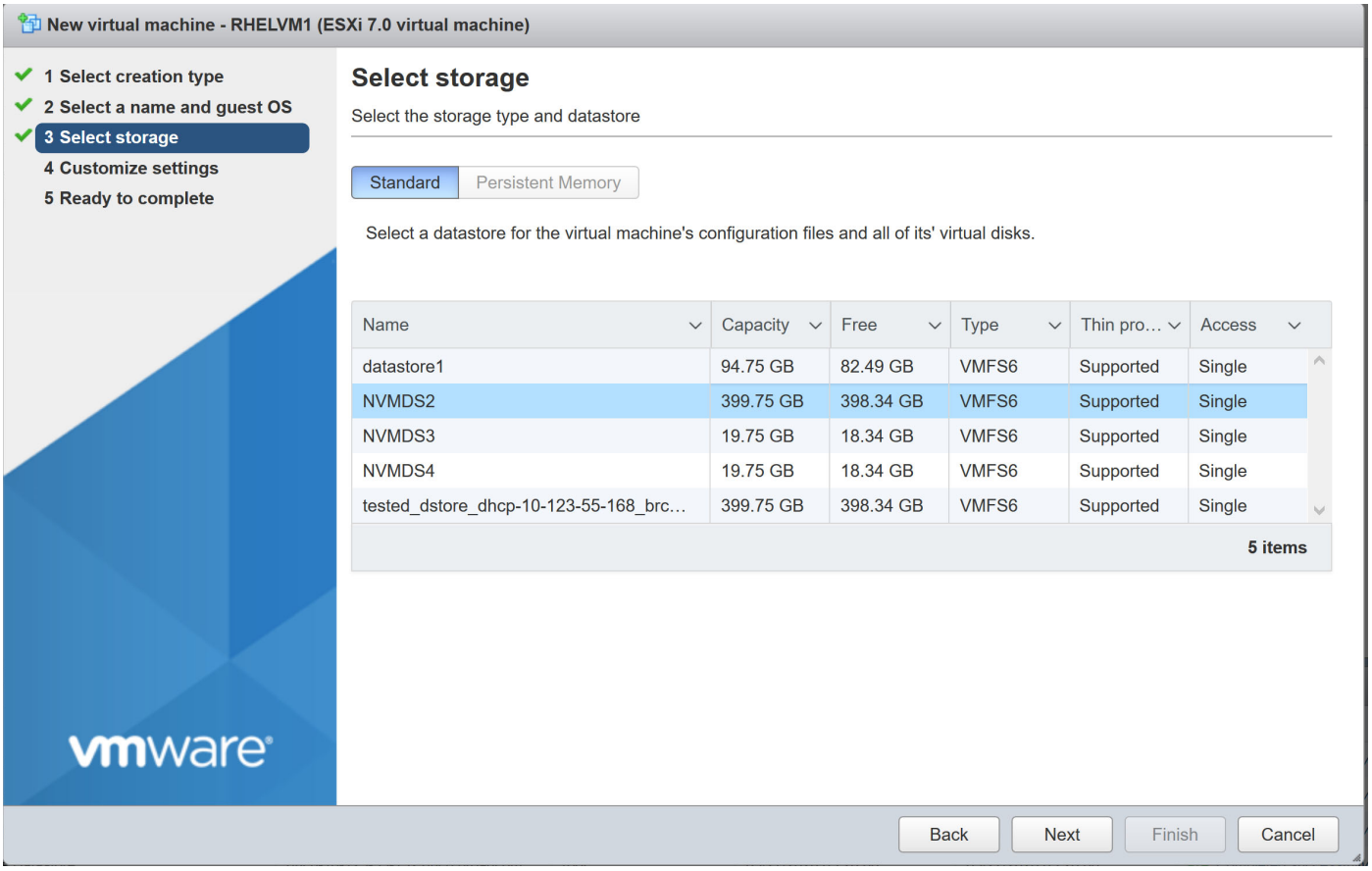
2.3.3 Completing the Initiator Configuration

Create VMs on the each datastore that you created in Section 2.3.1, Creating Datastores Using CLI Commands or Section 2.3.2, Creating Datastores Using the vSphere Client GUI. Each VM must have at least four CPUs and 4 GB of memory. Perform the following steps using the vSphere Client GUI:

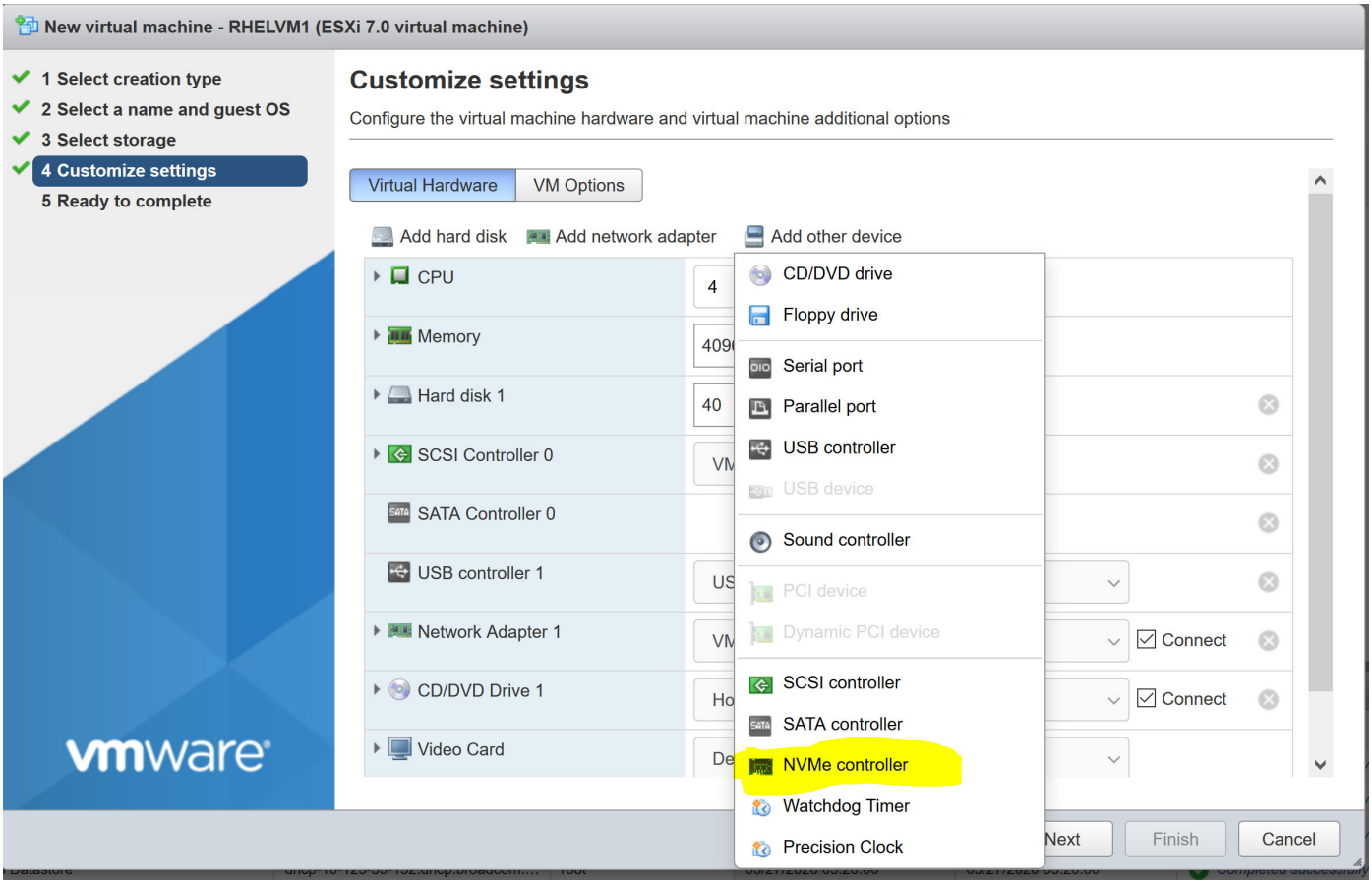
1. To create a new virtual machine, use the **New Virtual Machine** wizard following the instructions provided by VMware.

NOTE: Create the VM with at least four CPUs and 4 GB of memory.

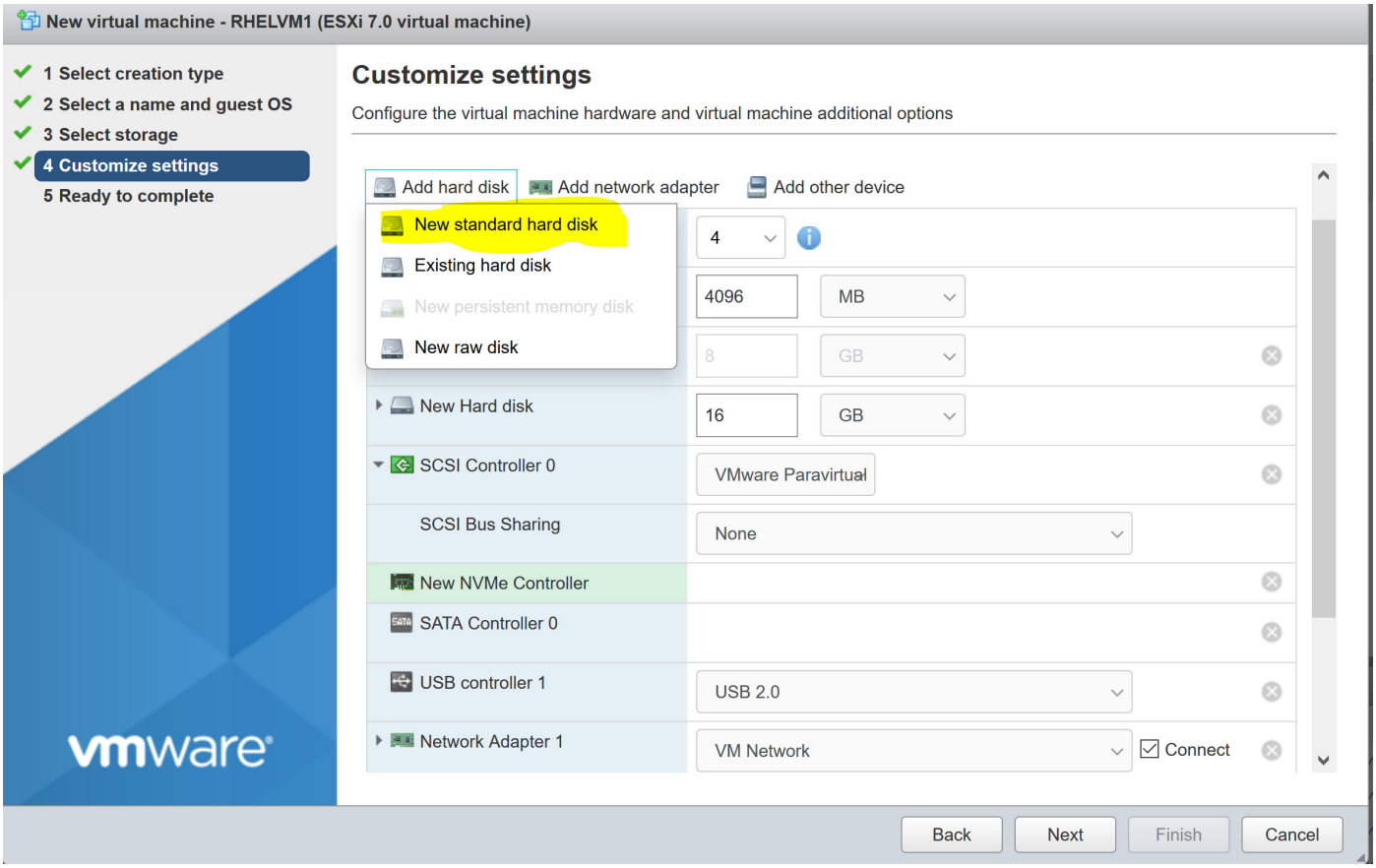
2. Select a name and a guest operating system for the virtual machine following the instructions provided by VMware. The **Select storage** dialog appears.



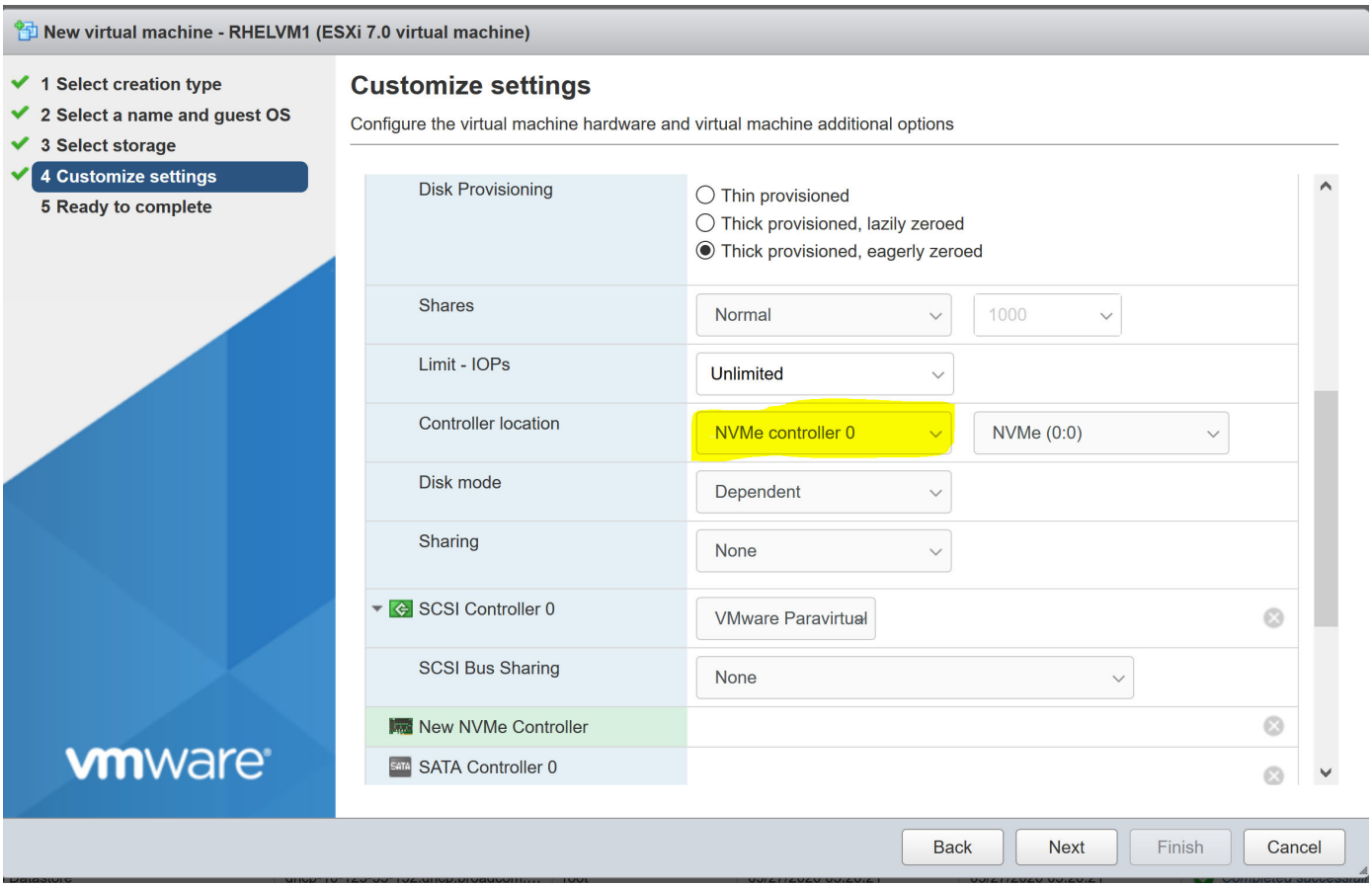
3. Select the datastore on which you want to create the VM and click **Next**. The **Customize settings** dialog appears.



4. Click **Add other device** and select **NVMe controller** to add an NVMe controller on the VM.
5. Click **Add hard disk** to attach the NVMe datastore as a new standard hard disk.



6. Select the NVMe controller on which to attach the new namespace, and click **Next**.



7. Verify your selections, and click **Finish**.

Repeat this procedure for each VM, and power on the VMs. NVMe over FC is configured on the initiator system.

Chapter 3: SCSI and NVMe Comparison

This section compares the availability of NVMe features against SCSI features.

The following table compares driver features.

Table 1: SCSI and NVMe Driver Feature

SCSI Feature	NVMe Feature
NPIV support	Not implemented in this release
VMID support	Not implemented in this release
Key value support for the transport driver	Not implemented in this release
External T10DIF	Not supported

Refer to the *Emulex NVMe over FC for ESXi 7.0 Release Notes* for known issues regarding NVMe over FC support.

Chapter 4: Troubleshooting

NVMe over FC on VMware ESXi 7.0 might operate in an unexpected manner in certain circumstances. This chapter describes such situations and their potential resolutions. This chapter also provides information about NVMe-related `esxcli` commands that are used in resolving issues.

4.1 Troubleshooting the NVMe Driver

Table 2: Troubleshooting the NVMe Driver

Situation	Resolution
An NVMe namespace is not available: ■ In the vSphere Client, the **Devices** tab under **Storage** does not list the namespace. ■ In the CLI, the command `esxcli nvme namespace list` does not show the namespace.	■ Make sure a controller is configured and visible. See Section 4.2.1, Checking the Status of an NVMe Controller for details on how to list the controllers. Refer to the target documentation for more details. ■ Make sure that the FC zones are properly configured. Refer to the switch documentation for more details. ■ Make sure that the driver parameter `lpfc_enable-fc4-type` is set to `3`. Refer to the *Emulex Drivers for VMware ESXi User Guide* for more details.
NVMe paths in the device path list or in the **Paths** tab of the **Storage adapter** dialog appear as dead paths. In addition, messages similar to the following appear in the `/var/log/vmkernel.log` file: ■ `Error claiming path vmhba <path_name>` ■ `cannot claim path <path_name> to 4K device`	Change the target VMFS block size for the namespace to 512 bytes.
In a multipath environment, NVMe paths in the device path list or in the **Paths** tab of the **Storage adapter** dialog appear as dead paths. If you run the `esxcfg-mpath -b` command (see Section 4.2.5, Viewing Multipath Information), LUNs appear as `dead`, and adapters and targets appear as `Unavailable`. If you run the `esxcli nvme controller list` command, NVMe contollers appear as offline. In addition, messages similar to the following appear in the `/var/log/vmkernel.log` file: ■ `0214 RSCN received Data: <data>` ■ `5973 RSCN received event <event>` ■ `Start 10 sec devloss` ■ `keep alive IO error <error>` ■ `Request to start controller <controller_number> recovery`	To bring a path online, verify its target configuration and zone setting, and adjust them as needed. **NOTE:** If some target ports are down, multipathing allows I/O to fail over to active paths.
Buffers become empty, or performance is slow. Messages similar to the following appear in the `/var/log/vmkernel.log` file: `6065 buffer pool is empty`	The FCP driver uses a separate buffer pool for NVMe resources. You can increase the buffers allocated for NVMe by reducing the percentage of XRI resources allocated to the FCP driver using the `lpfc_xri_split` parameter. Refer to the *Emulex Drivers for VMware ESXi User Guide* for detailed information about the `lpfc_xri_split` parameter.

Table 2: Troubleshooting the NVMe Driver (Continued)

Situation	Resolution
A newly added NVMe controller is not visible. Stale entries cannot be removed by a rescan.	Perform an initiator port link reset. For example, you can issue a LIP to an initiator port by typing the following command: `/usr/lib/vmware/vmkmgmt_keyval/vmkmgmt_keyval -i <vmhba>/Emulex -k adapter -s lip` where <*vmhba*> is the HBA number.

4.2 Using VMware Commands

This section provides information about VMware commands that you can use in troubleshooting NVMe issues.

4.2.1 Checking the Status of an NVMe Controller

To check the status of an NVMe controller, perform the following steps:

1. If necessary, determine the mapping between an NVMe namespace and an NVMe controller by typing the following command:
   `esxcli nvme namespace list`
   Information similar to the following is displayed:

```
Name                                    Controller Number  Namespace ID  Block Size  Capacity in MB
--------------------------------------- -----------------  ------------  ----------  --------------
uuid.cfb11df2e43a49779293f41319de4fb0   259                1             512         5120
uuid.cfb11df2e43a49779293f41319de4fb1   259                2             512         5120
uuid.cfb11df2e43a49779293f41319de4fb2   259                3             512         5120
uuid.cfb11df2e43a49779293f41319de4fb3   259                4             512         5120
uuid.cfb11df2e43a49779293f41319de4fb4   259                5             512         5120
uuid.cfb11df2e43a49779293f41319de4fb5   259                6             512         5120
uuid.cfb11df2e43a49779293f41319de4fb6   259                7             512         5120
uuid.cfb11df2e43a49779293f41319de4fb7   261                1             512         5120
uuid.cfb11df2e43a49779293f41319de4fb8   259                8             512         102400
uuid.cfb11df2e43a49779293f41319de4fb9   261                2             512         5120
uuid.cfb11df2e43a49779293f41319de4fba   261                3             512         5120
uuid.cfb11df2e43a49779293f41319de4fdb   259                9             512         5120
```

   You can obtain the NVMe controller number for the specific namespace from the displayed information.

NOTE: If the desired namespace is not listed, verify that the controller is connected (see the next step), the target is connected (see Section 4.2.2, Verifying that NVMe Target Ports Are Discovered), and NVMe is configured properly (Section 4.2.3, Listing NVMe Adapters on an ESXi Host).

2. To view the NVMe controller status, type the following command:
   `esxcli nvme controller list`
   Information similar to the following is displayed:

```
                                                                  Con-                Trans
                                                                  troller             -port Is
Name                                                              Number  Adapter     Type  Online
----------------------------------------------------------------  ------  ----------  ----  ------
nqn.1992-                                                         262     vmhba64     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba64#203c00a0986e4449:203e00a0986e4449
nqn.1992-                                                         264     vmhba66     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba66#203c00a0986e4449:203e00a0986e4449
nqn.1992-                                                         265     vmhba67     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba67#203c00a0986e4449:203e00a0986e4449
nqn.1992-                                                         263     vmhba65     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba65#203c00a0986e4449:203e00a0986e4449
nqn.1992-                                                         392     vmhba64     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba64#203c00a0986e4449:206600a0986e4449
nqn.1992-                                                         391     vmhba66     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba66#203c00a0986e4449:206600a0986e4449
nqn.1992-                                                         393     vmhba65     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba65#203c00a0986e4449:206600a0986e4449
nqn.1992-                                                         394     vmhba67     FC    true
08.com.netapp:sn.54a936ec00ac11ea829d00a0986e444a:subsystem.nvmevs_pa
ramesxi7_ss01#vmhba67#203c00a0986e4449:206600a0986e4449
```

3. Locate the controller you identified in Step 1. Its status is listed under `Is Online`.

4.2.2 Verifying that NVMe Target Ports Are Discovered

The following variables are used in this section:

- <*vmhba*> is the HBA number.

To list the NVMe target ports that are discovered by an initiator HBA port, type the following command:
`/usr/lib/vmware/vmkmgmt_keyval/vmkmgmt_keyval --instance <vmhba>/Emulex --get --key node`

Information similar to the following is displayed:

```
Key 'node':
lpfc Node page:

WWNN                      WWPN                      SCSI ID DID       Type      Status
10:00:00:05:33:7f:2f:56   20:0e:00:05:33:7f:2f:56   xffffe            Fabric    Node ok
10:00:00:05:33:7f:2f:56   21:fc:00:05:33:7f:2f:56   xfffffc           Fabric    Node ok
20:3c:00:a0:98:6e:44:49   20:3e:00:a0:98:6e:44:49   xcf1503           Target    Node ok
```

4.2.3 Listing NVMe Adapters on an ESXi Host

To list the NVMe adapters on an ESXi host, type the following command:

```
esxcli nvme adapter list
```

Information similar to the following is displayed:

```
Adapter     Adapter Qualified Name            Transport   Driver          Associated
                                              Type                        Devices
-------     ----------------------            ---------   ------          -----------
vmhba32     aqn:brcmnvmefc:100000109b8f2bea   FC          brcmnvmefc
vmhba33     aqn:brcmnvmefc:100000109b8f2beb   FC          brcmnvmefc
vmhba34     aqn:brcmnvmefc:10000090fa9488c9   FC          brcmnvmefc
vmhba35     aqn:brcmnvmefc:10000090fa9488ca   FC          brcmnvmefc
```

4.2.4 Discovering NVMe Controllers Connected to Target Ports

The following variables are used in this section:

- <*vmhba*> is the ESXi Host HBA number.
- <*wwpn*> is the WWPN of the target HBA.
- <*wwnn*> is the WWNN of the target HBA.

To list the NVMe controllers that are connected to target ports, type the following command:

```
esxcli nvme fabrics discover -a <vmhba> -w <wwpn> -W <wwnn> -c
```

Information similar to the following is displayed:

```
Trans-  Address Sub-    Controller Admin Transport Address  Trans-  Subsystem NQN             Con-
port    Family  system  ID         Queue                    port                              nected
Type            Type               Max                      Service
                                   Size                     ID
------  -----   ------  ------     -----  ----------------- -------  --------------           ------
Fibre   Fibre   NVM     65535      32     nn-               None     nqn.1992-                True
Channel Channel                           0x203c00a0986e4449         08.com.netapp:sn.54a936ec0
                                          :pn-                       0ac11ea829d00a0986e444a:su
                                          0x203e00a0986e4449         bsystem.nvmevs_paramesxi7_
                                                                     ss01
```

4.2.5 Viewing Multipath Information

To view multipath information, type the following command:

```
esxcfg-mpath -b
```

Information similar to the following is displayed:

```
uuid.a597cb7a665c410e88e59f3a3d4c134e : NVMe Fibre Channel Disk
(uuid.a597cb7a665c410e88e59f3a3d4c134e)
   vmhba32:C0:T0:L0 LUN:0 state:active fc Adapter: WWNN: 20:00:00:10:9b:8f:2b:ea WWPN:
10:00:00:10:9b:8f:2b:ea  Target: WWNN: 20:3c:00:a0:98:6e:44:49 WWPN: 20:3e:00:a0:98:6e:44:49
   vmhba33:C0:T1:L0 LUN:0 state:standby fc Adapter: WWNN: 20:00:00:10:9b:8f:2b:eb WWPN:
10:00:00:10:9b:8f:2b:eb  Target: WWNN: 20:3c:00:a0:98:6e:44:49 WWPN: 20:66:00:a0:98:6e:44:49
   vmhba33:C0:T0:L0 LUN:0 state:active fc Adapter: WWNN: 20:00:00:10:9b:8f:2b:eb WWPN:
10:00:00:10:9b:8f:2b:eb  Target: WWNN: 20:3c:00:a0:98:6e:44:49 WWPN: 20:3e:00:a0:98:6e:44:49
   vmhba32:C0:T1:L0 LUN:0 state:standby fc Adapter: WWNN: 20:00:00:10:9b:8f:2b:ea WWPN:
10:00:00:10:9b:8f:2b:ea  Target: WWNN: 20:3c:00:a0:98:6e:44:49 WWPN: 20:66:00:a0:98:6e:44:49
```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