# Lenovo

# Configuring VMware VMDirectPath I/O Passthrough with NVMe SSDs on ThinkSystem Servers

Describes how to make NVMe drives available to ESXi virtual machines Provides steps to implement VMDirectPath I/O on ESXi 7.0 and a RHEL 7.8 guest OS

Lists which NVMe Switch Adapters support the passthrough function

Shows how to confirm that the NVMe SSDs are working normally in VMs

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# Abstract

VMDirectPath I/O (PCI passthrough) enables direct assignment of hardware PCI functions such as NVMe solid-state drives to a virtual machine. This gives the VM access to the PCI functions with minimal intervention from the ESXi host, potentially improving performance.

In this paper we describe how to configure NVMe SSDs passthrough as PCI devices to VMs on Lenovo® ThinkSystem<sup>™</sup> servers. We provide step-by-step instructions using ESXi 7.0 U1.

This paper is intended for IT specialists and IT managers who want to learn more about NVMe SSDs passthrough.

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# Introduction

NVMe passthrough enables direct assignment of hardware NVMe devices to VMs. This gives the VM access to the NVMe SSDs with minimal intervention from the ESXi host, potentially improving performance. It is suitable for performance-critical workloads such as storage acceleration for VMs, and other high-speed storage solutions such as NetApp storage solutions.

While VMDirectPath I/O can improve the performance of a VM, enabling it makes several important features of vSphere unavailable to the VM, such as Suspend and Resume, Snapshots, Fault Tolerance, and vMotion.

Virtual Mach	ine		
Application			
	Guest	OS Kernel	
Lenovo	VMv	ware ESXi	
DirectP	ath I/(	n	

Figure 1 shows a workflow of DirectPath I/O.

Figure 1 Passthrough workflow

The prerequisites for VMDirectPath I/O are as follows:

- Verify that your NVMe SSD devices and PCIe NVMe switchs are supported in the specific ThinkSystem server you are using. Refer to Table 1 on page 4.
- Verify that the host has Intel Virtualization Technology for Directed I/O (VT-d) or AMD I/O Virtualization Technology (IOMMU) is enabled in BIOS of the server.

Notes:

1. Not all ESX servers have full support for VMDirectPath. Please refer to:

https://kb.vmware.com/s/article/2142307

2. A maximum of 16 passthrough devices is supported per VM on ESXi 6.x and 7.x. For the supported maximum devices number of each version of VMware vSphere, refer to:

https://configmax.vmware.com/

Onboard NVMe ports and the ThinkSystem 1611-8P NVMe Switch Adapter support VMDirectPath I/O Passthrough as indicated in Table 1.

Table 1 Support for VMDirectPath I/O Passthrough

NVMe connection	Support for VMDirectPath I/O Passthrough					
Onboard NVMe ports						
Intel Xeon Scalable processors (Gen 1, 2, 3)	Supported <sup>a</sup>					
AMD EYPC processors (Gen 2, 3)	Supported					
NVMe Switch Adapters						
810-4P NVMe Switch Adapter	No support					
1610-4P NVMe Switch Adapter	No support					
1610-8P NVMe Switch Adapter	No support					
1611-8P NVMe Switch Adapter	Supported					

a. For support, Intel VMD must be disabled.

For the latest server support of the NVMe Switch Adapters, refer to the Lenovo ThinkSystem RAID Adapter and HBA Reference:

https://lenovopress.com/lp1288-thinksystem-raid-adapter-and-hba-reference#term=nvm
e%2520switch

You can verify the PCIe NVMe SSDs compatibility of Lenovo ThinkSystem servers using the VMware Compatibility Guide, Figure 2, available at:

https://www.vmware.com/resources/compatibility/search.php?deviceCategory=io

Search Compatibility Guide: ?	(e.g. compatibility or esx or 3.0)	All Listings	✓ Search
What are you looking for: 10 De	vices	Compatibility Guides -	Help Current Results: 3
Product Release Version:	I/O Device Type:	Features:	VID :
All	All	All	All
ESXi 7.0 U1	FC	4K	
ESXi 7.0	FCoE CNAs	512e	DID :
ESXi 6.7 U3	Memory Channel Attached Sto	rage (MC. 512e	All
ESXI 6.7 U2	NVMe	DIF/DIX (Type 1)	
ESXI 6.7 U1	<ul> <li>Network</li> </ul>	Enhanced Data Path - Interrupt m	ode SVID :
	SAS	Enhanced data path - Poll mode	All
Brand Name :	SAS-RAID	Firmware NetDump	
Inspur	SAS-SATA-NVME Tri-mode	GENEVE-Offload	Max SSID:
Intel	SAS/SATA-RAID	GENEVE-RxFilter	All
Inventec Corp	SATA	GPU Technology	
Kioxia Corporation			Posted Date Range:
Lenovo	Driver Types:	Driver Model:	All
	All	All	
Keyword:	Partner Async	native	
PCIESSD	VMware Inbox	vmklinux	<b>*</b>

Figure 2 VMware Compatiblity Guide

In this paper, we are using the ThinkSystem SR650 V2 server as our test server, since it supports both onboard NVMe ports and the 1611-8P NVMe Switch Adapter.

There are two scenarios corresponding to the different connection modes of NVMe SSDs:

- 1. Directly connected to the PCIe NVMe ports on the motherboard
- Connected to a PCIe NVMe Switch Adapter which is plugged into the PCIe riser on the motherboard.

# Scenario 1: Connecting the NVMe SSDs to onboard NVMe ports

This scenario is divided into three steps:

- Step 1: Configure the UEFI Options"
- ▶ "Step 2: Install vSphere and VM, then configure NVMe SSDs passthrough" on page 7
- "Step 3: Check the NVMe SSDs on VM" on page 11

#### Step 1: Configure the UEFI Options

The PCIe NVMe ports (from PCIe port1 to port6) on the Lenovo SR650 V2 motherboard are multi-purpose ports. If we enable Intel VMD (Volume Management Device) in the UEFI setup, the PCIe port will be controlled by the VMD function. We need to configure these ports as the PCIe port and disable the VMD function in UEFI setup option.

**AMD processor servers:** AMD processor-based servers do not need a UEFI setting enabled, so this step can be skipped for these servers.

 Configure the UEFI setup: Enter the UEFI setup by pressing the F1 at server booting, choose System Settings → Devices and I/O Ports → Intel VMD technology → Enable/Disable Intel VMD and then change the option to Disabled as shown in Figure 3.

	Intel® VMD technology	
Enable∕Disable Intel© VMD	[Disabled]	Enable/Disable Intel© Volume Management Device Technology.
in the later MAD disabled		

Figure 3 Intel VMD disabled

- 2. Return to the main menu, save settings and reboot.
- Reenter UEFI setup by pressing the F1 at server boot, choose System Settings → Storage, and check that the NVMe SSDs have been identified in the list as shown in Figure 4.

Stora ▶ Bay 8: NVMe SSD 68-00-0 Bay 8 ▶ Bay 9: NVMe SSD 67-00-0 Bay 9	ge
▶ Bay 8: NVMe SSD 68-00-0 Bay 8 ▶ Bay 9: NVMe SSD 67-00-0 Bay 9	
▶ Bay 8: NVMe SSD 68-00-0 Bay 8 ▶ Bay 9: NVMe SSD 67-00-0 Bay 9	

Figure 4 SDD listing

4. Select an entry in the list to view the details of the drive, as shown in Figure 5.

	NVMe SSD 68-00-0 Bay 8	
POT Connector To Connect for		
PCI Generic Information	00000000000086538552000	
0010	5EE01	
Card Name	U.2 1.6TB Enterprise	
	Mainstream NVMe PCIe 3.0	
	Hot Swap SSD	
Manufacturer	Lenovo (Toshiba)	
Serial Number	79J0A008T00G	
Part Number	SSS7A23332	
Model	KCM51VUG1T60	
Card SKU	01PE204	
FoD UID	N/A	
Max Data Width	×4	
Connector Layout	PCI-E ×4	
Package Type	Storage Media Package	
Other Package Type	N/A	
AIM Spec Version	2.00	
UCM Version	N/A	
Firmware Information 1	•	
†↓=Move Highlight	<enter>=Select Entry <esc>=Backwards</esc></enter>	

Figure 5 Details of the selected SSD

5. Return to the main menu, save settings and reboot.

### Step 2: Install vSphere and VM, then configure NVMe SSDs passthrough

1. Install the OS. In our testing, we installed ESXi 7.0 U1 on the ThinkSystem SR650 V2 server, Figure 6.



Figure 6 Installing ESXi 7.0 U1

2. Enter the Host client, Figure 7



Figure 7 Login to the host client

3. Create a new VM and install OS on the VM as shown in Figure 8. We install REHL 8.3 as an example.



Figure 8 Creating the guest VM

4. Check the VM that has been installed, Figure 9.



Figure 9 VM configuration

5. From the left-hand navigation menu, click **Manage** and select **Hardware**  $\rightarrow$  **PCI Devices** and find the two NVMe SSD devices. Select them click **Toggle Passthrough**, Figure 10

Navigator	localhost.labs.lenovo.com	Manage			
Host	System Hardware	Licensing Packages S	ervices Security & users		
Manage					
Monitor	PCI Devices	Stroggle passthrough	Configure SR-IOV / Hardware label Streboot host	C Refresh	Q Search
Virtual Machines	Power Management	🗋., Address 🗸	Description	SR-IOV V	Passthro V Hardware V
Monitor		0000:64:02.0	Intel Corporation PCI bridge	Not capable	Not capable
More VMs			Intel Corporation PCI bridge	Not capable	Not capable
Storage	2	0000:64:04.0	Intel Corporation PCI bridge	Not capable	Not capable
* datastore1		<b>2</b> 0000:67:00.0	Toshiba Corporation Thinksystem U.2 CM5 NVMe SSD	Not capable	Disabled
Monitor		0000:64:05.0	Intel Corporation PCI bridge	Not capable	Not capable
More storage		0000:68:00.0	Toshiba Corporation Thinksystem U.2 CM5 NVMe SSD	Not capable	Disabled
Networking		Quick filters	U		291 items

Figure 10 Enabling passthrough on the SSDs

- 6. Some versions of VMware vSphere may prompt that system needs to reboot ESXi host to take effect. Reboot the server if prompted to do so at this point.
- 7. The status of passthrough for the devices should now change to "Active" as shown in Figure 11.

+ 🗍 Host	System Hardware	Licensing Packages S	Services Security & users		
Manage	Contraction of the second second second	<u></u>			
Monitor	PCI Devices	😹 Toggle passthrough	🥜 Configure SR-IOV 📝 Hardware label 🛛 🚯 Reboot host 🌖	C Refresh	Q Search
Virtual Machines	Power Management	🗌., Address 🗸 🗸	Description	SR-IOV ~	Passthro 🗸 Hardware 🗸
Monitor			Toshiba Corporation Thinksystem U.2 CM5 NVMe SSD	Not capable	Active
More VMs		0000:64:05.0	Intel Corporation PCI bridge	Not capable	Not capable
* El Storage			Toshiba Corporation Thinksystem U.2 CM5 NVMe SSD	Not capable	Active
• 🗐 datastore1		0000:7e:00.0	Intel Corporation System peripheral	Not capable	Not capable
Monitor			Intel Corporation System peripheral	Not capable	Not capable
More storage		0000:7e:00.2	Intel Corporation System peripheral	Not capable	Not capable
Q Networking		Quick filters	~		291 items

Figure 11 Drives are active

8. Go to the VM, Click the Edit button to edit settings of this VM, Figure 12.

Navigator	21	B NVMe_PassThru					
The set of the se	2	Console	Power on Power of Second Compatibility Wave Tools CPUs Memory	Suspend Restart Edit Red Hat Enterprise Linux 8 (64-bit) ESXI 7 U1 virtual machine Yes 4 4 GB	C Refresh Actions	15	CPU 0 MHz MEMORY 0 B STORAGE 100 GB
▼ ☐ datastore2		✓ General Information			* Hardware Configuration		
Monitor		Networking			• 🖬 CPU	4 vCPUs	
Networking	100	VMware Tools	VMware Tools is not m	anaged by vSphere	Memory	4 GB	
Networking		▶ I Storage	1 disk		Hard disk 1	100 GB	
		Di Notes		🥖 Edit notes	USB controller	USB 2.0	
					Network adapter 1	VM Network (Connected)	

Figure 12 Edit the VM

9. Click the Add other device  $\rightarrow$  PCI device, Figure 13.

Artual Hardware VM Options					
Add hard disk 🛤 Add networ	k adapter	Add other device			
CPU	4	CD/DVD drive			
Memory	4	Senal port			
Hard disk 1	100	Parallel port			٥
SCSI Controller 0	VM	USB controller			0
SATA Controller 0		Sound controller			0
USB controller 1	ús	Ter PCI device	÷		0
Network Adapter 1	VM	Dynamic P PCI device	~ 🗹 (	Connect	٥
GD/DVD Drive 1	Dat	SCSI controller	~ 00	Connect	0
Video Card	Def	NVMe controller	U.		

Figure 13 Add PCI device to the VM

10.Add the two NVMe SSDs as new PCI device and click Save to save the configuration, Figure 14.

Memory	4	GB 🗸			
Hard disk 1	100	GB v			0
SCSI Controller 0	VMware	Paravirtual			0
SATA Controller 0					0
USB controller 1			~		0
Retwork Adapter 1	VM Netw	rork	Ŷ	Connect	0
SCD/DVD Drive 1	Datastor	e ISO file	~	Connect	0
Video Card	Default s	ettings	~		
New PCI device	Thinksys	tem U.2 CM5 NVMe SSD	- 0000.67.00.0	v	0
New PCI device	Thinksys	tem U 2 CM5 NVMe SSD	- 0000:68:00.0	-	0

Figure 14 Add the SSDs to the VM

11. When the device is assigned, the VM must have a memory reservation for the full configured memory size. This means that we need to configure the memory reservation for NVMe devices and requires setting the reservation size equal to the memory capacity size. In Figure 15, you can either choose **Reserve all guest memory (All locked)** or fill the same size in the Reservation option, and save the configuration.

Virtual Hardware VM Options		
🛄 Add hard disk 🛤 Add net	vork adapter 🛛 🗏 Add other device	
CPU	4 0	
Memory		
RAM	4096 MB 🗸	
Reservation	None v MB v	
	Reserve all guest memory (All locked)	
Limit	Unlimited V MB V	
Shares	Normal ~ 1000 ~	
Memory Hot Plug	Enabled	
Hard disk 1	100 GB 🗸	0

Figure 15 Memory reservation

## Step 3: Check the NVMe SSDs on VM

- 1. Power on the VM. Our test environment uses a RHEL 8.3 guest OS.
- 2. Log in as an administrator and open a terminal.
- 3. Enter the command to find the NVMe SSDs which we configured as available via passthrough to the VM:

#### lspci | grep -i nvme



Figure 16 Ispci command output

4. Check the dmesg to make sure there are no errors or warnings in the log:

dmesg | grep - i nvme

[root@localhost ~]#	dmesg   grep -i nvme
[ 10.653080] nvme	nvme0: pci function 0000:13:00.0
[ 10.653165] nvme	nvmel: pci function 0000:1b:00.0
[ 10.653346] nvme	0000:13:00.0: enabling device (0000 -> 0002)
[ 10.657802] nvme	0000:1b:00.0: enabling device (0000 -> 0002)
[ 10.773986] nvme	nvme0: Shutdown timeout set to 16 seconds
[ 10.774045] nvme	nvme1: Shutdown timeout set to 16 seconds
[ 11.823029] nvme	nyme1: 4/0/0 default/read/poll queues
[ 11.824738] nvme	nvme0: 4/0/0 default/read/poll queues
[ 11.841976] nvm	elnl: pl p5 p6 p7 p8
[ 11.845611] nvm	0n1:

Figure 17 dmesg command output

5. Use fdisk to check if the hard disk has been mounted successfully.

fdisk -1



6. Now, the NVMe devices have been configured passthrough to the VM successfully, and you can access and use it as a real drive in the virtual OS.

# Scenario 2: Connecting the NVMe SSDs to an NVMe Switch

In this scenario, the SSDs you wish to enable passthrough on are connected via an NVMe Switch Adapter.

Note: First, we need to confirm that the NVMe switch supports PCI passthrough function. At present, there is a ThinkSystem 1611-8P NVMe Switch Adapter that can support this function on the corresponding Lenovo serves.

#### Step 1: Configure the UEFI Options

 Enter the UEFI setup by pressing the F1 at server booting, choose System Settings → Storage, and check that the NVMe switch and NVMe SSDs have been identified in the list, Figure 19.

Storage ▶ Bay 15: NVMe SSD 98–00–0 Bay 15 ▶ Bay 14: NVMe SSD 9C-00–0 Bay 14	Storage x5) Configuration
▶ Bay 15: NVMe SSD 9B-00-0 Bay 15 ▶ Bay 14: NVMe SSD 9C-00-0 Bay 14	x5) Configuration
▶ Bay 14: NVMe SSD 9C-00-0 Bay 14	x5) Configuration
	x5) Configuration
▶ Slot 5: 1611–8P NVMe Switch (PCISlot=0x5) Contiguration	

Figure 19 PCIe device listing - adapter and NVMe drives

2. Check the NVMe switch properties, and ensure the firmware is in recent versions, Figure 20.

Model Name PCI Bus:Dev:Func PCI Slot PCI VendorID:DeviceID Status Lenovo Serial Number Broadcom Serial Number Firmware Version UEFI HII Version Ports SLOT PROPERTIES Slot : PCIE Link 078 : G3:x4 / G4:x4 079 : G3:x4 / G4:x4	PEX88048 0xA3:0x00:0x0 5 0x1000:0x00B2 0ptimal (42 Celsius) L1ST03RS013 SP01201949 05.01.185.01 00.02.100.00 8	This field displays the model name programmed in the manufacturing data.
†∔=Move Highlight	<enter≻=select entry<="" td=""><td><esc>=Backwards</esc></td></enter≻=select>	<esc>=Backwards</esc>

Figure 20 Switch Adapter properties

### Step 2: Configure NVMe SSDs passthrough

We can repeat the steps in "Step 2: Install vSphere and VM, then configure NVMe SSDs passthrough" on page 7, then configure NVMe SSDs passthrough.

1. Activate the passthrough function of the NVMe SSDs, Figure 21.

- 🗐 Host	System Hardware	Licensing	Packages	Services	Security & user	5				
Manage										
Monitor	PCI Devices	8	Toggle passthrough	/ Co	nfigure SR-IOV 🥖 I	tardware label 🛛 💽 Reboo	t host C Refresh		(0	L Search
💮 Virtual Machines 👘	Power Management		Address v	Descrip	ition om PCI bridge		v	SR-IOV NOT CAPADIO	<ul> <li>Passthrough</li> <li>Not capablo</li> </ul>	✓ Hardware La ✓
Monitor		C	0000.9c.00.0	Toshiba	Corporation Thinksys	tem U.2 CM5 NVMe SSD		Not capable	Active	
More VMs * 🖬 Storage			0000 9a 00.0	Broadd	om PCI bridge			Not capable	Not capable	
		C	0.00.00 0000	Toshiba Corporation Thinksystem U.2 CM5 NVMe SSD			Not capable	Active		
* 🗐 datastore2			0.00 b0 00.0	Intel Co	provide the system period	pheral		Not capable	Not capable	
Monitor			0000.60.00.1	Intel Co	provide the system per	pheral		Not capable	Not capable	
More storage			0000 60 00 2	Intel Co	provide the system per	pheral		Not capable	Not capable	
Networking	1		0000.b0.00.4	Intel G	provation Host bridge			Not capable	Not capable	
			0000 b0 02 0	Intel Co	proportaion PCI bridge			Not capable	Not capable	
		c	uick filters		~					305 Item
	Recent tasks									
	Task	~	Target	v	Initiator ~	Queued ~	Started	<ul> <li>Result .</li> </ul>		<ul> <li>Completed •</li> </ul>
	Update Passthru Config	1	ocalhost labs lenovo	com	root	01/05/2021 07:30:20	01/05/2021 07:30:20	Complete	d successfully	01/05/2021 0

Figure 21 Activate passthrough on the NVMe SSDs

2. Add the NVMe SSDs to the VM, Figure 22.

Artual Hardware VM Options					
Add hard disk 🛤 Add netwo	ork adapter 🛛 🚍 /	Add other device			
CPU	4 ~	0			
Memory	4	GB	~		
Hard disk 1	100	GB	~		ø
SCSI Controller 0	VMware	Paravirtual			ø
SATA Controller 0					0
Network Adapter 1	VM Netw	ork	v	Connect	0
Video Card	Default s	ettings	Ŷ		
New PCI device	Thinksys	tem U.2 CM5 NVMe	SSD - 0000 9b 00 0	~	0
New PCI device	Thinksus	Iom 11.2 CM5 MAda	SSD 0000 0+ 00 0	21	0

Figure 22 Add the SSDs to the VM

3. Keep the reservation size equal to the memory capacity size, Figure 23.

Artual Hardware VM Options		
Add hard disk 🛤 Add net	ork adapter 🛛 🚍 Add other device	
CPU	4 ~ (1)	
Memory		
RAM	4096 MB ~	
Reservation	4096 ~ MB ~	
	Reserve all guest memory (All locked)	
Limit	Unlimited V MB V	
Shares	Normal ~ 1000 ~	
Memory Hot Plug	Enabled	
Hard disk 1	100 GB 🗸	0

Figure 23 Memory reservation

#### Step 3: Check the NVMe SSDs on VM

At the end, we can find these NVMe SSDs in the VM and verify there are no errors or warnings of NVMe SSDs in the log. Use the same commands as described in "Step 3: Check the NVMe SSDs on VM" on page 11. The output is shown in Figure 24.

NVMe_PassThru		🕼 🖬 🗂 🛄 🖨 Actions 🚷
e Activities 🕨	] Terminal - Jan 4 18:57	(1) (1) -
5	root@localhost:~	×
File Edit View	Search Terminal Help	
[root@localhost 13:00.0 Non-Vol 1b:00.0 Non-Vol [root@localhost [ 10.152854] [ 10.152925] [ 10.152927] [ 10.162615] [ 10.389871] [ 11.454493] [ 11.454493] [ 11.454493] [ 11.478152] [root@localhost GPT PMBR size r Disk /dev/nwme0nlp3 /dev/nwme0nlp5 /dev/nwme0nlp5 /dev/nwme0nlp5	<pre>t ~]# lspci   grep -i nvme latile memory controller: Toshiba Corporation NVMe SSD Controller Cx5 (rev 01) latile memory controller: Toshiba Corporation NVMe SSD Controller Cx5 (rev 01) t -]# dmesg   grep -i nvme nvme nvme0: pci function 0000:13:00.0 nvme nvme1: pci function 0000:13:00.0 nvme nvme1: pci function 0000:15:00.0 nvme nvme1: pci function 0000:15:00.0 nvme nvme1: shutdown timeout set to 16 seconds nvme nvme0: 4/0/0 default/read/poll queues nvme nvme0: 4/0/0 default/read/poll queues nvment: nvme0: 1: pi p5 p6 p7 p8 t ~]# fdisk -l   grep -i nvme mismatch (3125627534 != 3125627567) will be corrected by write. In1: 745.2 GiB, 800166076416 bytes, 1562824368 sectors 001: 1.5 TiB, 1600321314816 bytes, 3125627568 sectors 64 204863 204800 100M EFI System 208896 8595555 8386560 46 Microsoft basic data 8597504 16984063 8386560 46 Microsoft basic data 16986112 2068435455 251449344 119.9G unknown 20884754 3125627544 2852790831 13 TVMware VMES</pre>	

Figure 24 output from lspci, dmesg and fdisk commands

Now, the NVMe devices have been configured passthrough to the VM successfully, and you can access and use it as a real drives in the virtual OS.

# References

 vSphere VMDirectPath I/O and Dynamic DirectPath I/O: Requirements for Platforms and Devices

https://kb.vmware.com/s/article/2142307

VMware Configuration Maximums

https://configmax.vmware.com/

► vSphere VCG

https://www.vmware.com/resources/compatibility/search.php

- Storage Options for ThinkSystem Servers https://lenovopress.com/lp0761-storage-options-for-thinksystem-servers
- ► NVMe-Rich Configurations of the ThinkSystem SR650

https://lenovopress.com/lp0904-nvme-rich-configurations-of-the-sr650

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