



SUSE Linux Enterprise Server 12 SP5

# Virtualization Guide

## Virtualization Guide

SUSE Linux Enterprise Server 12 SP5

Describes virtualization technology in general, and introduces libvirt—the unified interface to virtualization—and detailed information on specific hypervisors.

Publication Date: December 12, 2024

<https://documentation.suse.com> 

Copyright © 2006–2024 SUSE LLC and contributors. All rights reserved.

Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or (at your option) version 1.3; with the Invariant Section being this copyright notice and license. A copy of the license version 1.2 is included in the section entitled “GNU Free Documentation License”.

For SUSE trademarks, see <https://www.suse.com/company/legal/> . All third-party trademarks are the property of their respective owners. Trademark symbols (®, <sup>™</sup> etc.) denote trademarks of SUSE and its affiliates. Asterisks (\*) denote third-party trademarks.

All information found in this book has been compiled with utmost attention to detail. However, this does not guarantee complete accuracy. Neither SUSE LLC, its affiliates, the authors nor the translators shall be held liable for possible errors or the consequences thereof.

# Contents

## About This Manual xvi

- 1 Available documentation xvi
- 2 Improving the documentation xvii
- 3 Documentation conventions xviii
- 4 Support xx
  - Support statement for SUSE Linux Enterprise Server xx • Technology previews xxi

## I INTRODUCTION 1

### 1 Virtualization Technology 2

- 1.1 Overview 2
- 1.2 Virtualization Capabilities 3
- 1.3 Virtualization Benefits 3
- 1.4 Virtualization Modes 4
- 1.5 I/O Virtualization 5

### 2 Introduction to Xen Virtualization 7

- 2.1 Basic Components 7
- 2.2 Xen Virtualization Architecture 8

### 3 Introduction to KVM Virtualization 10

- 3.1 Basic Components 10
- 3.2 KVM Virtualization Architecture 10

<b>4</b>	<b>Introduction to Linux Containers</b>	<b>12</b>
<b>5</b>	<b>Virtualization Tools</b>	<b>13</b>
5.1	Virtualization Console Tools	13
5.2	Virtualization GUI Tools	14
<b>6</b>	<b>Installation of Virtualization Components</b>	<b>18</b>
6.1	Installing KVM	18
6.2	Installing Xen	18
6.3	Installing Containers	19
6.4	Patterns	19
6.5	Installing UEFI Support	20
<b>7</b>	<b>Supported Hosts, Guests, and Features</b>	<b>21</b>
7.1	Host Environments (Hypervisors)	21
7.2	Guest Environments	22
	Availability of Paravirtualized Drivers	23
7.3	KVM Hardware Requirements	23
7.4	Feature Support	24
	Host (Dom0)	24
	• Paravirtualized Guest	26
	• Fully Virtualized Guest	27
<b>II</b>	<b>MANAGING VIRTUAL MACHINES WITH libvirt</b>	<b>29</b>
<b>8</b>	<b>Starting and Stopping libvirtd</b>	<b>30</b>
<b>9</b>	<b>Guest Installation</b>	<b>32</b>
9.1	GUI-Based Guest Installation	32
9.2	Installing from the Command Line with <b>virt-install</b>	34

- 9.3 Advanced Guest Installation Scenarios 37
  - Memory Ballooning with Windows Guests 37 • Including Add-on Products in the Installation 38

## 10 Basic VM Guest Management 39

- 10.1 Listing VM Guests 39
  - Listing VM Guests with Virtual Machine Manager 39 • Listing VM Guests with **virsh** 40
- 10.2 Accessing the VM Guest via Console 40
  - Opening a Graphical Console 40 • Opening a Serial Console 42
- 10.3 Changing a VM Guest's State: Start, Stop, Pause 43
  - Changing a VM Guest's State with Virtual Machine Manager 44 • Changing a VM Guest's State with **virsh** 44
- 10.4 Saving and Restoring the State of a VM Guest 45
  - Saving/Restoring with Virtual Machine Manager 46 • Saving and Restoring with **virsh** 47
- 10.5 Creating and Managing Snapshots 47
  - Terminology 48 • Creating and Managing Snapshots with Virtual Machine Manager 48 • Creating and Managing Snapshots with **virsh** 50
- 10.6 Deleting a VM Guest 53
  - Deleting a VM Guest with Virtual Machine Manager 53 • Deleting a VM Guest with **virsh** 53
- 10.7 Migrating VM Guests 53
  - Migration Requirements 54 • Supported Migration Scenarios 55 • Migrating with Virtual Machine Manager 55 • Migrating with **virsh** 57 • Step-by-Step Example 58
- 10.8 Monitoring 61
  - Monitoring with Virtual Machine Manager 61 • Monitoring with **virt-top** 62 • Monitoring with **kvm\_stat** 63

## 11 Connecting and Authorizing 65

### 11.1 Authentication 65

libvirtd Authentication 66 • VNC Authentication 70

### 11.2 Connecting to a VM Host Server 74

“system” Access for Non-Privileged Users 75 • Managing Connections with Virtual Machine Manager 76

### 11.3 Configuring Remote Connections 77

Remote Tunnel over SSH (qemu+ssh or xen+ssh) 78 • Remote TLS/SSL Connection with x509 Certificate (qemu+tls or xen+tls) 78

## 12 Managing Storage 86

### 12.1 Managing Storage with Virtual Machine Manager 88

Adding a Storage Pool 89 • Managing Storage Pools 92

### 12.2 Managing Storage with **virsh** 94

Listing Pools and Volumes 94 • Starting, Stopping and Deleting Pools 96 • Adding Volumes to a Storage Pool 97 • Deleting Volumes from a Storage Pool 98 • Attaching Volumes to a VM Guest 98 • Detaching Volumes from a VM Guest 99

### 12.3 Locking Disk Files and Block Devices with **virtlockd** 100

Enable Locking 100 • Configure Locking 101

### 12.4 Online Resizing of Guest Block Devices 102

### 12.5 Sharing Directories between Host and Guests (File System Pass-Through) 103

### 12.6 Using RADOS Block Devices with **libvirt** 104

## 13 Managing Networks 105

### 13.1 Network Bridge 105

Managing Network Bridges with YaST 105 • Managing Network Bridges from the Command Line 106 • Using VLAN Interfaces 108

- 13.2 Virtual Networks **109**
  - Managing Virtual Networks with Virtual Machine Manager **110** • Managing Virtual Networks with **virsh** **114**
- 14 Configuring Virtual Machines 120**
  - 14.1 Machine Setup **121**
    - Overview **121** • Performance **122** • Processor **123** • Memory **124** • Boot Options **125**
  - 14.2 Storage **126**
  - 14.3 Controllers **127**
  - 14.4 Networking **128**
  - 14.5 Enabling Seamless and Synchronized Mouse Pointer Movement **130**
  - 14.6 Adding a CD/DVD-ROM Device with Virtual Machine Manager **130**
  - 14.7 Adding a Floppy Device with Virtual Machine Manager **131**
  - 14.8 Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager **132**
  - 14.9 Editing VM Configuration with **virsh** **133**
  - 14.10 Changing the Machine Type with **virsh** **134**
  - 14.11 Assigning a Host PCI Device to a VM Guest **135**
    - Adding a PCI Device with Virtual Machine Manager **135** • Adding a PCI Device with **virsh** **136**
  - 14.12 Assigning a Host USB Device to a VM Guest **139**
    - Adding a USB Device with Virtual Machine Manager **139** • Adding a USB Device with **virsh** **140**
  - 14.13 Adding SR-IOV Devices **141**
    - Requirements **142** • Loading and Configuring the SR-IOV Host Drivers **143** • Adding a VF Network Device to an Existing VM Guest **146** • Dynamic Allocation of VFs from a Pool **148**
  - 14.14 Using Macvtap to Share VM Host Server Network Interfaces **150**



- 14.15 Managing Guest Memory Allocation (Xen only) 151
- 14.16 Disabling a Memory Balloon Device 152
- 14.17 Configuring Multiple Monitors (Dual Head) 153

### III HYPERVISOR-INDEPENDENT FEATURES 155

## 15 Disk Cache Modes 156

- 15.1 Disk Interface Cache Modes 156
- 15.2 Description of Cache Modes 156
- 15.3 Data Integrity Implications of Cache Modes 158
- 15.4 Performance Implications of Cache Modes 159
- 15.5 Effect of Cache Modes on Live Migration 159

## 16 VM Guest Clock Settings 160

- 16.1 KVM: Using `kvm_clock` 160
  - Other Timekeeping Methods 161
- 16.2 Xen Virtual Machine Clock Settings 161

## 17 libguestfs 162

- 17.1 VM Guest Manipulation Overview 162
  - VM Guest Manipulation Risk 162 • libguestfs Design 163
- 17.2 Package Installation 163
- 17.3 Guestfs Tools 164
  - Modifying Virtual Machines 164 • Supported File Systems and Disk Images 164 • **virt-rescue** 165 • **virt-resize** 165 • Other virt-\* Tools 167 • **guestfish** 169 • Converting a Physical Machine into a KVM Guest 170
- 17.4 Troubleshooting 172
  - Btrfs-related Problems 172 • Environment 173 • **libguestfs-test-tool** 173

17.5 External References 173

IV MANAGING VIRTUAL MACHINES WITH XEN 174

**18 Setting Up a Virtual Machine Host 175**

18.1 Best Practices and Suggestions 175

18.2 Managing Dom0 memory 176

Setting a Maximum Amount of Memory 177

18.3 Network Card in Fully Virtualized Guests 178

18.4 Starting the Virtual Machine Host 178

18.5 PCI Pass-Through 180

Configuring the Hypervisor for PCI Pass-Through 181 • Assigning  
PCI Devices to VM Guest Systems 182 • VGA Pass-  
Through 182 • Troubleshooting 183 • For More Information 184

18.6 USB Pass-Through 184

Identify the USB Device 184 • Emulated USB Device 184 • Paravirtualized  
PVUSB 185

**19 Virtual Networking 187**

19.1 Network Devices for Guest Systems 187

19.2 Host-Based Routing in Xen 189

19.3 Creating a Masqueraded Network Setup 192

19.4 Special Configurations 194

Bandwidth Throttling in Virtual Networks 194 • Monitoring the Network  
Traffic 195

**20 Managing a Virtualization Environment 196**

20.1 XL—Xen Management Tool 196

Guest Domain Configuration File 197

20.2 Automatic Start of Guest Domains 198

20.3 Event Actions 198

20.4	Time Stamp Counter	199
20.5	Saving Virtual Machines	200
20.6	Restoring Virtual Machines	200
20.7	Virtual Machine States	201
<b>21</b>	<b>Block Devices in Xen</b>	<b>202</b>
21.1	Mapping Physical Storage to Virtual Disks	202
21.2	Mapping Network Storage to Virtual Disk	203
21.3	File-Backed Virtual Disks and Loopback Devices	203
21.4	Resizing Block Devices	204
21.5	Scripts for Managing Advanced Storage Scenarios	205
<b>22</b>	<b>Virtualization: Configuration Options and Settings</b>	<b>206</b>
22.1	Virtual CD Readers	206
	Virtual CD Readers on Paravirtual Machines	206 • Virtual CD Readers on Fully Virtual Machines 206 • Adding Virtual CD Readers 207 • Removing Virtual CD Readers 208
22.2	Remote Access Methods	208
22.3	VNC Viewer	208
	Assigning VNC Viewer Port Numbers to Virtual Machines	209 • Using SDL instead of a VNC Viewer 210
22.4	Virtual Keyboards	210
22.5	Dedicating CPU Resources	211
	Dom0	211 • VM Guests 212
22.6	HVM Features	212
	Specify Boot Device on Boot	213 • Changing CPUIDs for Guests 213 • Increasing the Number of PCI-IRQs 214

## 23 Administrative Tasks 215

- 23.1 The Boot Loader Program 215
- 23.2 Sparse Image Files and Disk Space 216
- 23.3 Migrating Xen VM Guest Systems 217
  - Preparing Block Devices for Migrations 218 • Migrating VM Guest Systems 219
- 23.4 Monitoring Xen 219
  - Monitor Xen with **xentop** 219 • Additional Tools 220
- 23.5 Providing Host Information for VM Guest Systems 221

## 24 XenStore: Configuration Database Shared between Domains 223

- 24.1 Introduction 223
- 24.2 File System Interface 223
  - XenStore Commands 224 • /vm 224 • /local/domain/<domid> 226

## 25 Xen as a High-Availability Virtualization Host 228

- 25.1 Xen HA with Remote Storage 228
- 25.2 Xen HA with Local Storage 229
- 25.3 Xen HA and Private Bridges 230

## V MANAGING VIRTUAL MACHINES WITH QEMU 231

## 26 QEMU Overview 232

## 27 Setting Up a KVM VM Host Server 233

- 27.1 CPU Support for Virtualization 233
- 27.2 Required Software 233
- 27.3 KVM Host-Specific Features 235
  - Using the Host Storage with **virtio-scsi** 235 • Accelerated Networking with **vhost-net** 236 • Scaling Network Performance with Multiqueue **virtio-**

net 237 • VFIO: Secure Direct Access to Devices 238 • VirtFS: Sharing Directories between Host and Guests 240 • KSM: Sharing Memory Pages between Guests 241

## 28 Guest Installation 243

28.1 Basic Installation with **qemu-system-ARCH** 243

28.2 Managing Disk Images with **qemu-img** 244

General Information on qemu-img Invocation 245 • Creating, Converting and Checking Disk Images 246 • Managing Snapshots of Virtual Machines with qemu-img 251 • Manipulate Disk Images Effectively 254

## 29 Running Virtual Machines with **qemu-system-ARCH** 259

29.1 Basic **qemu-system-ARCH** Invocation 259

29.2 General **qemu-system-ARCH** Options 259

Basic Virtual Hardware 260 • Storing and Reading Configuration of Virtual Devices 262 • Guest Real-Time Clock 263

29.3 Using Devices in QEMU 263

Block Devices 264 • Graphic Devices and Display Options 269 • USB Devices 271 • Character Devices 273

29.4 Networking in QEMU 275

Defining a Network Interface Card 275 • User-Mode Networking 276 • Bridged Networking 278

29.5 Viewing a VM Guest with VNC 281

Secure VNC Connections 284

## 30 Virtual Machine Administration Using QEMU Monitor 288

30.1 Accessing Monitor Console 288

30.2 Getting Information about the Guest System 289

30.3 Changing VNC Password 291

- 30.4 Managing Devices 292
- 30.5 Controlling Keyboard and Mouse 293
- 30.6 Changing Available Memory 293
- 30.7 Dumping Virtual Machine Memory 294
- 30.8 Managing Virtual Machine Snapshots 295
- 30.9 Suspending and Resuming Virtual Machine Execution 296
- 30.10 Live Migration 296
- 30.11 QMP - QEMU Machine Protocol 298
  - Access QMP via Standard Input/Output 298 • Access QMP via Telnet 299 • Access QMP via Unix Socket 300 • Access QMP via libvirt's **virsh** Command 301

## VI MANAGING VIRTUAL MACHINES WITH LXC 302

### 31 Linux Containers 303

- 31.1 Setting Up LXC Distribution Containers 303
- 31.2 Setting Up LXC Application Containers 306
- 31.3 Securing a Container Using AppArmor 307
- 31.4 Differences Between the libvirt LXC Driver and LXC 307
- 31.5 Sharing Namespaces Across Containers 309
- 31.6 For More Information 309

### 32 Migration from LXC to libvirt-lxc 310

- 32.1 Host Migration 310
- 32.2 Container Migration 310
- 32.3 Starting the Container 311

## Glossary 312

<b>A</b>	<b>Virtual Machine Drivers</b>	<b>323</b>
<b>B</b>	<b>Appendix</b>	<b>324</b>
B.1	Installing Paravirtualized Drivers	324
	Installing virtio Drivers for Microsoft Windows*	324
B.2	Generating x509 Client/Server Certificates	324
<b>C</b>	<b>XM, XL Tool Stacks and Libvirt framework</b>	<b>326</b>
C.1	Xen Tool Stacks	326
	Upgrading from xend/xm to xl/libxl	326 • XL design 327 • Checklist before Upgrade 328
C.2	Import Xen Domain Configuration into libvirt	328
C.3	Differences Between the <b>xm</b> and <b>xl</b> Applications	330
	Notation Conventions	330 • New Global Options 331 • Unchanged Options 331 • Removed Options 335 • Changed Options 338 • New Options 352
C.4	External links	353
C.5	Saving a Xen Guest Configuration in an <b>xm</b> Compatible Format	354
<b>D</b>	<b>GNU licenses</b>	<b>355</b>

# About This Manual

This manual offers an introduction to setting up and managing virtualization with KVM (Kernel-based Virtual Machine), Xen, and Linux Containers (LXC) on SUSE Linux Enterprise Server. The first part introduces the different virtualization solutions by describing their requirements, their installations and SUSE's support status. The second part deals with managing VM Guests and VM Host Servers with `libvirt`. The following parts describe various administration tasks and practices and the last three parts deal with hypervisor-specific topics.

## 1 Available documentation

### Online documentation

Our documentation is available online at <https://documentation.suse.com>. Browse or download the documentation in various formats.



### Note: Latest updates

The latest updates are usually available in the English-language version of this documentation.

### SUSE Knowledgebase

If you have run into an issue, also check out the Technical Information Documents (TIDs) that are available online at <https://www.suse.com/support/kb/>. Search the SUSE Knowledgebase for known solutions driven by customer need.

### Release notes

For release notes, see <https://www.suse.com/releasenotes/>.

### In your system

For offline use, the release notes are also available under `/usr/share/doc/release-notes` on your system. The documentation for individual packages is available at `/usr/share/doc/packages`.

Many commands are also described in their *manual pages*. To view them, run `man`, followed by a specific command name. If the `man` command is not installed on your system, install it with `sudo zypper install man`.



## 2 Improving the documentation

Your feedback and contributions to this documentation are welcome. The following channels for giving feedback are available:

### Service requests and support

For services and support options available for your product, see <https://www.suse.com/support/>.

To open a service request, you need a SUSE subscription registered at SUSE Customer Center. Go to <https://scc.suse.com/support/requests>, log in, and click *Create New*.

### Bug reports

Report issues with the documentation at <https://bugzilla.suse.com/>.

To simplify this process, click the *Report an issue* icon next to a headline in the HTML version of this document. This preselects the right product and category in Bugzilla and adds a link to the current section. You can start typing your bug report right away.

A Bugzilla account is required.

### Contributions

To contribute to this documentation, click the *Edit source document* icon next to a headline in the HTML version of this document. This will take you to the source code on GitHub, where you can open a pull request.

A GitHub account is required.



### Note: *Edit source document* only available for English

The *Edit source document* icons are only available for the English version of each document. For all other languages, use the *Report an issue* icons instead.



For more information about the documentation environment used for this documentation, see the repository's README.

### Mail

You can also report errors and send feedback concerning the documentation to [doc-team@suse.com](mailto:doc-team@suse.com). Include the document title, the product version, and the publication date of the document. Additionally, include the relevant section number and title (or provide the URL) and provide a concise description of the problem.

### 3 Documentation conventions

The following notices and typographic conventions are used in this document:

- /etc/passwd: Directory names and file names
- PLACEHOLDER: Replace PLACEHOLDER with the actual value
- PATH: An environment variable
- ls, --help: Commands, options, and parameters
- user: The name of a user or group
- package\_name: The name of a software package
- **Alt**, **Alt + F1**: A key to press or a key combination. Keys are shown in uppercase as on a keyboard.
- *File*, *File > Save As*: menu items, buttons
- **AMD/Intel** This paragraph is only relevant for the AMD64/Intel 64 architectures. The arrows mark the beginning and the end of the text block. 
- **IBM Z, POWER** This paragraph is only relevant for the architectures IBM Z and POWER. The arrows mark the beginning and the end of the text block. 
- *Chapter 1, “Example chapter”*: A cross-reference to another chapter in this guide.
- Commands that must be run with root privileges. You can also prefix these commands with the sudo command to run them as a non-privileged user:

```
root # command
tux > sudo command
```

- Commands that can be run by non-privileged users:

```
tux > command
```

- Commands can be split into two or multiple lines by a backslash character (\) at the end of a line. The backslash informs the shell that the command invocation will continue after the line's end:

```
tux > echo a b \
```

```
c d
```

- A code block that shows both the command (preceded by a prompt) and the respective output returned by the shell:

```
tux > command  
output
```

- Notices



### Warning: Warning notice

Vital information you must be aware of before proceeding. Warns you about security issues, potential loss of data, damage to hardware, or physical hazards.



### Important: Important notice

Important information you should be aware of before proceeding.



### Note: Note notice

Additional information, for example about differences in software versions.



### Tip: Tip notice

Helpful information, like a guideline or a piece of practical advice.

- Compact Notices



Additional information, for example about differences in software versions.



Helpful information, like a guideline or a piece of practical advice.

## 4 Support

Find the support statement for SUSE Linux Enterprise Server and general information about technology previews below. For details about the product lifecycle, see <https://www.suse.com/lifecycle>.

If you are entitled to support, find details on how to collect information for a support ticket at <https://documentation.suse.com/sles-15/html/SLES-all/cha-adm-support.html>.

### 4.1 Support statement for SUSE Linux Enterprise Server

To receive support, you need an appropriate subscription with SUSE. To view the specific support offers available to you, go to <https://www.suse.com/support/> and select your product.

The support levels are defined as follows:

#### L1

Problem determination, which means technical support designed to provide compatibility information, usage support, ongoing maintenance, information gathering and basic troubleshooting using available documentation.

#### L2

Problem isolation, which means technical support designed to analyze data, reproduce customer problems, isolate a problem area and provide a resolution for problems not resolved by Level 1 or prepare for Level 3.

#### L3

Problem resolution, which means technical support designed to resolve problems by engaging engineering to resolve product defects which have been identified by Level 2 Support.

For contracted customers and partners, SUSE Linux Enterprise Server is delivered with L3 support for all packages, except for the following:

- Technology previews.
- Sound, graphics, fonts, and artwork.
- Packages that require an additional customer contract.

- Some packages shipped as part of the module *Workstation Extension* are L2-supported only.
- Packages with names ending in `-devel` (containing header files and similar developer resources) will only be supported together with their main packages.


SUSE will only support the usage of original packages. That is, packages that are unchanged and not recompiled.

## 4.2 Technology previews

Technology previews are packages, stacks, or features delivered by SUSE to provide glimpses into upcoming innovations. Technology previews are included for your convenience to give you a chance to test new technologies within your environment. We would appreciate your feedback. If you test a technology preview, please contact your SUSE representative and let them know about your experience and use cases. Your input is helpful for future development.

Technology previews have the following limitations:

- Technology previews are still in development. Therefore, they may be functionally incomplete, unstable, or otherwise *not* suitable for production use.
- Technology previews are *not* supported.
- Technology previews may only be available for specific hardware architectures.
- Details and functionality of technology previews are subject to change. As a result, upgrading to subsequent releases of a technology preview may be impossible and require a fresh installation.
- SUSE may discover that a preview does not meet customer or market needs, or does not comply with enterprise standards. Technology previews can be removed from a product at any time. SUSE does not commit to providing a supported version of such technologies in the future.

For an overview of technology previews shipped with your product, see the release notes at <https://www.suse.com/releasenotes> .

# I Introduction

- 1 Virtualization Technology 2
- 2 Introduction to Xen Virtualization 7
- 3 Introduction to KVM Virtualization 10
- 4 Introduction to Linux Containers 12
- 5 Virtualization Tools 13
- 6 Installation of Virtualization Components 18
- 7 Supported Hosts, Guests, and Features 21

# 1 Virtualization Technology

Virtualization is a technology that provides a way for a machine (Host) to run another operating system (guest virtual machines) on top of the host operating system.

## 1.1 Overview

SUSE Linux Enterprise Server includes the latest open source virtualization technologies, Xen and KVM. With these hypervisors, SUSE Linux Enterprise Server can be used to provision, de-provision, install, monitor and manage multiple virtual machines (VM Guests) on a single physical system (for more information see [Hypervisor](#)).

Out of the box, SUSE Linux Enterprise Server can create virtual machines running both modified, highly tuned, paravirtualized operating systems and fully virtualized unmodified operating systems. Full virtualization allows the guest OS to run unmodified and requires the presence of AMD64/Intel 64 processors that support either Intel\* Virtualization Technology (Intel VT) or AMD\* Virtualization (AMD-V).

The primary component of the operating system that enables virtualization is a hypervisor (or virtual machine manager), which is a layer of software that runs directly on server hardware. It controls platform resources, sharing them among multiple VM Guests and their operating systems by presenting virtualized hardware interfaces to each VM Guest.

SUSE Linux Enterprise is an enterprise-class Linux server operating system that offers two types of hypervisors: Xen and KVM.

Both hypervisors support virtualization on the AMD64/Intel 64 architecture. Both Xen and KVM support full virtualization mode. In addition, Xen supports paravirtualized mode, and you can run both paravirtualized and fully virtualized guests on the same host.

SUSE Linux Enterprise Server with Xen or KVM acts as a virtualization host server ([VHS](#)) that supports VM Guests with its own guest operating systems. The SUSE VM Guest architecture consists of a hypervisor and management components that constitute the VHS, which runs many application-hosting VM Guests.

In Xen, the management components run in a privileged VM Guest often called [Dom0](#). In KVM, where the Linux kernel acts as the hypervisor, the management components run directly on the VHS.

## 1.2 Virtualization Capabilities

Virtualization design provides many capabilities to your organization. Virtualization of operating systems is used in many computing areas:

- **Server consolidation:** Many servers can be replaced by one big physical server, so hardware is consolidated, and Guest Operating Systems are converted to virtual machine. It provides the ability to run legacy software on new hardware.
- **Isolation:** guest operating system can be fully isolated from the Host running it. So if the virtual machine is corrupted, the Host system is not harmed.
- **Migration:** A process to move a running virtual machine to another physical machine. Live migration is an extended feature that allows this move without disconnection of the client or the application.
- **Disaster recovery:** *Virtualized* guests are less dependent on the hardware, and the Host server provides snapshot features to be able to restore a known running system without any corruption.
- **Dynamic load balancing:** A migration feature that brings a simple way to load-balance your service across your infrastructure.

## 1.3 Virtualization Benefits

Virtualization brings a lot of advantages while providing the same service as a hardware server. First, it reduces the cost of your infrastructure. Servers are mainly used to provide a service to a customer, and a virtualized operating system can provide the same service, with:

- **Less hardware:** You can run several operating system on one host, so all hardware maintenance will be reduced.
- **Less power/cooling:** Less hardware means you do not need to invest more in electric power, backup power, and cooling if you need more service.
- **Save space:** Your data center space will be saved because you do not need more hardware servers (less servers than service running).



- **Less management:** Using a VM Guest simplifies the administration of your infrastructure.
- **Agility and productivity:** Virtualization provides *migration* capabilities, *live migration* and *snapshots*. These features reduce downtime, and bring an easy way to move your service from one place to another without any service interruption.

## 1.4 Virtualization Modes

Guest operating systems are hosted on virtual machines in either full virtualization (FV) mode or paravirtual (PV) mode. Each virtualization mode has advantages and disadvantages.

- Full virtualization mode lets virtual machines run unmodified operating systems, such as Windows\* Server 2003. It can use either Binary Translation or *hardware-assisted* virtualization technology, such as AMD\* Virtualization or Intel\* Virtualization Technology. Using hardware assistance allows for better performance on processors that support it.  
Some guest operating systems hosted in full virtualization mode can be configured to use drivers from the SUSE Virtual Machine Drivers Pack (VMDP) instead of drivers originating from the operating system. Running virtual machine drivers improves performance dramatically on guest operating systems, such as Windows Server 2003. For more information, see [Appendix A, Virtual Machine Drivers](#).
- To be able to run under paravirtual mode, guest operating systems usually need to be modified for the virtualization environment. However, operating systems running in paravirtual mode have better performance than those running under full virtualization. Operating systems currently modified to run in paravirtual mode are called *paravirtualized operating systems* and include SUSE Linux Enterprise Server and NetWare® 6.5 SP8.

## 1.5 I/O Virtualization

VM Guests not only share CPU and memory resources of the host system, but also the I/O subsystem. Because software I/O virtualization techniques deliver less performance than bare metal, hardware solutions that deliver almost “native” performance have been developed recently. SUSE Linux Enterprise Server supports the following I/O virtualization techniques:

### Full Virtualization

Fully Virtualized (FV) drivers emulate widely supported real devices, which can be used with an existing driver in the VM Guest. The guest is also called *Hardware Virtual Machine* (HVM). Since the physical device on the VM Host Server may differ from the emulated one, the hypervisor needs to process all I/O operations before handing them over to the physical device. Therefore all I/O operations need to traverse two software layers, a process that not only significantly impacts I/O performance, but also consumes CPU time.

### Paravirtualization

Paravirtualization (PV) allows direct communication between the hypervisor and the VM Guest. With less overhead involved, performance is much better than with full virtualization. However, paravirtualization requires either the guest operating system to be modified to support the paravirtualization API or paravirtualized drivers. See [Section 7.2.1, “Availability of Paravirtualized Drivers”](#) for a list of guest operating systems supporting paravirtualization.

### PVHVM

This type of virtualization enhances HVM (see [Full Virtualization](#)) with paravirtualized (PV) drivers, and PV interrupt and timer handling.

### VFIO

VFIO stands for *Virtual Function I/O* and is a new user-level driver framework for Linux. It replaces the traditional KVM PCI Pass-Through device assignment. The VFIO driver exposes direct device access to user space in a secure memory (*IOMMU*) protected environment. With VFIO, a VM Guest can directly access hardware devices on the VM Host Server (pass-through), avoiding performance issues caused by emulation in performance critical paths. This method does not allow to share devices—each device can only be assigned to a single VM Guest. VFIO needs to be supported by the VM Host Server CPU, chipset and the BIOS/EFI.

Compared to the legacy KVM PCI device assignment, VFIO has the following advantages:

- Resource access is compatible with secure boot.
- Device is isolated and its memory access protected.
- Offers a user space device driver with more flexible device ownership model.
- Is independent of KVM technology, and not bound to x86 architecture only.

As of SUSE Linux Enterprise Server 12 SP2, the USB and PCI Pass-through methods of device assignment are considered deprecated and were superseded by the VFIO model.

### SR-IOV

The latest I/O virtualization technique, Single Root I/O Virtualization SR-IOV combines the benefits of the aforementioned techniques—performance and the ability to share a device with several VM Guests. SR-IOV requires special I/O devices, that are capable of replicating resources so they appear as multiple separate devices. Each such “pseudo” device can be directly used by a single guest. However, for network cards for example the number of concurrent queues that can be used is limited, potentially reducing performance for the VM Guest compared to paravirtualized drivers. On the VM Host Server, SR-IOV must be supported by the I/O device, the CPU and chipset, the BIOS/EFI and the hypervisor—for setup instructions see [Section 14.11, “Assigning a Host PCI Device to a VM Guest”](#).



### Important: Requirements for VFIO and SR-IOV

To be able to use the VFIO and SR-IOV features, the VM Host Server needs to fulfill the following requirements:

- IOMMU needs to be enabled in the BIOS/EFI.
- For Intel CPUs, the kernel parameter `intel_iommu=on` needs to be provided on the kernel command line. For more information, see *Book “Administration Guide”, Chapter 13 “The Boot Loader GRUB 2”, Section 13.3.3.2 “Kernel Parameters Tab”*.
- The VFIO infrastructure needs to be available. This can be achieved by loading the kernel module `vfio_pci`. For more information, see *Book “Administration Guide”, Chapter 14 “The systemd daemon”, Section 14.6.4 “Loading Kernel Modules”*.

## 2 Introduction to Xen Virtualization

This chapter introduces and explains the components and technologies you need to understand to set up and manage a Xen-based virtualization environment.

### 2.1 Basic Components

The basic components of a Xen-based virtualization environment are the *Xen hypervisor*, the *Dom0*, any number of other *VM Guests*, and the tools, commands, and configuration files that let you manage virtualization. Collectively, the physical computer running all these components is called a *VM Host Server* because together these components form a platform for hosting virtual machines.

#### The Xen Hypervisor

The Xen hypervisor, sometimes simply called a virtual machine monitor, is an open source software program that coordinates the low-level interaction between virtual machines and physical hardware.

#### The Dom0

The virtual machine host environment, also called *Dom0* or controlling domain, is composed of several components, such as:

- SUSE Linux Enterprise Server provides a graphical and a command line environment to manage the virtual machine host components and its virtual machines.



#### Note

The term “Dom0” refers to a special domain that provides the management environment. This may be run either in graphical or in command line mode.

- The xl tool stack based on the xenlight library (libxl). Use it to manage Xen guest domains.
- QEMU—an open source software that emulates a full computer system, including a processor and various peripherals. It provides the ability to host operating systems in both full virtualization or paravirtualization mode.

## Xen-Based Virtual Machines

A Xen-based virtual machine, also called a *VM Guest* or *DomU*, consists of the following components:

- At least one virtual disk that contains a bootable operating system. The virtual disk can be based on a file, partition, volume, or other type of block device.
- A configuration file for each guest domain. It is a text file following the syntax described in the manual page `man 5 xl.conf`.
- Several network devices, connected to the virtual network provided by the controlling domain.

## Management Tools, Commands, and Configuration Files

There is a combination of GUI tools, commands, and configuration files to help you manage and customize your virtualization environment.

## 2.2 Xen Virtualization Architecture

The following graphic depicts a virtual machine host with four virtual machines. The Xen hypervisor is shown as running directly on the physical hardware platform. Note that the controlling domain is also a virtual machine, although it has several additional management tasks compared to all the other virtual machines.

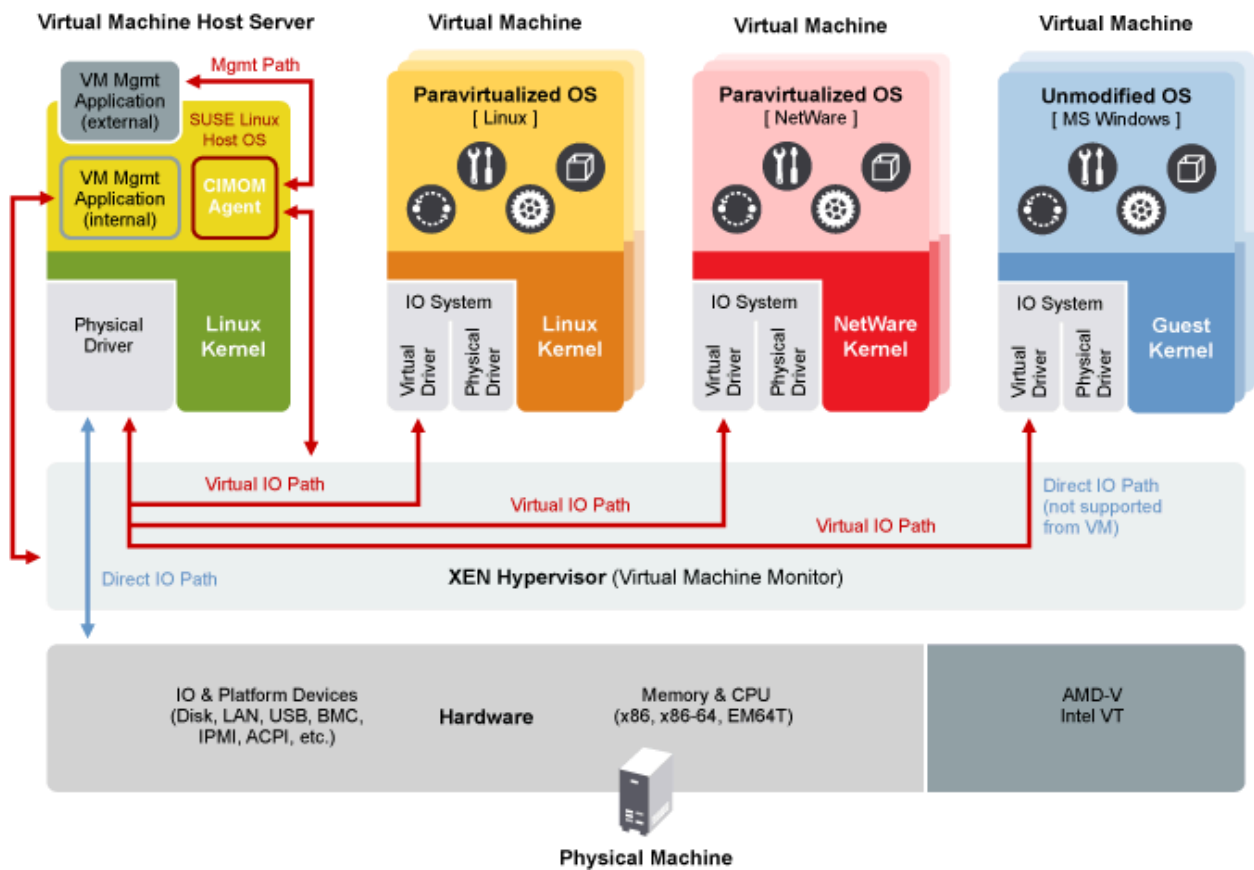


FIGURE 2.1: XEN VIRTUALIZATION ARCHITECTURE

On the left, the virtual machine host's Dom0 is shown running the SUSE Linux Enterprise Server operating system. The two virtual machines shown in the middle are running paravirtualized operating systems. The virtual machine on the right shows a fully virtual machine running an unmodified operating system, such as the latest version of Microsoft Windows/Server.

## 3 Introduction to KVM Virtualization

### 3.1 Basic Components

KVM is a full virtualization solution for the AMD64/Intel 64 and the IBM Z architectures supporting hardware virtualization.

VM Guests (virtual machines), virtual storage, and virtual networks can be managed with QEMU tools directly, or with the `libvirt`-based stack. The QEMU tools include `qemu-system-ARCH`, the QEMU monitor, `qemu-img`, and `qemu-nbd`. A `libvirt`-based stack includes `libvirt` itself, along with `libvirt`-based applications such as `virsh`, `virt-manager`, `virt-install`, and `virt-viewer`.

### 3.2 KVM Virtualization Architecture

This full virtualization solution consists of two main components:

- A set of kernel modules (`kvm.ko`, `kvm-intel.ko`, and `kvm-amd.ko`) that provides the core virtualization infrastructure and processor-specific drivers.
- A user space program (`qemu-system-ARCH`) that provides emulation for virtual devices and control mechanisms to manage VM Guests (virtual machines).

The term KVM more properly refers to the kernel level virtualization functionality, but is in practice more commonly used to refer to the user space component.

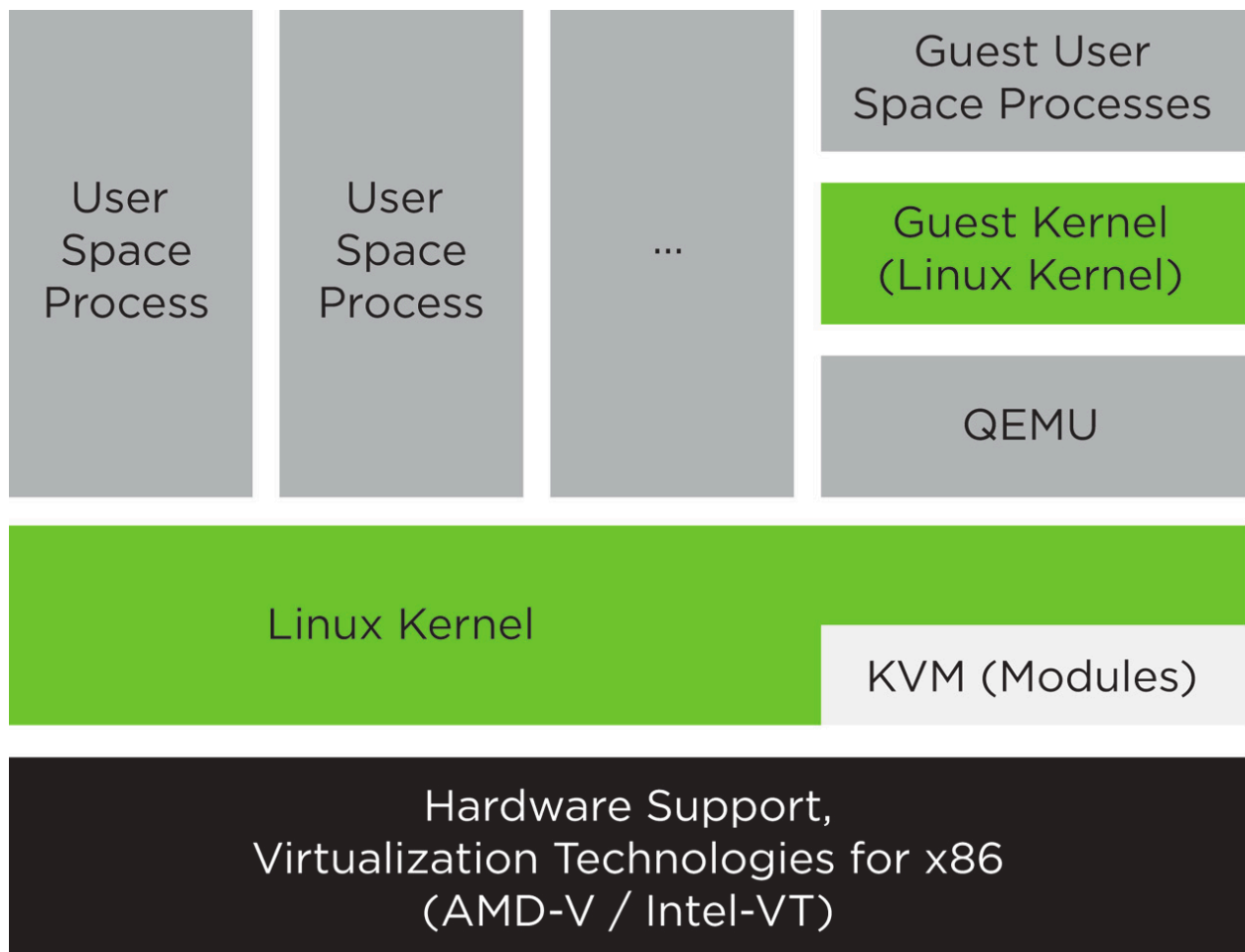


FIGURE 3.1: KVM VIRTUALIZATION ARCHITECTURE



### Note: Hyper-V Emulation Support

QEMU can provide certain Hyper-V hypercalls for Windows\* guests to partly emulate a Hyper-V environment. This can be used to achieve better behavior for Windows\* guests that are Hyper-V enabled.



## 4 Introduction to Linux Containers

*Linux containers* are a lightweight virtualization method to run multiple virtual units (“containers”) simultaneously on a single host. This is similar to the *chroot* environment. Containers are isolated with kernel Control Groups (*cgroups*) and kernel Namespaces.

Containers provide virtualization at the operating system level where the *kernel* controls the isolated containers. This is unlike full virtualization solutions like Xen or KVM where the *processor* simulates a complete hardware environment and controls virtual machines.

Conceptually, containers can be seen as an improved *chroot* technique. The difference is that a *chroot* environment separates only the file system, whereas containers go further and provide resource management and control via *cgroups*.

### BENEFITS OF CONTAINERS

- Isolating applications and operating systems through containers.
- Providing nearly native performance as container manages allocation of resources in real-time.
- Controlling network interfaces and applying resources inside containers through *cgroups*.

### LIMITATIONS OF CONTAINERS

- All containers run inside the host system's kernel and not with a different kernel.
- Only allows Linux “guest” operating systems.
- Security depends on the host system. Container is not secure. If you need a secure system, you can confine it using an AppArmor or SELinux profile.

## 5 Virtualization Tools

libvirt is a library that provides a common API for managing popular virtualization solutions, among them KVM, LXC, and Xen. The library provides a normalized management API for these virtualization solutions, allowing a stable, cross-hypervisor interface for higher-level management tools. The library also provides APIs for management of virtual networks and storage on the VM Host Server. The configuration of each VM Guest is stored in an XML file.

With libvirt you can also manage your VM Guests remotely. It supports TLS encryption, x509 certificates and authentication with SASL. This enables managing VM Host Servers centrally from a single workstation, alleviating the need to access each VM Host Server individually.

Using the libvirt-based tools is the recommended way of managing VM Guests. Interoperability between libvirt and libvirt-based applications has been tested and is an essential part of SUSE's support stance.

### 5.1 Virtualization Console Tools

The following libvirt-based tools for the command line are available on SUSE Linux Enterprise Server:

#### **virsh** (Package: libvirt-client)

A command line tool to manage VM Guests with similar functionality as the Virtual Machine Manager. Allows you to change a VM Guest's status (start, stop, pause, etc.), to set up new guests and devices, or to edit existing configurations. virsh is also useful to script VM Guest management operations.

virsh takes the first argument as a command and further arguments as options to this command:

```
virsh [-c URI] COMMAND DOMAIN-ID [OPTIONS]
```

Like **zypper**, **virsh** can also be called without a command. In this case it starts a shell waiting for your commands. This mode is useful when having to run subsequent commands:

```
~> virsh -c qemu+ssh://wilber@mercury.example.com/system
Enter passphrase for key '/home/wilber/.ssh/id_rsa':
Welcome to virsh, the virtualization interactive terminal.

Type:  'help' for help with commands
       'quit' to quit

virsh # hostname
mercury.example.com
```

### **virt-install** (Package: virt-install)

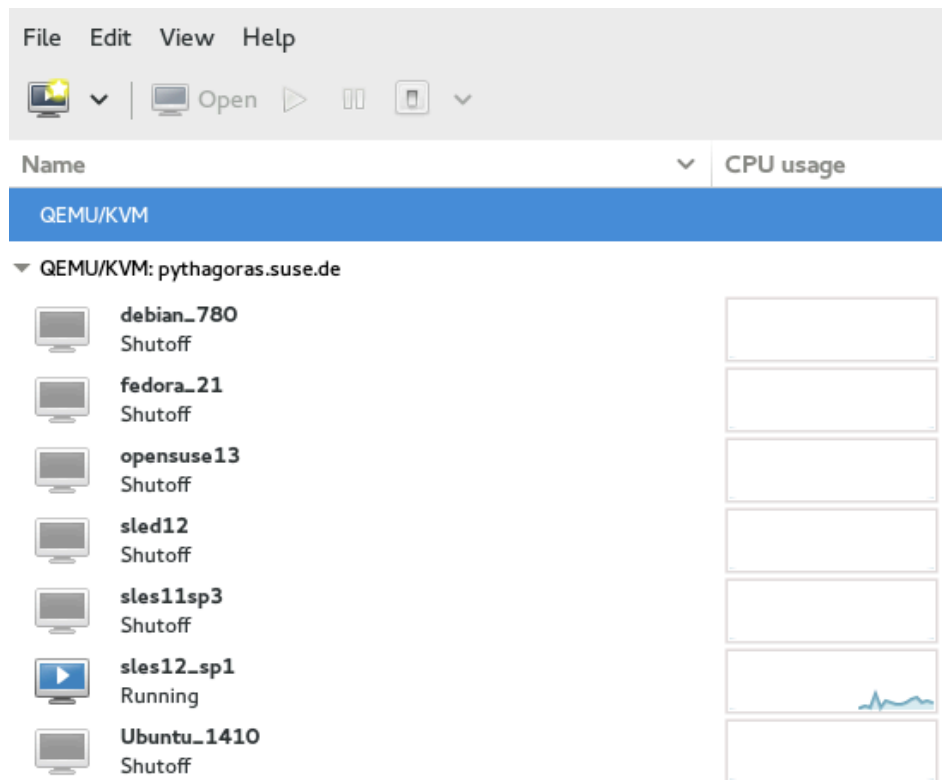
A command line tool for creating new VM Guests using the libvirt library. It supports graphical installations via VNC or *SPICE* protocols. Given suitable command line arguments, **virt-install** can run completely unattended. This allows for easy automation of guest installs. **virt-install** is the default installation tool used by the Virtual Machine Manager.

## 5.2 Virtualization GUI Tools

The following libvirt-based graphical tools are available on SUSE Linux Enterprise Server. All tools are provided by packages carrying the tool's name.

### Virtual Machine Manager (Package: virt-manager)

The Virtual Machine Manager is a desktop tool for managing VM Guests. It provides the ability to control the life cycle of existing machines (start/shutdown, pause/resume, save/restore) and create new VM Guests. It allows managing various types of storage and virtual networks. It provides access to the graphical console of VM Guests with a built-in VNC viewer and can be used to view performance statistics. **virt-manager** supports connecting to a local libvirtd, managing a local VM Host Server, or a remote libvirtd managing a remote VM Host Server.



To start the Virtual Machine Manager, enter **virt-manager** at the command prompt.



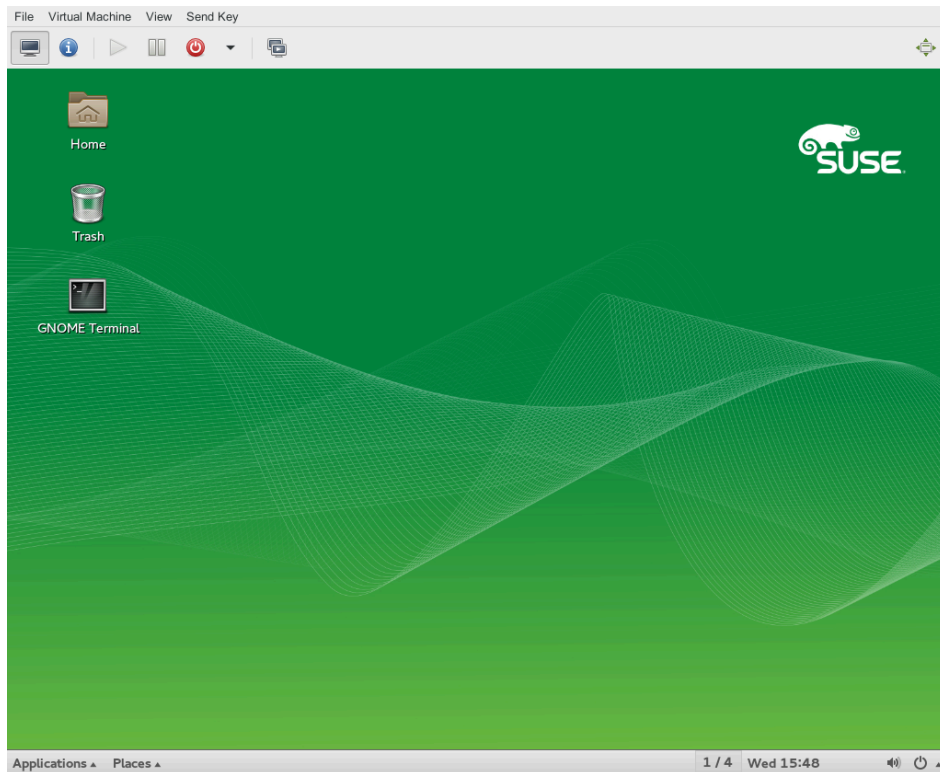
## Note

To disable automatic USB device redirection for VM Guest using spice, either launch **virt-manager** with the **--spice-disable-auto-usbredir** parameter or run the following command to persistently change the default behavior:

```
tux > dconf write /org/virt-manager/virt-manager/console/auto-redirect false
```

## **virt-viewer** (Package: virt-viewer)

A viewer for the graphical console of a VM Guest. It uses SPICE (configured by default on the VM Guest) or VNC protocols and supports TLS and x509 certificates. VM Guests can be accessed by name, ID, or UUID. If the guest is not already running, the viewer can be told to wait until the guest starts, before attempting to connect to the console. **virt-viewer** is not installed by default and is available after installing the package virt-viewer.

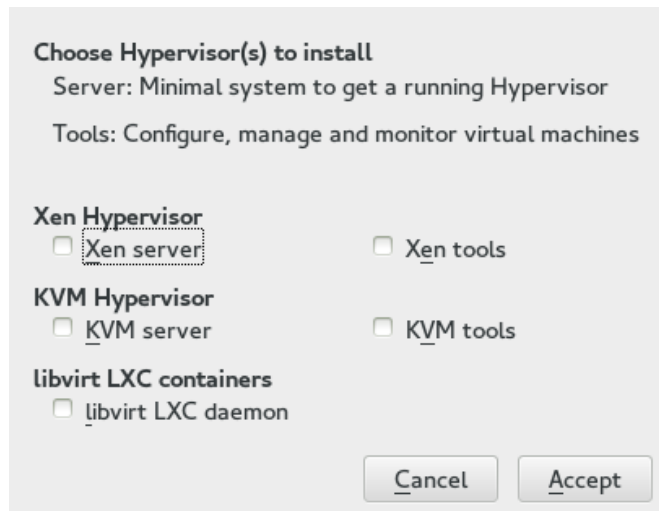


### Note

To disable automatic USB device redirection for VM Guest using spice, add an empty filter using the --spice-usbredir-auto-redirect-filter='' parameter.

**yast2 vm** (Package: `yast2-vm`)

A YaST module that simplifies the installation of virtualization tools and can set up a network bridge:



## 6 Installation of Virtualization Components

None of the virtualization tools is installed by default. They will be automatically installed when configuring the hypervisor with the YaST module *Virtualization > Install Hypervisor and Tools*. In case this module is not available in YaST, install the package `yast2-vm`.

### 6.1 Installing KVM

To install KVM and KVM tools, proceed as follows:

1. Verify that the `yast2-vm` package is installed. This package is YaST's configuration tool that simplifies the installation of virtualization hypervisors.
2. Start YaST and choose *Virtualization > Install Hypervisor and Tools*.
3. Select *KVM server* for a minimal installation of QEMU tools. Select *KVM tools* if a `libvirt`-based management stack is also desired. Confirm with *Accept*.
4. To enable normal networking for the VM Guest, using a network bridge is recommended. YaST offers to automatically configure a bridge on the VM Host Server. Agree to do so by choosing *Yes*, otherwise choose *No*.
5. After the setup has been finished, you can start setting up VM Guests. Rebooting the VM Host Server is not required.

### 6.2 Installing Xen

To install Xen and Xen tools, proceed as follows:

1. Start YaST and choose *Virtualization > Install Hypervisor and Tools*.
2. Select *Xen server* for a minimal installation of Xen tools. Select *Xen tools* if a `libvirt`-based management stack is also desired. Confirm with *Accept*.
3. To enable normal networking for the VM Guest, using a network bridge is recommended. YaST offers to automatically configure a bridge on the VM Host Server. Agree to do so by choosing *Yes*, otherwise choose *No*.

4. After the setup has been finished, you need to reboot the machine with the *Xen kernel*.



### Tip: Default Boot Kernel

If everything works as expected, change the default boot kernel with YaST and make the Xen-enabled kernel the default. For more information about changing the default kernel, see *Book "Administration Guide", Chapter 13 "The Boot Loader GRUB 2", Section 13.3 "Configuring the Boot Loader with YaST"*.

## 6.3 Installing Containers

To install containers, proceed as follows:

1. Start YaST and choose *Virtualization > Install Hypervisor and Tools*.
2. Select *libvirt lxc daemon* and confirm with *Accept*.

## 6.4 Patterns

It is possible using Zypper and patterns to install virtualization packages. Run the command **`zypper in -t pattern PATTERN`**. Available patterns are:

### KVM

- kvm\_server: sets up the KVM VM Host Server with QEMU tools for management
- kvm\_tools: installs the libvirt tools for managing and monitoring VM Guests

### Xen

- xen\_server: sets up the Xen VM Host Server with Xen tools for management
- xen\_tools: installs the libvirt tools for managing and monitoring VM Guests

### Containers

There is no pattern for containers; install the *libvirt-daemon-lxc* package.



## 6.5 Installing UEFI Support

UEFI support is provided by *OVMF (Open Virtual Machine Firmware)*. To enable UEFI boot, first install the `qemu-ovmf-x86_64` or `qemu-uefi-aarch64` package.

`libvirt` is configured to use `/usr/share/qemu/ovmf-x86_64-ms-4m-code.bin` and `/usr/share/qemu/ovmf-x86_64-ms-4m-vars.bin` as default UEFI firmware and VARS images. For ARM the defaults are `/usr/share/qemu/aavmf-aarch64-code.bin` and `/usr/share/qemu/aavmf-aarch64-vars.bin`.

The packages contain the following files:


```
root # rpm -ql qemu-ovmf-x86_64
/usr/share/qemu/ovmf-x86_64-ms-code.bin
/usr/share/qemu/ovmf-x86_64-ms-vars.bin
/usr/share/qemu/ovmf-x86_64-ms.bin
/usr/share/qemu/ovmf-x86_64-opensuse-code.bin
/usr/share/qemu/ovmf-x86_64-opensuse-vars.bin
/usr/share/qemu/ovmf-x86_64-opensuse.bin
/usr/share/qemu/ovmf-x86_64-suse-code.bin
/usr/share/qemu/ovmf-x86_64-suse-vars.bin
/usr/share/qemu/ovmf-x86_64-suse.bin
/usr/share/qemu/ovmf-x86_64-code.bin
/usr/share/qemu/ovmf-x86_64-vars.bin
/usr/share/qemu/ovmf-x86_64.bin
```

The `*-code.bin` files are the UEFI firmwares. The `*-vars.bin` files are corresponding variable store images that can be used as a template for a per-VM non-volatile store. `libvirt` copies the specified `vars` template to a per-VM path under `/var/lib/libvirt/qemu/nvram/` when first creating the VM. Files without `code` or `vars` in the name can be used as a single UEFI image. They are not as useful since no UEFI variables persist across power cycles of the VM.

The `*-ms*.bin` files contain Microsoft keys as found on real hardware. Therefore, they are configured as the default in `libvirt`. Likewise, the `*-suse*.bin` files contain preinstalled SUSE and openSUSE keys. There is also a set of files with no preinstalled keys.

For details, see *Using UEFI and Secure Boot* and <http://www.linux-kvm.org/downloads/lrsek/ovmf-whitepaper-c770f8c.txt>.

## 7 Supported Hosts, Guests, and Features

Supported architectures and virtualization limits for Xen and KVM are outlined in the [Release Notes \(https://www.suse.com/releasenotes/\)](https://www.suse.com/releasenotes/) .

### 7.1 Host Environments (Hypervisors)

This section lists the support status of SUSE Linux Enterprise Server 12 SP5 running as a guest on top of various virtualization hosts (*Hypervisor*).

THE FOLLOWING SUSE HOST ENVIRONMENTS ARE SUPPORTED (XEN + KVM):

- SLES 11 SP4
- SLES 12 SP1, SP2, SP3, SP4, SP5
- SLES 15 SP0, SP1, SP2

THE FOLLOWING 3RD PARTY HOST ENVIRONMENTS ARE SUPPORTED:

- VMware ESXi 6.5, 6.7
- Microsoft Windows 2008 R2 SP1 +, 2012+, 2012 R2+, 2016, 2019
- Citrix XenServer 7.0, 7.1, 8.0
- Oracle VM 3.4

THE LEVEL OF SUPPORT IS AS FOLLOWS:

- Support for SUSE host operating systems is full L3, both for the guest and host.
- Support for 3rd party host environments is full L3 for the guest and needs the host vendor cooperation and support for the host.



#### Note: Support for Third Party Virtualization Hosts

SUSE only provides full L3 support if both the virtualization host and guest are using SUSE products.

If the virtualization host uses third party software, SUSE only guarantees L3 support for the guest. For the host, the cooperation of the vendor is required.

## 7.2 Guest Environments

This section lists the support status for various guest operating systems virtualized on top of SUSE Linux Enterprise Server 12 SP5. All guest operating systems are supported both fully-virtualized (“FV” in the following table) and paravirtualized (“PV” in the following table) with two exceptions: Windows, which is only supported fully-virtualized, and NetWare operating systems, which are only supported on Xen paravirtualized. All guest operating systems are supported both in 32-bit and 64-bit flavors, unless stated otherwise (see NetWare).



### Important

Microsoft Windows guests can be rebooted by `libvirt/virsh` only if paravirtualized drivers are installed in the guest. Refer to <https://www.suse.com/products/vmdriverpack/> for more details on downloading and installing PV drivers.

#### THE FOLLOWING GUEST OPERATING SYSTEMS ARE FULLY SUPPORTED (L3):

- SLES 10 SP4
- SLES 11 SP3, SP4
- SLES 12 SP0, SP1, SP2, SP3, SP4, SP5
- VMware ESXi 2016
- SLES 15 SP0, SP1, SP2
- OES 11 SP2, 2015, 2015 SP1, 2018, 2018 SP1, 2018 SP2
- Netware 6.5 SP8 (32-bit only)
- Windows Server 2008 SP2 +, 2008 R2 SP1 +, 2012 +, 2012 R2 +, 2016, 2019
- Nutanix Acropolis Hypervisor with AOS 5.8

#### THE FOLLOWING GUEST OPERATING SYSTEMS ARE SUPPORTED AS A TECHNOLOGY PREVIEW (L2, FIXES IF REASONABLE):

- SLED 15 SP1

#### RED HAT AND CENTOS GUEST OPERATING SYSTEMS ARE FULLY SUPPORTED (L3) IF THE CUSTOMER HAS PURCHASED SUSE LIBERTY LINUX.

- Refer to the SUSE Liberty Linux documentation at <https://documentation.suse.com/liberty> for the list of available combinations and supported releases. In other cases, they are supported on a limited basis (L2, fixes if reasonable).

THE FOLLOWING GUEST OPERATING SYSTEMS ARE SUPPORTED ON A COMMERCIALY REASONABLE BASIS (L2, FIXES IF REASONABLE):

- Windows 8+, 8.1+, 10+

## 7.2.1 Availability of Paravirtualized Drivers

To improve the performance of the guest operating system, paravirtualized drivers are provided when available. Although they are not required, it is strongly recommended to use them. The paravirtualized drivers are available as follows:

SUSE Linux Enterprise Server 12 / 12 SP1 / 12 SP2

Included in kernel

SUSE Linux Enterprise Server 11 / 11 SP1 / 11 SP2 / 11 SP3 / 11 SP4

Included in kernel

SUSE Linux Enterprise Server 10 SP4

Included in kernel

RedHat

Available in RedHat Enterprise Linux 5.4 and newer

Windows

SUSE has developed virtio-based drivers for Windows, which are available in the Virtual Machine Driver Pack (VMDP). For more information, see <https://www.suse.com/products/vmdriverpack/>.

## 7.3 KVM Hardware Requirements

Currently, SUSE supports KVM full virtualization on AMD64/Intel 64 and Arm AArch64 hosts, and on IBM Z.

- On the AMD64/Intel 64 architecture, KVM is designed around hardware virtualization features included in AMD\* (AMD-V) and Intel\* (VT-x) CPUs. It supports virtualization features of chipsets and PCI devices, such as an I/O Memory Mapping Unit (*IOMMU*) and Single Root I/O Virtualization (*SR-IOV*). You can test whether your CPU supports hardware virtualization with the following command:

```
tux > egrep '(vmx|svm)' /proc/cpuinfo
```

If this command returns no output, your processor either does not support hardware virtualization, or this feature has been disabled in the BIOS or firmware.

The following Web sites identify AMD64/Intel 64 processors that support hardware virtualization: <http://ark.intel.com/Products/VirtualizationTechnology> (for Intel CPUs), and <http://products.amd.com/> (for AMD CPUs).

- On the Arm AArch64 architecture, virtualization support was initially added to ARMv7-A processors starting with Cortex-A15 and including Cortex-A7 and Cortex-A17. ARMv8-A processors include support for virtualization.



### Note: KVM Kernel Modules Not Loading

The KVM kernel modules only load if the CPU hardware virtualization features are available.

The general minimum hardware requirements for the VM Host Server are the same as for a physical machine. However, additional RAM for each virtualized guest is needed. It should at least be the same amount that is needed for a physical installation. It is also strongly recommended to have at least one processor core or hyper-thread for each running guest.

## 7.4 Feature Support

### 7.4.1 Host (Dom0)

TABLE 7.1: FEATURE SUPPORT—HOST (Dom0)

Features	Xen
Network and block device hotplugging	Yes
Physical <i>CPU hot-plugging</i>	No

Features	Xen
Virtual <i>CPU hot-plugging</i>	Yes
Virtual <i>CPU pinning</i>	Yes
Virtual <i>CPU capping</i>	Yes
Intel* VT-x2: FlexPriority, FlexMigrate (migration constraints apply to dissimilar CPU architectures)	Yes
Intel* VT-d2 (DMA remapping with interrupt filtering and queued invalidation)	Yes
AMD* IOMMU (I/O page table with guest-to-host physical address translation)	Yes



## Note: Adding or Removing Physical CPUs at Runtime Is Not Supported

The addition or removal of physical CPUs at runtime is not supported. However, virtual CPUs can be added or removed for each VM Guest.

### 7.4.2 Paravirtualized Guest

TABLE 7.2: FEATURE SUPPORT—PARAVIRTUALIZED GUEST

Features	Xen
Virtual network and virtual block device hot-plugging	Yes
Virtual <i>CPU hotplugging</i>	Yes
Virtual <i>CPU over-commitment</i>	Yes
Dynamic virtual memory resize	Yes
VM save and restore	Yes
VM live migration	Yes, between like virtual host systems with similar resources
Advanced debugging with GDB	Yes
Dom0 metrics visible to VM	Yes
Memory ballooning	Yes
PCI pass-through	Yes (Netware guests are excluded)

For live migration, both source and target system architectures need to match; that is, the processors (AMD\* or Intel\*) must be the same. Unless CPU ID masking is used, such as with Intel FlexMigration, the target should feature the same processor revision or a more recent processor revision than the source. If VMs are moved among different systems, the same rules apply for each move. To avoid failing optimized code at runtime or application start-up, source and target

CPUs need to expose the same processor extensions. Xen exposes the physical CPU extensions to the VMs transparently. To summarize, guests can be 32-bit or 64-bit, but the *VHS* must be identical.



### Note: Intel FlexMigration

For machines that support Intel FlexMigration, CPU-ID masking and faulting allow more flexibility in cross-CPU migration.

## 7.4.3 Fully Virtualized Guest

TABLE 7.3: FEATURE SUPPORT—FULLY VIRTUALIZED GUEST

Features	Xen	KVM
Virtual network and virtual block device hotplugging	Yes	Yes
Virtual <i>CPU hotplugging</i>	No	No
Virtual <i>CPU over-commitment</i>	Yes	Yes
Dynamic virtual memory re-size	Yes	Yes
VM save and restore	Yes	Yes
VM Live Migration	Yes between like virtual host systems with similar resources (that is, from 32-bit to 32-bit, 64-bit to 64-bit)	Yes
VM snapshot	Yes	Yes
Advanced debugging with GDB	Yes	Yes
Dom0 metrics visible to VM	Yes	Yes
PCI pass-through	Yes	Yes





## Note: Windows Guest

Hotplugging of virtual network and virtual block devices, and resizing, shrinking, and restoring dynamic virtual memory are supported in Xen and KVM only if PV drivers are being used (VMDP).

For KVM, a detailed description of supported limits, features, recommended settings and scenarios, and other useful information is maintained in [`kvm-supported.txt`](#). This file is part of the KVM package and can be found in [`/usr/share/doc/packages/kvm`](#).

## II Managing Virtual Machines with libvirt

- 8 Starting and Stopping libvirtd 30
- 9 Guest Installation 32
- 10 Basic VM Guest Management 39
- 11 Connecting and Authorizing 65
- 12 Managing Storage 86
- 13 Managing Networks 105
- 14 Configuring Virtual Machines 120

## 8 Starting and Stopping libvirtd

The communication between the virtualization solutions (KVM, Xen, LXC) and the libvirt API is managed by the daemon `libvirtd`. It needs to run on the VM Host Server. libvirt client applications such as `virt-manager`, possibly running on a remote machine, communicate with `libvirtd` running on the VM Host Server, which services the request using native hypervisor APIs. Use the following commands to start and stop `libvirtd` or check its status:

```
tux > sudo systemctl start libvirtd

tux > sudo systemctl status libvirtd
libvirtd.service - Virtualization daemon
Loaded: loaded (/usr/lib/systemd/system/libvirtd.service; enabled)
Active: active (running) since Mon 2014-05-12 08:49:40 EDT; 2s ago
[...]

tux > sudo systemctl stop libvirtd

tux > sudo systemctl status libvirtd
[...]
Active: inactive (dead) since Mon 2014-05-12 08:51:11 EDT; 4s ago
[...]
```

To automatically start `libvirtd` at boot time, either activate it using the YaST *Services Manager* module or by entering the following command:

```
tux > sudo systemctl enable libvirtd
```



### Important: Conflicting Services: libvirtd and xendomains

If `libvirtd` fails to start, check if the service `xendomains` is loaded:

```
tux > systemctl is-active xendomains
active
```

If the command returns `active`, you need to stop `xendomains` before you can start the `libvirtd` daemon. If you want `libvirtd` to also start after rebooting, additionally prevent `xendomains` from starting automatically. Disable the service:

```
tux > sudo systemctl stop xendomains
tux > sudo systemctl disable xendomains
tux > sudo systemctl start libvirtd
```

xendomains and libvirtd provide the same service and when used in parallel may interfere with one another. As an example, xendomains may attempt to start a domU already started by libvirtd.

## 9 Guest Installation

A VM Guest consists of an image containing an operating system and data files and a configuration file describing the VM Guest's virtual hardware resources. VM Guests are hosted on and controlled by the VM Host Server. This section provides generalized instructions for installing a VM Guest. For a list of supported VM Guests refer to *Chapter 7, Supported Hosts, Guests, and Features*.

Virtual machines have few if any requirements above those required to run the operating system. If the operating system has not been optimized for the virtual machine host environment, it can only run on *hardware-assisted* virtualization computer hardware, in full virtualization mode, and requires specific device drivers to be loaded. The hardware that is presented to the VM Guest depends on the configuration of the host.

You should be aware of any licensing issues related to running a single licensed copy of an operating system on multiple virtual machines. Consult the operating system license agreement for more information.

### 9.1 GUI-Based Guest Installation

The *New VM* wizard helps you through the steps required to create a virtual machine and install its operating system. There are two ways to start it: Within Virtual Machine Manager, either click *Create New Virtual Machine* or choose *File > New Virtual Machine*. Alternatively, start YaST and choose *Virtualization > Create Virtual Machines for Xen and KVM*.

1. Start the *New VM* wizard either from YaST or Virtual Machine Manager.
2. Choose an installation source—either a locally available media or a network installation source. If you want to set up your VM Guest from an existing image, choose *import existing disk image*.

On a VM Host Server running the Xen hypervisor, you can choose whether to install a paravirtualized or a fully virtualized guest. The respective option is available under *Architecture Options*. Depending on this choice, not all installation options may be available.

3. Depending on your choice in the previous step, you need to provide the following data:

#### *Local Installation Media (ISO image or CDROM)*

Specify the path on the VM Host Server to an ISO image containing the installation data. If it is available as a volume in a libvirt storage pool, you can also select it using *Browse*. For more information, see [Chapter 12, Managing Storage](#).

Alternatively, choose a physical CD-ROM or DVD inserted in the optical drive of the VM Host Server.

#### *Network Installation (HTTP, FTP, or NFS)*

Provide the *URL* pointing to the installation source. Valid URL prefixes are, for example, `ftp://`, `http://`, `https://`, and `nfs://`.

Under *URL Options*, provide a path to an auto-installation file (AutoYaST or Kickstart, for example) and kernel parameters. Having provided a URL, the operating system should be automatically detected correctly. If this is not the case, deselect *Automatically Detect Operating System Based on Install-Media* and manually select the *OS Type* and *Version*.

#### *Network Boot (PXE)*

When booting via PXE, you only need to provide the *OS Type* and the *Version*.

#### *Import Existing Disk Image*

To set up the VM Guest from an existing image, you need to specify the path on the VM Host Server to the image. If it is available as a volume in a libvirt storage pool, you can also select it using *Browse*. For more information, see [Chapter 12, Managing Storage](#).

4. Choose the memory size and number of CPUs for the new virtual machine.

5. This step is omitted when *Import an Existing Image* is chosen in the first step.

Set up a virtual hard disk for the VM Guest. Either create a new disk image or choose an existing one from a storage pool (for more information, see [Chapter 12, Managing Storage](#)). If you choose to create a disk, a `qcow2` image will be created. By default, it is stored under `/var/lib/libvirt/images`.

Setting up a disk is optional. If you are running a live system directly from CD or DVD, for example, you can omit this step by deactivating *Enable Storage for this Virtual Machine*.

6. On the last screen of the wizard, specify the name for the virtual machine. To be offered the possibility to review and make changes to the virtualized hardware selection, activate *Customize configuration before install*. Find options to specify the network device under *Network Selection*.  
Click *Finish*.
7. (Optional) If you kept the defaults in the previous step, the installation will now start. If you selected *Customize configuration before install*, a VM Guest configuration dialog opens. For more information about configuring VM Guests, see [Chapter 14, Configuring Virtual Machines](#). When you are done configuring, click *Begin Installation*.



### Tip: Passing Key Combinations to Virtual Machines

The installation starts in a Virtual Machine Manager console window. Some key combinations, such as `Ctrl – Alt – F1`, are recognized by the VM Host Server but are not passed to the virtual machine. To bypass the VM Host Server, Virtual Machine Manager provides the “sticky key” functionality. Pressing `Ctrl`, `Alt`, or `Shift` three times makes the key sticky, then you can press the remaining keys to pass the combination to the virtual machine.

For example, to pass `Ctrl – Alt – F2` to a Linux virtual machine, press `Ctrl` three times, then press `Alt – F2`. You can also press `Alt` three times, then press `Ctrl – F2`.

The sticky key functionality is available in the Virtual Machine Manager during and after installing a VM Guest.

## 9.2 Installing from the Command Line with **virt-install**

**virt-install** is a command line tool that helps you create new virtual machines using the `libvirt` library. It is useful if you cannot use the graphical user interface, or need to automatize the process of creating virtual machines.

**virt-install** is a complex script with a lot of command line switches. The following are required. For more information, see the man page of **virt-install** (1).

## General Options

- `--name VM_GUEST_NAME`: Specify the name of the new virtual machine. The name must be unique across all guests known to the hypervisor on the same connection. It is used to create and name the guest's configuration file and you can access the guest with this name from `virsh`. Alphanumeric and `_ - . : +` characters are allowed.
- `--memory REQUIRED_MEMORY`: Specify the amount of memory to allocate for the new virtual machine in megabytes.
- `--vcpus NUMBER_OF_CPUS`: Specify the number of virtual CPUs. For best performance, the number of virtual processors should be less than or equal to the number of physical processors.

## Virtualization Type

- `--paravirt`: Set up a paravirtualized guest. This is the default if the VM Host Server supports paravirtualization and full virtualization.
- `--hvm`: Set up a fully virtualized guest.
- `--virt-type HYPERVISOR`: Specify the hypervisor. Supported values are `kvm`, `xen`, or `lxc`.

## Guest Storage

Specify one of `--disk`, `--filesystem` or `--nodisks` the type of the storage for the new virtual machine. For example, `--disk size=10` creates 10 GB disk in the default image location for the hypervisor and uses it for the VM Guest. `--filesystem /export/path/on/vmhost` specifies the directory on the VM Host Server to be exported to the guest. And `--nodisks` sets up a VM Guest without a local storage (good for Live CDs).

## Installation Method

Specify the installation method using one of `--location`, `--cdrom`, `--pxe`, `--import`, or `--boot`.

## Accessing the Installation

Use the `--graphics VALUE` option to specify how to access the installation. SUSE Linux Enterprise Server supports the values `vnc` or `none`.



If using VNC **virt-install** tries to launch **virt-viewer**. If it is not installed or cannot be run, connect to the VM Guest manually with your preferred viewer. To explicitly prevent **virt-install** from launching the viewer use `--noautoconsole`. To define a password for accessing the VNC session, use the following syntax: `--graphics vnc,password=PASSWORD`.

In case you are using `--graphics none`, you can access the VM Guest through operating system supported services, such as SSH or VNC. Refer to the operating system installation manual on how to set up these services in the installation system.

### Passing Kernel and Initrd Files

It is possible to directly specify the Kernel and Initrd of the installer, for example from a network source. To set up a network source, see *Book "Deployment Guide", Chapter 8 "Setting Up the Server Holding the Installation Sources", Section 8.4 "Setting Up an HTTP Repository Manually"*.

To pass additional boot parameters, use the `--extra-args` option. This can be used to specify a network configuration. For details, see *Book "Deployment Guide", Chapter 6 "Installation with YaST", Section 6.2 "System Start-up for Installation"*.

#### EXAMPLE 9.1: LOADING KERNEL AND INITRD FROM HTTP SERVER

```
root # virt-install --location "http://example.tld/REPOSITORY/DVD1/" \
--extra-args="textmode=1" --name "SLES15" --memory 2048 --virt-type kvm \
--connect qemu:///system --disk size=10 --graphics vnc \
--network network=vnet_nated
```

### Enabling the Console

By default, the console is not enabled for new virtual machines installed using **virt-install**. To enable it, use `--extra-args="console=ttyS0 textmode=1"` as in the following example:

```
virt-install --virt-type kvm --name sles12 --memory 1024 \
--disk /var/lib/libvirt/images/disk1.qcow2 --os-variant sles12
--extra-args="console=ttyS0 textmode=1" --graphics none
```

After the installation finished, the `/etc/default/grub` file in the VM image will be updated with the `console=ttyS0` option on the `GRUB_CMDLINE_LINUX_DEFAULT` line.

### Using UEFI and Secure Boot

Install OVMF as described in *Section 6.5, "Installing UEFI Support"*. Then add the `--boot uefi` option to the **virt-install** command.

Secure boot will be used automatically when setting up a new VM with OMVF. To use a specific firmware, use `--boot loader=/usr/share/qemu/ovmf-VERSION.bin`. Replace *VERSION* with the file you need.

#### EXAMPLE 9.2: EXAMPLE OF A `virt-install` COMMAND LINE

The following command line example creates a new SUSE Linux Enterprise Desktop 12 virtual machine with a virtio accelerated disk and network card. It creates a new 10 GB qcow2 disk image as a storage, the source installation media being the host CD-ROM drive. It will use VNC graphics, and it will auto-launch the graphical client.

##### KVM

```
virt-install --connect qemu:///system --virt-type kvm --name sled12 \  
--memory 1024 --disk size=10 --cdrom /dev/cdrom --graphics vnc \  
--os-variant sled12
```

##### Xen


```
virt-install --connect xen:// --virt-type xen --name sled12 \  
--memory 1024 --disk size=10 --cdrom /dev/cdrom --graphics vnc \  
--os-variant sled12
```

## 9.3 Advanced Guest Installation Scenarios

This section provides instructions for operations exceeding the scope of a normal installation, such as including modules and extensions packages.

### 9.3.1 Memory Ballooning with Windows Guests

Memory ballooning is a method to change the amount of memory used by VM Guest at runtime. Both the KVM and Xen hypervisors provide this method, but it needs to be supported by the guest as well.

While openSUSE and SLE-based guests support memory ballooning, Windows guests need the [Virtual Machine Driver Pack \(VMDP\)](https://www.suse.com/products/vmdriverpack/) (<https://www.suse.com/products/vmdriverpack/>)  to provide ballooning. To set the maximum memory greater than the initial memory configured for Windows guests, follow these steps:

1. Install the Windows guest with the maximum memory equal or less than the initial value.

2. Install the Virtual Machine Driver Pack in the Windows guest to provide required drivers.
3. Shut down the Windows guest.
4. Reset the maximum memory of the Windows guest to the required value.
5. Start the Windows guest again.

### 9.3.2 Including Add-on Products in the Installation

Some operating systems such as SUSE Linux Enterprise Server offer to include add-on products in the installation process. In case the add-on product installation source is provided via network, no special VM Guest configuration is needed. If it is provided via CD/DVD or ISO image, it is necessary to provide the VM Guest installation system with both, the standard installation medium and an image for the add-on product.

In case you are using the GUI-based installation, select *Customize Configuration Before Install* in the last step of the wizard and add the add-on product ISO image via *Add Hardware > Storage*. Specify the path to the image and set the *Device Type* to *CD-ROM*.

If installing from the command line, you need to set up the virtual CD/DVD drives with the `--disk` parameter rather than with `--cdrom`. The device that is specified first is used for booting. The following example will install SUSE Linux Enterprise Server 12 plus SDK:

```
virt-install --name sles12+sdk --memory 1024 --disk size=10 \  
--disk /virt/iso/SLES12.iso,device=cdrom \  
--disk /virt/iso/SLES12_SDK.iso,device=cdrom \  
--graphics vnc --os-variant sles12
```

## 10 Basic VM Guest Management

Most management tasks, such as starting or stopping a VM Guest, can either be done using the graphical application Virtual Machine Manager or on the command line using **virsh**. Connecting to the graphical console via VNC is only possible from a graphical user interface.



### Note: Managing VM Guests on a Remote VM Host Server

If started on a VM Host Server, the **libvirt** tools Virtual Machine Manager, **virsh**, and **virt-viewer** can be used to manage VM Guests on the host. However, it is also possible to manage VM Guests on a remote VM Host Server. This requires configuring remote access for **libvirt** on the host. For instructions, see [Chapter 11, Connecting and Authorizing](#).

To connect to such a remote host with Virtual Machine Manager, you need to set up a connection as explained in [Section 11.2.2, “Managing Connections with Virtual Machine Manager”](#). If connecting to a remote host using **virsh** or **virt-viewer**, you need to specify a connection URI with the parameter **-c** (for example, **virsh -c qemu+tls://saturn.example.com/system** or **virsh -c xen+ssh://**). The form of connection URI depends on the connection type and the hypervisor—see [Section 11.2, “Connecting to a VM Host Server”](#) for details.

Examples in this chapter are all listed without a connection URI.

## 10.1 Listing VM Guests

The VM Guest listing shows all VM Guests managed by **libvirt** on a VM Host Server.

### 10.1.1 Listing VM Guests with Virtual Machine Manager

The main window of the Virtual Machine Manager lists all VM Guests for each VM Host Server it is connected to. Each VM Guest entry contains the machine's name, its status (*Running*, *Paused*, or *Shutoff*) displayed as an icon and literally, and a CPU usage bar.

## 10.1.2 Listing VM Guests with **virsh**

Use the command **virsh list** to get a list of VM Guests:

List all running guests

```
tux > virsh list
```

List all running and inactive guests

```
tux > virsh list --all
```

For more information and further options, see **virsh help list** or **man 1 virsh**.

## 10.2 Accessing the VM Guest via Console

VM Guests can be accessed via a VNC connection (graphical console) or, if supported by the guest operating system, via a serial console.

### 10.2.1 Opening a Graphical Console

Opening a graphical console to a VM Guest lets you interact with the machine like a physical host via a VNC connection. If accessing the VNC server requires authentication, you are prompted to enter a user name (if applicable) and a password.

When you click into the VNC console, the cursor is “grabbed” and cannot be used outside the console anymore. To release it, press **Alt – Ctrl**.



#### Tip: Seamless (Absolute) Cursor Movement

To prevent the console from grabbing the cursor and to enable seamless cursor movement, add a tablet input device to the VM Guest. See [Section 14.5, “Enabling Seamless and Synchronized Mouse Pointer Movement”](#) for more information.

Certain key combinations such as **Ctrl – Alt – Del** are interpreted by the host system and are not passed to the VM Guest. To pass such key combinations to a VM Guest, open the *Send Key* menu from the VNC window and choose the desired key combination entry. The *Send Key*

menu is only available when using Virtual Machine Manager and **virt-viewer**. With Virtual Machine Manager, you can alternatively use the “sticky key” feature as explained in [Tip: Passing Key Combinations to Virtual Machines](#).



## Note: Supported VNC Viewers

Principally all VNC viewers can connect to the console of a VM Guest. However, if you are using SASL authentication and/or TLS/SSL connection to access the guest, the options are limited. Common VNC viewers such as **tightvnc** or **tigervnc** support neither SASL authentication nor TLS/SSL. The only supported alternative to Virtual Machine Manager and **virt-viewer** is Vinagre.

### 10.2.1.1 Opening a Graphical Console with Virtual Machine Manager

1. In the Virtual Machine Manager, right-click a VM Guest entry.
2. Choose *Open* from the pop-up menu.

### 10.2.1.2 Opening a Graphical Console with **virt-viewer**

**virt-viewer** is a simple VNC viewer with added functionality for displaying VM Guest consoles. For example, it can be started in “wait” mode, where it waits for a VM Guest to start before it connects. It also supports automatically reconnecting to a VM Guest that is rebooted.

**virt-viewer** addresses VM Guests by name, by ID or by UUID. Use **virsh** **list --all** to get this data.

To connect to a guest that is running or paused, use either the ID, UUID, or name. VM Guests that are shut off do not have an ID—you can only connect to them by UUID or name.

Connect to guest with the ID 8

```
tux > virt-viewer 8
```

Connect to the inactive guest named sles12; the connection window will open once the guest starts

```
tux > virt-viewer --wait sles12
```

With the `--wait` option, the connection will be upheld even if the VM Guest is not running at the moment. When the guest starts, the viewer will be launched.

For more information, see `virt-viewer --help` or `man 1 virt-viewer`.



### Note: Password Input on Remote connections with SSH

When using `virt-viewer` to open a connection to a remote host via SSH, the SSH password needs to be entered twice. The first time for authenticating with `libvirt`, the second time for authenticating with the VNC server. The second password needs to be provided on the command line where `virt-viewer` was started.

## 10.2.2 Opening a Serial Console

Accessing the graphical console of a virtual machine requires a graphical environment on the client accessing the VM Guest. As an alternative, virtual machines managed with `libvirt` can also be accessed from the shell via the serial console and `virsh`. To open a serial console to a VM Guest named “sles12”, run the following command:

```
tux > virsh console sles12
```

`virsh console` takes two optional flags: `--safe` ensures exclusive access to the console, `--force` disconnects any existing sessions before connecting. Both features need to be supported by the guest operating system.

Being able to connect to a VM Guest via serial console requires that the guest operating system supports serial console access and is properly supported. Refer to the guest operating system manual for more information.



### Tip: Enabling Serial Console Access for SUSE Linux Enterprise and openSUSE Guests

Serial console access in SUSE Linux Enterprise and openSUSE is disabled by default. To enable it, proceed as follows:

#### SLES 12 / openSUSE

Launch the YaST Boot Loader module and switch to the *Kernel Parameters* tab. Add `console=ttyS0` to the field *Optional Kernel Command Line Parameter*.

Launch the YaST Boot Loader module and select the boot entry for which to activate serial console access. Choose *Edit* and add `console=ttyS0` to the field *Optional Kernel Command Line Parameter*. Additionally, edit `/etc/inittab` and uncomment the line with the following content:

```
#S0:12345:respawn:/sbin/agetty -L 9600 ttyS0 vt102
```

## 10.3 Changing a VM Guest's State: Start, Stop, Pause

Starting, stopping or pausing a VM Guest can be done with either Virtual Machine Manager or **virsh**. You can also configure a VM Guest to be automatically started when booting the VM Host Server.

When shutting down a VM Guest, you may either shut it down gracefully, or force the shutdown. The latter is equivalent to pulling the power plug on a physical host and is only recommended if there are no alternatives. Forcing a shutdown may cause file system corruption and loss of data on the VM Guest.



### Tip: Graceful Shutdown

To be able to perform a graceful shutdown, the VM Guest must be configured to support **ACPI**. If you have created the guest with the Virtual Machine Manager, ACPI should be available in the VM Guest.

Depending on the guest operating system, availability of ACPI may not be sufficient to perform a graceful shutdown. It is strongly recommended to test shutting down and rebooting a guest before using it in production. openSUSE or SUSE Linux Enterprise Desktop, for example, can require Polkit authorization for shutdown and reboot. Make sure this policy is turned off on all VM Guests.

If ACPI was enabled during a Windows XP/Windows Server 2003 guest installation, turning it on in the VM Guest configuration only is not sufficient. For more information, see:

- <https://support.microsoft.com/en-us/kb/314088> ↗
- <https://support.microsoft.com/en-us/kb/309283> ↗



Regardless of the VM Guest's configuration, a graceful shutdown is always possible from within the guest operating system.

### 10.3.1 Changing a VM Guest's State with Virtual Machine Manager

Changing a VM Guest's state can be done either from Virtual Machine Manager's main window, or from a VNC window.

#### PROCEDURE 10.1: STATE CHANGE FROM THE VIRTUAL MACHINE MANAGER WINDOW

1. Right-click a VM Guest entry.
2. Choose *Run*, *Pause*, or one of the *Shutdown options* from the pop-up menu.

#### PROCEDURE 10.2: STATE CHANGE FROM THE VNC WINDOW

1. Open a VNC Window as described in [Section 10.2.1.1, "Opening a Graphical Console with Virtual Machine Manager"](#).
2. Choose *Run*, *Pause*, or one of the *Shut Down* options either from the toolbar or from the *Virtual Machine* menu.

#### 10.3.1.1 Automatically Starting a VM Guest

You can automatically start a guest when the VM Host Server boots. This feature is not enabled by default and needs to be enabled for each VM Guest individually. There is no way to activate it globally.

1. Double-click the VM Guest entry in Virtual Machine Manager to open its console.
2. Choose *View > Details* to open the VM Guest configuration window.
3. Choose *Boot Options* and check *Start virtual machine on host boot up*.
4. Save the new configuration with *Apply*.

### 10.3.2 Changing a VM Guest's State with **virsh**

In the following examples, the state of a VM Guest named "sles12" is changed.

### Start

```
tux > virsh start sles12
```

### Pause

```
tux > virsh suspend sles12
```

### Resume (a Suspended VM Guest)

```
tux > virsh resume sles12
```

### Reboot

```
tux > virsh reboot sles12
```

### Graceful shutdown

```
tux > virsh shutdown sles12
```

### Force shutdown

```
tux > virsh destroy sles12
```

### Turn on automatic start

```
tux > virsh autostart sles12
```

### Turn off automatic start

```
tux > virsh autostart --disable sles12
```

## 10.4 Saving and Restoring the State of a VM Guest

Saving a VM Guest preserves the exact state of the guest's memory. The operation is similar to *hibernating* a computer. A saved VM Guest can be quickly restored to its previously saved running condition.

When saved, the VM Guest is paused, its current memory state is saved to disk, and then the guest is stopped. The operation does not make a copy of any portion of the VM Guest's virtual disk. The amount of time taken to save the virtual machine depends on the amount of memory allocated. When saved, a VM Guest's memory is returned to the pool of memory available on the VM Host Server.

The restore operation loads a VM Guest's previously saved memory state file and starts it. The guest is not booted but instead resumed at the point where it was previously saved. The operation is similar to coming out of hibernation.

The VM Guest is saved to a state file. Make sure there is enough space on the partition you are going to save to. For an estimation of the file size in megabytes to be expected, issue the following command on the guest:

```
tux > free -mh | awk '/^Mem:/ {print $3}'
```



### Warning: Always Restore Saved Guests

After using the save operation, do not boot or start the saved VM Guest. Doing so would cause the machine's virtual disk and the saved memory state to get out of synchronization. This can result in critical errors when restoring the guest.

To be able to work with a saved VM Guest again, use the restore operation. If you used **virsh** to save a VM Guest, you cannot restore it using Virtual Machine Manager. In this case, make sure to restore using **virsh**.



### Important: Only for VM Guests with Disk Types raw, qcow2, qed

Saving and restoring VM Guests is only possible if the VM Guest is using a virtual disk of the type **raw** (**.img**), **qcow2**, or **qed**.

## 10.4.1 Saving/Restoring with Virtual Machine Manager

### PROCEDURE 10.3: SAVING A VM GUEST

1. Open a VNC connection window to a VM Guest. Make sure the guest is running.
2. Choose *Virtual Machine* > *Shutdown* > *Save*.

### PROCEDURE 10.4: RESTORING A VM GUEST

1. Open a VNC connection window to a VM Guest. Make sure the guest is not running.
2. Choose *Virtual Machine* > *Restore*.

If the VM Guest was previously saved using Virtual Machine Manager, you will not be offered an option to *Run* the guest. However, note the caveats on machines saved with **virsh** outlined in *Warning: Always Restore Saved Guests*.

## 10.4.2 Saving and Restoring with **virsh**

Save a running VM Guest with the command **virsh save** and specify the file which it is saved to.

Save the guest named opensuse13

```
tux > virsh save opensuse13 /virtual/saves/opensuse13.vmsav
```

Save the guest with the ID 37

```
tux > virsh save 37 /virtual/saves/opensuse13.vmsave
```

To restore a VM Guest, use **virsh restore**:

```
tux > virsh restore /virtual/saves/opensuse13.vmsave
```

## 10.5 Creating and Managing Snapshots

VM Guest snapshots are snapshots of the complete virtual machine including the state of CPU, RAM, devices, and the content of all writable disks. To use virtual machine snapshots, all the attached hard disks need to use the qcow2 disk image format, and at least one of them needs to be writable.

Snapshots let you restore the state of the machine at a particular point in time. This is useful when undoing a faulty configuration or the installation of a lot of packages. After starting a snapshot that was created while the VM Guest was shut off, you will need to boot it. Any changes written to the disk after that point in time will be lost when starting the snapshot.



### Note

Snapshots are supported on KVM VM Host Servers only.

## 10.5.1 Terminology

There are several specific terms used to describe the type of snapshots:

### Internal snapshots

Snapshots that are saved into the qcow2 file of the original VM Guest. The file holds both the saved state of the snapshot and the changes made since the snapshot was taken. The main advantage of internal snapshots is that they are all stored in one file and therefore it is easy to copy or move them across multiple machines.

### External snapshots

When creating an external snapshot, the original qcow2 file is saved and made read-only, while a new qcow2 file is created to hold the changes. The original file is sometimes called a 'backing' or 'base' file, while the new file with all the changes is called an 'overlay' or 'derived' file. External snapshots are useful when performing backups of VM Guests. However, external snapshots are not supported by Virtual Machine Manager, and cannot be deleted by **virsh** directly. For more information on external snapshots in QEMU, refer to [Section 28.2.4, "Manipulate Disk Images Effectively"](#).

### Live snapshots

Snapshots created when the original VM Guest is running. Internal live snapshots support saving the devices, and memory and disk states, while external live snapshots with **virsh** support saving either the memory state, or the disk state, or both.

### Offline snapshots

Snapshots created from a VM Guest that is shut off. This ensures data integrity as all the guest's processes are stopped and no memory is in use.

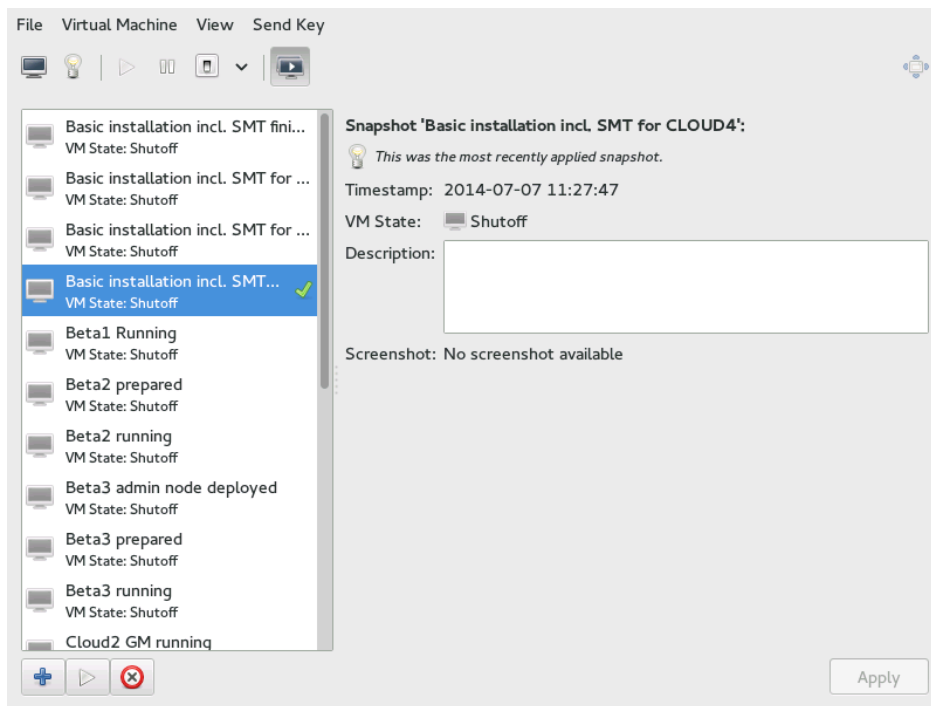
## 10.5.2 Creating and Managing Snapshots with Virtual Machine Manager



### Important: Internal Snapshots Only

Virtual Machine Manager supports only internal snapshots, both live and offline.

To open the snapshot management view in Virtual Machine Manager, open the VNC window as described in [Section 10.2.1.1, "Opening a Graphical Console with Virtual Machine Manager"](#). Now either choose *View > Snapshots* or click *Manage VM Snapshots* in the toolbar.



The list of existing snapshots for the chosen VM Guest is displayed in the left-hand part of the window. The snapshot that was last started is marked with a green tick. The right-hand part of the window shows details of the snapshot currently marked in the list. These details include the snapshot's title and time stamp, the state of the VM Guest at the time the snapshot was taken and a description. Snapshots of running guests also include a screenshot. The *Description* can be changed directly from this view. Other snapshot data cannot be changed.

### 10.5.2.1 Creating a Snapshot

To take a new snapshot of a VM Guest, proceed as follows:

1. Optionally, shut down the VM Guest if you want to create an offline snapshot.
2. Click *Add* in the bottom left corner of the VNC window.  
The window *Create Snapshot* opens.
3. Provide a *Name* and, optionally, a description. The name cannot be changed after the snapshot has been taken. To be able to identify the snapshot later easily, use a “speaking name”.
4. Confirm with *Finish*.

### 10.5.2.2 Deleting a Snapshot

To delete a snapshot of a VM Guest, proceed as follows:

1. Click *Delete* in the bottom left corner of the VNC window.
2. Confirm the deletion with *Yes*.

### 10.5.2.3 Starting a Snapshot

To start a snapshot, proceed as follows:

1. Click *Run* in the bottom left corner of the VNC window.
2. Confirm the start with *Yes*.

## 10.5.3 Creating and Managing Snapshots with `virsh`

To list all existing snapshots for a domain (*admin\_server* in the following), run the `snapshot-list` command:

```
tux > virsh snapshot-list --domain admin_server
Name                               Creation Time           State
-----
Basic installation incl. SMT finished 2013-09-18 09:45:29 +0200 shutoff
Basic installation incl. SMT for CLOUD3 2013-12-11 15:11:05 +0100 shutoff
Basic installation incl. SMT for CLOUD3-HA 2014-03-24 13:44:03 +0100 shutoff
Basic installation incl. SMT for CLOUD4 2014-07-07 11:27:47 +0200 shutoff
Beta1 Running                      2013-07-12 12:27:28 +0200 shutoff
Beta2 prepared                     2013-07-12 17:00:44 +0200 shutoff
Beta2 running                      2013-07-29 12:14:11 +0200 shutoff
Beta3 admin node deployed 2013-07-30 16:50:40 +0200 shutoff
Beta3 prepared                     2013-07-30 17:07:35 +0200 shutoff
Beta3 running                      2013-09-02 16:13:25 +0200 shutoff
Cloud2 GM running                  2013-12-10 15:44:58 +0100 shutoff
CLOUD3 RC prepared                 2013-12-20 15:30:19 +0100 shutoff
CLOUD3-HA Build 680 prepared 2014-03-24 14:20:37 +0100 shutoff
CLOUD3-HA Build 796 installed (zypper up) 2014-04-14 16:45:18 +0200 shutoff
GMC2 post Cloud install 2013-09-18 10:53:03 +0200 shutoff
GMC2 pre Cloud install 2013-09-18 10:31:17 +0200 shutoff
GMC2 prepared (incl. Add-On Installation) 2013-09-17 16:22:37 +0200 shutoff
GMC_pre prepared                   2013-09-03 13:30:38 +0200 shutoff
OS + SMT + eth[01]                2013-06-14 16:17:24 +0200 shutoff
```

```
OS + SMT + Mirror + eth[01] 2013-07-30 15:50:16 +0200 shutoff
```

The snapshot that was last started is shown with the `snapshot-current` command:

```
tux > virsh snapshot-current --domain admin_server
Basic installation incl. SMT for CLOUD4
```

Details about a particular snapshot can be obtained by running the `snapshot-info` command:

```
tux > virsh snapshot-info --domain admin_server \
    -name "Basic installation incl. SMT for CLOUD4"
Name:          Basic installation incl. SMT for CLOUD4
Domain:        admin_server
Current:       yes
State:         shutoff
Location:      internal
Parent:        Basic installation incl. SMT for CLOUD3-HA
Children:      0
Descendants:     0
Metadata:      yes
```

### 10.5.3.1 Creating Internal Snapshots

To take an internal snapshot of a VM Guest, both live and offline, use the `snapshot-create-as` command as follows:

```
tux > virsh snapshot-create-as --domain admin_server ❶ --name "Snapshot 1" ❷ \
    --description "First snapshot" ❸
```

- ❶ Domain name. Mandatory.
- ❷ Name of the snapshot. It is recommended to use a “speaking name”, since that makes it easier to identify the snapshot. Mandatory.
- ❸ Description for the snapshot. Optional.

### 10.5.3.2 Creating External Snapshots

With `virsh`, you can take external snapshots of the guest's memory state, disk state, or both.

To take both live and offline external snapshots of the guest's disk, specify the `--disk-only` option:

```
tux > virsh snapshot-create-as --domain admin_server --name \
```



```
"Offline external snapshot" --disk-only
```

You can specify the `--diskspec` option to control how the external files are created:

```
tux > virsh snapshot-create-as --domain admin_server --name \
"Offline external snapshot" \
--disk-only --diskspec vda,snapshot=external,file=/path/to/snapshot_file
```

To take a live external snapshot of the guest's memory, specify the `--live` and `--memspec` options:

```
tux > virsh snapshot-create-as --domain admin_server --name \
"Offline external snapshot" --live \
--memspec snapshot=external,file=/path/to/snapshot_file
```

To take a live external snapshot of both the guest's disk and memory states, combine the `--live`, `--diskspec`, and `--memspec` options:

```
tux > virsh snapshot-create-as --domain admin_server --name \
"Offline external snapshot" --live \
--memspec snapshot=external,file=/path/to/snapshot_file
--diskspec vda,snapshot=external,file=/path/to/snapshot_file
```

Refer to the *SNAPSHOT COMMANDS* section in [man 1 virsh](#) for more details.

### 10.5.3.3 Deleting a Snapshot

External snapshots cannot be deleted with `virsh`. To delete an internal snapshot of a VM Guest and restore the disk space it occupies, use the `snapshot-delete` command:

```
tux > virsh snapshot-delete --domain admin_server --snapshotname "Snapshot 2"
```

### 10.5.3.4 Starting a Snapshot

To start a snapshot, use the `snapshot-revert` command:

```
tux > virsh snapshot-revert --domain admin_server --snapshotname "Snapshot 1"
```

To start the current snapshot (the one the VM Guest was started off), it is sufficient to use `--current` rather than specifying the snapshot name:

```
tux > virsh snapshot-revert --domain admin_server --current
```

## 10.6 Deleting a VM Guest

By default, deleting a VM Guest using `virsh` removes only its XML configuration. Since attached storage is not deleted by default, you can reuse it with another VM Guest. With Virtual Machine Manager, you can also delete a guest's storage files as well—this will completely erase the guest.

### 10.6.1 Deleting a VM Guest with Virtual Machine Manager

1. In the Virtual Machine Manager, right-click a VM Guest entry.
2. From the context menu, choose *Delete*.
3. A confirmation window opens. Clicking *Delete* will permanently erase the VM Guest. The deletion is not recoverable.  
You can also permanently delete the guest's virtual disk by activating *Delete Associated Storage Files*. The deletion is not recoverable either.

### 10.6.2 Deleting a VM Guest with `virsh`

To delete a VM Guest, it needs to be shut down first. It is not possible to delete a running guest. For information on shutting down, see [Section 10.3, “Changing a VM Guest's State: Start, Stop, Pause”](#).

To delete a VM Guest with `virsh`, run `virsh undefine VM_NAME`.

```
tux > virsh undefine sles12
```

There is no option to automatically delete the attached storage files. If they are managed by libvirt, delete them as described in [Section 12.2.4, “Deleting Volumes from a Storage Pool”](#).

## 10.7 Migrating VM Guests

One of the major advantages of virtualization is that VM Guests are portable. When a VM Host Server needs to go down for maintenance, or when the host gets overloaded, the guests can easily be moved to another VM Host Server. KVM and Xen even support “live” migrations during which the VM Guest is constantly available.

## 10.7.1 Migration Requirements

To successfully migrate a VM Guest to another VM Host Server, the following requirements need to be met:

- It is recommended that the source and destination systems have the same architecture. However, it is possible to migrate between hosts with AMD\* and Intel\* architectures.
- Storage devices must be accessible from both machines (for example, via NFS or iSCSI) and must be configured as a storage pool on both machines. For more information, see *Chapter 12, Managing Storage*.  
This is also true for CD-ROM or floppy images that are connected during the move. However, you can disconnect them prior to the move as described in *Section 14.8, "Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager"*.
- `libvirtd` needs to run on both VM Host Servers and you must be able to open a remote `libvirt` connection between the target and the source host (or vice versa). Refer to *Section 11.3, "Configuring Remote Connections"* for details.
- If a firewall is running on the target host, ports need to be opened to allow the migration. If you do not specify a port during the migration process, `libvirt` chooses one from the range 49152:49215. Make sure that either this range (recommended) or a dedicated port of your choice is opened in the firewall on the *target host*.
- Host and target machine should be in the same subnet on the network, otherwise networking will not work after the migration.
- All VM Host Servers participating in migration must have the same UID for the `qemu` user and the same GIDs for the `kvm`, `qemu`, and `libvirt` groups.
- No running or paused VM Guest with the same name must exist on the target host. If a shut down machine with the same name exists, its configuration will be overwritten.
- All CPU models except *host cpu* model are supported when migrating VM Guests.
- *SATA* disk device type is not migratable.
- File system pass-through feature is incompatible with migration.
- The VM Host Server and VM Guest need to have proper timekeeping installed. See *Chapter 16, VM Guest Clock Settings*.

- No physical devices can be passed from host to guest. Live migration is currently not supported when using devices with PCI pass-through or *SR-IOV*. If live migration needs to be supported, you need to use software virtualization (paravirtualization or full virtualization).
- Cache mode setting is an important setting for migration. See: *Section 15.5, “Effect of Cache Modes on Live Migration”*.
- Backward migration (for example, from SLES 15 SP2 to 15 SP1) is not supported.
- SUSE strives to support live migration of VM Guests from a VM Host Server running a service pack under LTSS to a VM Host Server running a newer service pack, within the same SLES major version. For example VM Guest migration from a SLES 12 SP2 host to a SLES 12 SP5 host. SUSE only performs minimal testing of LTSS-to-newer migration scenarios and recommends thorough on-site testing before attempting to migrate critical VM Guests.
- The image directory should be located in the same path on both hosts.
- All hosts should be on the same level of microcode (especially the spectre microcode updates). This can be achieved by installing the latest updates of SUSE Linux Enterprise Server on all hosts.

## 10.7.2 Supported Migration Scenarios

The following list enumerates supported migration scenarios for SLES 12 SP5 VM Host Servers:

- SLES 12 SP4 to SLES 12 SP5
- SLES 12 SP5 to SLES 12 SP5
- SLES 12 SP5 to SLES 15 SP1

## 10.7.3 Migrating with Virtual Machine Manager

When using the Virtual Machine Manager to migrate VM Guests, it does not matter on which machine it is started. You can start Virtual Machine Manager on the source or the target host or even on a third host. In the latter case you need to be able to open remote connections to both the target and the source host.

1. Start Virtual Machine Manager and establish a connection to the target or the source host. If the Virtual Machine Manager was started neither on the target nor the source host, connections to both hosts need to be opened.
2. Right-click the VM Guest that you want to migrate and choose *Migrate*. Make sure the guest is running or paused—it is not possible to migrate guests that are shut down.



### Tip: Increasing the Speed of the Migration

To increase the speed of the migration somewhat, pause the VM Guest. This is the equivalent of the former so-called “offline migration” option of Virtual Machine Manager.

3. Choose a *New Host* for the VM Guest. If the desired target host does not show up, make sure that you are connected to the host.

To change the default options for connecting to the remote host, under *Connection*, set the *Mode*, and the target host's *Address* (IP address or host name) and *Port*. If you specify a *Port*, you must also specify an *Address*.

Under *Advanced options*, choose whether the move should be permanent (default) or temporary, using *Temporary move*.

Additionally, there is the option *Allow unsafe*, which allows migrating without disabling the cache of the VM Host Server. This can speed up the migration but only works when the current configuration allows for a consistent view of the VM Guest storage without using `cache="none" / 0_DIRECT`.



### Note: Bandwidth Option

In recent versions of Virtual Machine Manager, the option of setting a bandwidth for the migration has been removed. To set a specific bandwidth, use `virsh` instead.

4. To perform the migration, click *Migrate*.  
When the migration is complete, the *Migrate* window closes and the VM Guest is now listed on the new host in the Virtual Machine Manager window. The original VM Guest will still be available on the target host (in shut down state).

## 10.7.4 Migrating with **virsh**

To migrate a VM Guest with **virsh migrate**, you need to have direct or remote shell access to the VM Host Server, because the command needs to be run on the host. The migration command looks like this:

```
tux > virsh migrate [OPTIONS] VM_ID_or_NAME CONNECTION_URI [--migrateuri
tcp://REMOTE_HOST:PORT]
```

The most important options are listed below. See **virsh help migrate** for a full list.

### --live

Does a live migration. If not specified, the guest will be paused during the migration (“offline migration”).

### --suspend

Does an offline migration and does not restart the VM Guest on the target host.

### --persistent

By default a migrated VM Guest will be migrated temporarily, so its configuration is automatically deleted on the target host if it is shut down. Use this switch to make the migration persistent.

### --undefinesource

When specified, the VM Guest definition on the source host will be deleted after a successful migration (however, virtual disks attached to this guest will *not* be deleted).

The following examples use `mercury.example.com` as the source system and `jupiter.example.com` as the target system; the VM Guest's name is `opensuse131` with Id `37`.

### Offline migration with default parameters

```
tux > virsh migrate 37 qemu+ssh://tux@jupiter.example.com/system
```

### Transient live migration with default parameters

```
tux > virsh migrate --live opensuse131 qemu+ssh://tux@jupiter.example.com/system
```

### Persistent live migration; delete VM definition on source

```
tux > virsh migrate --live --persistent --undefinesource 37 \
```

```
qemu+tls://tux@jupiter.example.com/system
```

## Offline migration using port 49152

```
tux > virsh migrate opensuse131 qemu+ssh://tux@jupiter.example.com/system \
--migrateuri tcp://@jupiter.example.com:49152
```



### Note: Transient Compared to Persistent Migrations

By default **virsh migrate** creates a temporary (transient) copy of the VM Guest on the target host. A shut down version of the original guest description remains on the source host. A transient copy will be deleted from the server after it is shut down.

To create a permanent copy of a guest on the target host, use the switch **--persistent**. A shut down version of the original guest description remains on the source host, too. Use the option **--undefinesource** together with **--persistent** for a “real” move where a permanent copy is created on the target host and the version on the source host is deleted.

It is not recommended to use **--undefinesource** without the **--persistent** option, since this will result in the loss of both VM Guest definitions when the guest is shut down on the target host.

## 10.7.5 Step-by-Step Example

### 10.7.5.1 Exporting the Storage

First you need to export the storage, to share the Guest image between host. This can be done by an NFS server. In the following example we want to share the **/volume1/VM** directory for all machines that are on the network 10.0.1.0/24. We will use a SUSE Linux Enterprise NFS server. As root user, edit the **/etc/exports** file and add:

```
/volume1/VM 10.0.1.0/24 (rw,sync,no_root_squash)
```

You need to restart the NFS server:

```
tux > sudo systemctl restart nfsserver
tux > sudo exportfs
/volume1/VM      10.0.1.0/24
```

### 10.7.5.2 Defining the Pool on the Target Hosts

On each host where you want to migrate the VM Guest, the pool must be defined to be able to access the volume (that contains the Guest image). Our NFS server IP address is 10.0.1.99, its share is the `/volume1/VM` directory, and we want to get it mounted in the `/var/lib/libvirt/images/VM` directory. The pool name will be `VM`. To define this pool, create a `VM.xml` file with the following content:

```
<pool type='netfs'>
  <name>VM</name>
  <source>
    <host name='10.0.1.99' />
    <dir path='/volume1/VM' />
    <format type='auto' />
  </source>
  <target>
    <path>/var/lib/libvirt/images/VM</path>
    <permissions>
      <mode>0755</mode>
      <owner>-1</owner>
      <group>-1</group>
    </permissions>
  </target>
</pool>
```

Then load it into `libvirt` using the **pool-define** command:

```
root # virsh pool-define VM.xml
```

An alternative way to define this pool is to use the **virsh** command:

```
root # virsh pool-define-as VM --type netfs --source-host 10.0.1.99 \
      --source-path /volume1/VM --target /var/lib/libvirt/images/VM
Pool VM created
```

The following commands assume that you are in the interactive shell of **virsh** which can also be reached by using the command **virsh** without any arguments. Then the pool can be set to start automatically at host boot (autostart option):

```
virsh # pool-autostart VM
Pool VM marked as autostarted
```

If you want to disable the autostart:

```
virsh # pool-autostart VM --disable
Pool VM unmarked as autostarted
```



Check if the pool is present:

```
virsh # pool-list --all
Name                               State      Autostart
-----
default                            active     yes
VM                                  active     yes

virsh # pool-info VM
Name:                               VM
UUID:                               42efe1b3-7eaa-4e24-a06a-ba7c9ee29741
State:                              running
Persistent:                         yes
Autostart:                          yes
Capacity:                           2,68 TiB
Allocation:                         2,38 TiB
Available:                          306,05 GiB
```



### Warning: Pool Needs to Exist on All Target Hosts

Remember: this pool must be defined on each host where you want to be able to migrate your VM Guest.

#### 10.7.5.3 Creating the Volume

The pool has been defined—now we need a volume which will contain the disk image:

```
virsh # vol-create-as VM sled12.qcow2 8G --format qcow2
Vol sled12.qcow2 created
```

The volume names shown will be used later to install the guest with `virt-install`.

#### 10.7.5.4 Creating the VM Guest

Let's create a SUSE Linux Enterprise Server VM Guest with the `virt-install` command. The VM pool will be specified with the `--disk` option, `cache=none` is recommended if you do not want to use the `--unsafe` option while doing the migration.

```
root # virt-install --connect qemu:///system --virt-type kvm --name \
sled12 --memory 1024 --disk vol=VM/sled12.qcow2,cache=none --cdrom \
/mnt/install/ISO/SLE-12-Desktop-DVD-x86_64-Build0327-Media1.iso --graphics \
```

```
vnc --os-variant sled12
Starting install...
Creating domain...
```

### 10.7.5.5 Migrate the VM Guest

Everything is ready to do the migration now. Run the **migrate** command on the VM Host Server that is currently hosting the VM Guest, and choose the destination.

```
virsh # migrate --live sled12 --verbose qemu+ssh://IP/Hostname/system
Password:
Migration: [ 12 %]
```

## 10.8 Monitoring

### 10.8.1 Monitoring with Virtual Machine Manager

After starting Virtual Machine Manager and connecting to the VM Host Server, a CPU usage graph of all the running guests is displayed.

It is also possible to get information about disk and network usage with this tool, however, you must first activate this in *Preferences*:

1. Run **virt-manager**.
2. Select *Edit > Preferences*.
3. Change the tab from *General* to *Polling*.
4. Activate the check boxes for the kind of activity you want to see: *Poll Disk I/O*, *Poll Network I/O*, and *Poll Memory stats*.
5. If desired, also change the update interval using *Update status every n seconds*.
6. Close the *Preferences* dialog.
7. Activate the graphs that should be displayed under *View > Graph*.

Afterward, the disk and network statistics are also displayed in the main window of the Virtual Machine Manager.

More precise data is available from the VNC window. Open a VNC window as described in [Section 10.2.1, “Opening a Graphical Console”](#). Choose *Details* from the toolbar or the *View* menu. The statistics are displayed from the *Performance* entry of the left-hand tree menu.

## 10.8.2 Monitoring with **virt-top**

**virt-top** is a command line tool similar to the well-known process monitoring tool **top**. **virt-top** uses libvirt and therefore is capable of showing statistics for VM Guests running on different hypervisors. It is recommended to use **virt-top** instead of hypervisor-specific tools like **xentop**.

By default **virt-top** shows statistics for all running VM Guests. Among the data that is displayed is the percentage of memory used (**%MEM**) and CPU (**%CPU**) and the uptime of the guest (**TIME**). The data is updated regularly (every three seconds by default). The following shows the output on a VM Host Server with seven VM Guests, four of them inactive:

```
virt-top 13:40:19 - x86_64 8/8CPU 1283MHz 16067MB 7.6% 0.5%
7 domains, 3 active, 3 running, 0 sleeping, 0 paused, 4 inactive D:0 O:0 X:0
CPU: 6.1% Mem: 3072 MB (3072 MB by guests)

  ID S RDRQ WRRQ RXBY TXBY %CPU %MEM  TIME  NAME
  7 R  123   1  18K  196  5.8  6.0  0:24.35 sled12_sp1
  6 R   1   0  18K   0  0.2  6.0  0:42.51 sles12_sp1
  5 R   0   0  18K   0  0.1  6.0 85:45.67 opensuse_leap
    -                                     (Ubuntu_1410)
    -                                     (debian_780)
    -                                     (fedora_21)
    -                                     (sles11sp3)
```

By default the output is sorted by ID. Use the following key combinations to change the sort field:

**Shift** - **P** : CPU usage

**Shift** - **M** : Total memory allocated by the guest

**Shift** - **T** : Time

**Shift** - **I** : ID

To use any other field for sorting, press **Shift** - **F** and select a field from the list. To toggle the sort order, use **Shift** - **R**.

**virt-top** also supports different views on the VM Guests data, which can be changed on-the-fly by pressing the following keys:

**0** : default view

- 1** : show physical CPUs
- 2** : show network interfaces
- 3** : show virtual disks

**virt-top** supports more hot keys to change the view of the data and many command line switches that affect the behavior of the program. For more information, see [man 1 virt-top](#).

### 10.8.3 Monitoring with **kvm\_stat**

**kvm\_stat** can be used to trace KVM performance events. It monitors `/sys/kernel/debug/kvm`, so it needs the debugfs to be mounted. On SUSE Linux Enterprise Server it should be mounted by default. In case it is not mounted, use the following command:

```
tux > sudo mount -t debugfs none /sys/kernel/debug
```

**kvm\_stat** can be used in three different modes:

```
kvm_stat           # update in 1 second intervals
kvm_stat -l        # 1 second snapshot
kvm_stat -l > kvmstats.log # update in 1 second intervals in log format
                        # can be imported to a spreadsheet
```

#### EXAMPLE 10.1: TYPICAL OUTPUT OF **kvm\_stat**

```
kvm statistics

efer_reload          0      0
exits                11378946 218130
fpu_reload           62144   152
halt_exits           414866   100
halt_wakeup          260358   50
host_state_reload    539650   249
hypercalls           0      0
insn_emulation       6227331 173067
insn_emulation_fail  0      0
invlpg               227281   47
io_exits              113148   18
irq_exits             168474   127
irq_injections        482804   123
irq_window            51270   18
largepages            0      0
mmio_exits            6925    0
mmu_cache_miss        71820   19
mmu_flooded           35420    9
```

mmu_pde_zapped	64763	20
mmu_pte_updated	0	0
mmu_pte_write	213782	29
mmu_recycled	0	0
mmu_shadow_zapped	128690	17
mmu_unsync	46	-1
nmi_injections	0	0
nmi_window	0	0
pf_fixed	1553821	857
pf_guest	1018832	562
remote_tlb_flush	174007	37
request_irq	0	0
signal_exits	0	0
tlb_flush	394182	148

See <http://clalance.blogspot.com/2009/01/kvm-performance-tools.html> for further information on how to interpret these values.

# 11 Connecting and Authorizing

Managing several VM Host Servers, each hosting multiple VM Guests, quickly becomes difficult. One benefit of `libvirt` is the ability to connect to several VM Host Servers at once, providing a single interface to manage all VM Guests and to connect to their graphical console.

To ensure only authorized users can connect, `libvirt` offers several connection types (via TLS, SSH, Unix sockets, and TCP) that can be combined with different authorization mechanisms (socket, Polkit, SASL and Kerberos).

## 11.1 Authentication

The power to manage VM Guests and to access their graphical console is something that should be restricted to a well defined circle of persons. To achieve this goal, you can use the following authentication techniques on the VM Host Server:

- Access control for Unix sockets with permissions and group ownership. This method is available for `libvirtd` connections only.
- Access control for Unix sockets with Polkit. This method is available for local `libvirtd` connections only.
- User name and password authentication with SASL (Simple Authentication and Security Layer). This method is available for both, `libvirtd` and VNC connections. Using SASL does not require real user accounts on the server, since it uses its own database to store user names and passwords. Connections authenticated with SASL are encrypted.
- Kerberos authentication. This method, available for `libvirtd` connections only, is not covered in this manual. Refer to [https://libvirt.org/auth.html#ACL\\_server\\_kerberos](https://libvirt.org/auth.html#ACL_server_kerberos) for details.
- Single password authentication. This method is available for VNC connections only.

## Important: Authentication for `libvirtd` and VNC need to be configured separately

Access to the VM Guest's management functions (via `libvirtd`) on the one hand, and to its graphical console on the other hand, always needs to be configured separately. When restricting access to the management tools, these restrictions do *not* automatically apply to VNC connections!

When accessing VM Guests from remote via TLS/SSL connections, access can be indirectly controlled on each client by restricting read permissions to the certificate's key file to a certain group. See [Section 11.3.2.5, "Restricting Access \(Security Considerations\)"](#) for details.

### 11.1.1 `libvirtd` Authentication

`libvirtd` authentication is configured in `/etc/libvirt/libvirtd.conf`. The configuration made here applies to all `libvirt` tools such as the Virtual Machine Manager or `virsh`.

`libvirt` offers two sockets: a read-only socket for monitoring purposes and a read-write socket to be used for management operations. Access to both sockets can be configured independently. By default, both sockets are owned by `root.root`. Default access permissions on the read-write socket are restricted to the user `root` (`0700`) and fully open on the read-only socket (`0777`).

In the following instructions, you will learn how to configure access permissions for the read-write socket. The same instructions also apply to the read-only socket. All configuration steps need to be carried out on the VM Host Server.

## Note: Default Authentication Settings on SUSE Linux Enterprise Server

The default authentication method on SUSE Linux Enterprise Server is access control for Unix sockets. Only the user `root` may authenticate. When accessing the `libvirt` tools as a non-root user directly on the VM Host Server, you need to provide the `root` password through Polkit once. You are then granted access for the current and for future sessions.

Alternatively, you can configure `libvirt` to allow “system” access to non-privileged users. See [Section 11.2.1, ““system” Access for Non-Privileged Users”](#) for details.

## RECOMMENDED AUTHORIZATION METHODS

### Local Connections

*Section 11.1.1.2, "Local Access Control for Unix Sockets with Polkit"*

*Section 11.1.1.1, "Access Control for Unix Sockets with Permissions and Group Ownership"*

### Remote Tunnel over SSH

*Section 11.1.1.1, "Access Control for Unix Sockets with Permissions and Group Ownership"*

### Remote TLS/SSL Connection

*Section 11.1.1.3, "User name and Password Authentication with SASL"*

none (access controlled on the client side by restricting access to the certificates)

#### 11.1.1.1 Access Control for Unix Sockets with Permissions and Group Ownership

To grant access for non-root accounts, configure the sockets to be owned and accessible by a certain group (libvirt in the following example). This authentication method can be used for local and remote SSH connections.

1. In case it does not exist, create the group that should own the socket:

```
groupadd libvirt
```



#### Important: Group Needs to Exist

The group must exist prior to restarting libvirtd. If not, the restart will fail.

2. Add the desired users to the group:

```
usermod --append --groups libvirt tux
```

3. Change the configuration in /etc/libvirt/libvirtd.conf as follows:

```
unix_sock_group = "libvirt" ❶  
unix_sock_rw_perms = "0770" ❷  
auth_unix_rw = "none" ❸
```

- ❶ Group ownership will be set to group libvirt.



- ② Sets the access permissions for the socket ( `srwxrwx---` ).
- ③ Disables other authentication methods (Polkit or SASL). Access is solely controlled by the socket permissions.

#### 4. Restart `libvirtd`:

```
systemctl start libvirtd
```

### 11.1.1.2 Local Access Control for Unix Sockets with Polkit

Access control for Unix sockets with Polkit is the default authentication method on SUSE Linux Enterprise Server for non-remote connections. Therefore, no `libvirt` configuration changes are needed. With Polkit authorization enabled, permissions on both sockets default to `0777` and each application trying to access a socket needs to authenticate via Polkit.



#### Important: Polkit Authentication for Local Connections Only

Authentication with Polkit can only be used for local connections on the VM Host Server itself, since Polkit does not handle remote authentication.

Two policies for accessing `libvirt`'s sockets exist:

- `org.libvirt.unix.monitor`: accessing the read-only socket
- `org.libvirt.unix.manage`: accessing the read-write socket

By default, the policy for accessing the read-write socket is to authenticate with the `root` password once and grant the privilege for the current and for future sessions.

To grant users access to a socket without having to provide the `root` password, you need to create a rule in `/etc/polkit-1/rules.d`. Create the file `/etc/polkit-1/rules.d/10-grant-libvirt` with the following content to grant access to the read-write socket to all members of the group `libvirt`:

```
polkit.addRule(function(action, subject) {  
  if (action.id == "org.libvirt.unix.manage" && subject.isInGroup("libvirt")) {  
    return polkit.Result.YES;  
  }  
});
```

### 11.1.1.3 User name and Password Authentication with SASL

SASL provides user name and password authentication and data encryption (digest-md5, by default). Since SASL maintains its own user database, the users do not need to exist on the VM Host Server. SASL is required by TCP connections and on top of TLS/SSL connections.



#### Important: Plain TCP and SASL with digest-md5 Encryption

Using digest-md5 encryption on an otherwise not encrypted TCP connection does not provide enough security for production environments. It is recommended to only use it in testing environments.



#### Tip: SASL Authentication on Top of TLS/SSL

Access from remote TLS/SSL connections can be indirectly controlled on the *client side* by restricting access to the certificate's key file. However, this might prove error-prone when dealing with many clients. Using SASL with TLS adds security by additionally controlling access on the server side.

To configure SASL authentication, proceed as follows:

1. Change the configuration in `/etc/libvirt/libvirtd.conf` as follows:

- a. To enable SASL for TCP connections:

```
auth_tcp = "sasl"
```

- b. To enable SASL for TLS/SSL connections:

```
auth_tls = "sasl"
```

2. Restart `libvirtd`:

```
systemctl restart libvirtd
```

3. The libvirt SASL configuration file is located at `/etc/sasl2/libvirtd.conf`. Normally, there is no need to change the defaults. However, if using SASL on top of TLS, you may turn off session encryption to avoid additional overhead (TLS connections are already encrypted) by commenting the line setting the `mech_list` parameter. Only do this for TLS/SASL, for TCP connections this parameter must be set to digest-md5.

```
#mech_list: digest-md5
```

4. By default, no SASL users are configured, so no logins are possible. Use the following commands to manage users:

Add the user `tux`

```
saslpaswd2 -a libvirt tux
```

Delete the user `tux`

```
saslpaswd2 -a libvirt -d tux
```

List existing users

```
sasldblistusers2 -f /etc/libvirt/passwd.db
```



### Tip: **virsh** and SASL Authentication

When using SASL authentication, you will be prompted for a user name and password every time you issue a **virsh** command. Avoid this by using **virsh** in shell mode.

## 11.1.2 VNC Authentication

Since access to the graphical console of a VM Guest is not controlled by `libvirt`, but rather by the specific hypervisor, it is always necessary to additionally configure VNC authentication. The main configuration file is `/etc/libvirt/<hypervisor>.conf`. This section describes the QEMU/KVM hypervisor, so the target configuration file is `/etc/libvirt/qemu.conf`.



### Note: VNC Authentication for Xen

In contrast to KVM and LXC, Xen does not yet offer more sophisticated VNC authentication than setting a password on a per VM basis. See the `<graphics type='vnc'... libvirt` configuration option below.

Two authentication types are available: SASL and single password authentication. If you are using SASL for `libvirt` authentication, it is strongly recommended to use it for VNC authentication as well—it is possible to share the same database.

A third method to restrict access to the VM Guest is to enable the use of TLS encryption on the VNC server. This requires the VNC clients to have access to x509 client certificates. By restricting access to these certificates, access can indirectly be controlled on the client side. Refer to [Section 11.3.2.4.2, “VNC over TLS/SSL: Client Configuration”](#) for details.

### 11.1.2.1 User name and Password Authentication with SASL

SASL provides user name and password authentication and data encryption. Since SASL maintains its own user database, the users do not need to exist on the VM Host Server. As with SASL authentication for `libvirt`, you may use SASL on top of TLS/SSL connections. Refer to [Section 11.3.2.4.2, “VNC over TLS/SSL: Client Configuration”](#) for details on configuring these connections.

To configure SASL authentication for VNC, proceed as follows:

1. Create a SASL configuration file. It is recommended to use the existing `libvirt` file. If you have already configured SASL for `libvirt` and are planning to use the same settings including the same user name and password database, a simple link is suitable:

```
ln -s /etc/sasl2/libvirt.conf /etc/sasl2/qemu.conf
```

If are setting up SASL for VNC only or you are planning to use a different configuration than for `libvirt`, copy the existing file to use as a template:

```
cp /etc/sasl2/libvirt.conf /etc/sasl2/qemu.conf
```

Then edit it according to your needs.

2. Change the configuration in `/etc/libvirt/qemu.conf` as follows:

```
vnc_listen = "0.0.0.0"
vnc_sasl = 1
sasldb_path: /etc/libvirt/qemu_passwd.db
```

The first parameter enables VNC to listen on all public interfaces (rather than to the local host only), and the second parameter enables SASL authentication.

3. By default, no SASL users are configured, so no logins are possible. Use the following commands to manage users:

Add the user `tux`

```
saslpasswd2 -f /etc/libvirt/qemu_passwd.db -a qemu tux
```

### Delete the user tux

```
saslpaswd2 -f /etc/libvirt/qemu_passwd.db -a qemu -d tux
```

### List existing users

```
sasldblistusers2 -f /etc/libvirt/qemu_passwd.db
```

#### 4. Restart libvirtd:

```
systemctl restart libvirtd
```

5. Restart all VM Guests that have been running prior to changing the configuration. VM Guests that have not been restarted will not use SASL authentication for VNC connects.



### Note: Supported VNC Viewers

SASL authentication is currently supported by Virtual Machine Manager and **virt-viewer**. Both of these viewers also support TLS/SSL connections.

## 11.1.2.2 Single Password Authentication

Access to the VNC server may also be controlled by setting a VNC password. You can either set a global password for all VM Guests or set individual passwords for each guest. The latter requires to edit the VM Guest's configuration files.



### Note: Always Set a Global Password

If you are using single password authentication, it is good practice to set a global password even if setting passwords for each VM Guest. This will always leave your virtual machines protected with a “fallback” password if you forget to set a per-machine password. The global password will only be used if no other password is set for the machine.

#### PROCEDURE 11.1: SETTING A GLOBAL VNC PASSWORD

1. Change the configuration in /etc/libvirt/qemu.conf as follows:

```
vnc_listen = "0.0.0.0"
```

```
vnc_password = "PASSWORD"
```

The first parameter enables VNC to listen on all public interfaces (rather than to the local host only), and the second parameter sets the password. The maximum length of the password is eight characters.

2. Restart `libvirtd`:

```
root # systemctl restart libvirtd
```

3. Restart all VM Guests that have been running prior to changing the configuration. VM Guests that have not been restarted will not use password authentication for VNC connects.

#### PROCEDURE 11.2: SETTING A VM GUEST SPECIFIC VNC PASSWORD

1. Change the configuration in `/etc/libvirt/qemu.conf` as follows to enable VNC to listen on all public interfaces (rather than to the local host only).

```
vnc_listen = "0.0.0.0"
```

2. Open the VM Guest's XML configuration file in an editor. Replace `VM NAME` in the following example with the name of the VM Guest. The editor that is used defaults to `$EDITOR`. If that variable is not set, `vi` is used.

```
virsh edit VM NAME
```

3. Search for the element `<graphics>` with the attribute `type='vnc'`, for example:

```
<graphics type='vnc' port='-1' autoport='yes'/>
```

4. Add the `passwd=PASSWORD` attribute, save the file and exit the editor. The maximum length of the password is eight characters.

```
<graphics type='vnc' port='-1' autoport='yes' passwd='PASSWORD'/>
```

5. Restart `libvirtd`:

```
root # systemctl restart libvirtd
```

6. Restart all VM Guests that have been running prior to changing the configuration. VM Guests that have not been restarted will not use password authentication for VNC connects.



## Warning: Security of the VNC Protocol

The VNC protocol is not considered to be safe. Although the password is sent encrypted, it might be vulnerable when an attacker can sniff both the encrypted password and the encryption key. Therefore, it is recommended to use VNC with TLS/SSL or tunneled over SSH. **virt-viewer**, Virtual Machine Manager and **vinagre** from version 2.30 onward support both methods.

## 11.2 Connecting to a VM Host Server

To connect to a hypervisor with **libvirt**, you need to specify a uniform resource identifier (URI). This URI is needed with **virsh** and **virt-viewer** (except when working as **root** on the VM Host Server) and is optional for the Virtual Machine Manager. Although the latter can be called with a connection parameter (for example, **virt-manager -c qemu:///system**), it also offers a graphical interface to create connection URIs. See [Section 11.2.2, “Managing Connections with Virtual Machine Manager”](#) for details.

```
HYPERVERSOR ❶ +PROTOCOL ❷ : //USER@REMOTE ❸ /CONNECTION_TYPE ❹
```

- ❶ Specify the hypervisor. SUSE Linux Enterprise Server currently supports the following hypervisors: **test** (dummy for testing), **qemu** (KVM), and **xen** (Xen). This parameter is mandatory.
- ❷ When connecting to a remote host, specify the protocol here. It can be one of: **ssh** (connection via SSH tunnel), **tcp** (TCP connection with SASL/Kerberos authentication), **tls** (TLS/SSL encrypted connection with authentication via x509 certificates).
- ❸ When connecting to a remote host, specify the user name and the remote host name. If no user name is specified, the user name that has called the command (**\$USER**) is used. See below for more information. For TLS connections, the host name needs to be specified exactly as in the x509 certificate.
- ❹ When connecting to the **QEMU/KVM** hypervisor, two connection types are accepted: **system** for full access rights, or **session** for restricted access. Since **session** access is not supported on SUSE Linux Enterprise Server, this documentation focuses on **system** access.

### EXAMPLE HYPERVISOR CONNECTION URIS

```
test:///default
```

Connect to the local dummy hypervisor. Useful for testing.

qemu:///system or xen:///system

Connect to the QEMU/Xen hypervisor on the local host having full access (type system).

qemu+ssh://tux@mercury.example.com/system or xen+ssh://tux@mercury.example.com/system

Connect to the QEMU/Xen hypervisor on the remote host mercury.example.com. The connection is established via an SSH tunnel.

qemu+tls://saturn.example.com/system or xen+tls://saturn.example.com/system

Connect to the QEMU/Xen hypervisor on the remote host mercury.example.com. The connection is established using TLS/SSL.

For more details and examples, refer to the libvirt documentation at <https://libvirt.org/uri.html>.



### Note: User Names in URIs

A user name needs to be specified when using Unix socket authentication (regardless of whether using the user/password authentication scheme or Polkit). This applies to all SSH and local connections.

There is no need to specify a user name when using SASL authentication (for TCP or TLS connections) or when doing no additional server-side authentication for TLS connections. With SASL the user name will not be evaluated—you will be prompted for an SASL user/password combination in any case.

## 11.2.1 “system” Access for Non-Privileged Users

As mentioned above, a connection to the QEMU hypervisor can be established using two different protocols: session and system. A “session” connection is spawned with the same privileges as the client program. Such a connection is intended for desktop virtualization, since it is restricted (for example no USB/PCI device assignments, no virtual network setup, limited remote access to libvirtd).



The “system” connection intended for server virtualization has no functional restrictions but is, by default, only accessible by root. However, with the addition of the DAC (Discretionary Access Control) driver to libvirt it is now possible to grant non-privileged users “system” access. To grant “system” access to the user tux, proceed as follows:

#### PROCEDURE 11.3: GRANTING “SYSTEM” ACCESS TO A REGULAR USER

1. Enable access via Unix sockets as described in *Section 11.1.1.1, “Access Control for Unix Sockets with Permissions and Group Ownership”*. In that example access to libvirt is granted to all members of the group libvirt and tux made a member of this group. This ensures that tux can connect using virsh or Virtual Machine Manager.
2. Edit /etc/libvirt/qemu.conf and change the configuration as follows:

```
user = "tux"
group = "libvirt"
dynamic_ownership = 1
```

This ensures that the VM Guests are started by tux and that resources bound to the guest (for example virtual disks) can be accessed and modified by tux.

3. Make tux a member of the group kvm:

```
usermod --append --groups kvm tux
```

This step is needed to grant access to /dev/kvm, which is required to start VM Guests.

4. Restart libvirtd:

```
root # systemctl restart libvirtd
```

## 11.2.2 Managing Connections with Virtual Machine Manager

The Virtual Machine Manager uses a Connection for every VM Host Server it manages. Each connection contains all VM Guests on the respective host. By default, a connection to the local host is already configured and connected.

All configured connections are displayed in the Virtual Machine Manager main window. Active connections are marked with a small triangle, which you can click to fold or unfold the list of VM Guests for this connection.

Inactive connections are listed gray and are marked with `Not Connected`. Either double-click or right-click it and choose *Connect* from the context menu. You can also *Delete* an existing connection from this menu.



### Note: Editing Existing Connections

It is not possible to edit an existing connection. To change a connection, create a new one with the desired parameters and delete the “old” one.

To add a new connection in the Virtual Machine Manager, proceed as follows:

1. Choose *File > Add Connection*
2. Choose the host's *Hypervisor* (*Xen* or *QEMU/KVM*)
3. *(Optional)* To set up a remote connection, choose *Connect to remote host*. For more information, see [Section 11.3, “Configuring Remote Connections”](#).  
In case of a remote connection, specify the *Hostname* of the remote machine in the format `USERNAME@REMOTE_HOST`.



### Important: Specifying a User Name

There is no need to specify a user name for TCP and TLS connections: In these cases, it will not be evaluated. However, in the case of SSH connections, specifying a user name is necessary when you want to connect as a user other than `root`.

4. If you do not want the connection to be automatically started when starting the Virtual Machine Manager, deactivate *Autoconnect*.
5. Finish the configuration by clicking *Connect*.

## 11.3 Configuring Remote Connections

A major benefit of `libvirt` is the ability to manage VM Guests on different remote hosts from a central location. This section gives detailed instructions on how to configure server and client to allow remote connections.

### 11.3.1 Remote Tunnel over SSH (qemu+ssh or xen+ssh)

Enabling a remote connection that is tunneled over SSH on the VM Host Server only requires the ability to accept SSH connections. Make sure the SSH daemon is started (`systemctl status sshd`) and that the ports for service `SSH` are opened in the firewall.

User authentication for SSH connections can be done using traditional file user/group ownership and permissions as described in [Section 11.1.1.1, “Access Control for Unix Sockets with Permissions and Group Ownership”](#). Connecting as user `tux` (`qemu+ssh://tuxsIVname;/system` or `xen+ssh://tuxsIVname;/system`) works out of the box and does not require additional configuration on the `libvirt` side.

When connecting via SSH `qemu+ssh://USER@SYSTEM` or `xen+ssh://USER@SYSTEM` you need to provide the password for `USER`. This can be avoided by copying your public key to `~USER/.ssh/authorized_keys` on the VM Host Server as explained in *Book “Security and Hardening Guide”, Chapter 15 “SSH: Secure Network Operations”, Section 15.5.2 “Copying an SSH Key”*. Using an `ssh-agent` on the machine from which you are connecting adds even more convenience. For more information, see *Book “Security and Hardening Guide”, Chapter 15 “SSH: Secure Network Operations”, Section 15.5.3 “Using the **ssh-agent**”*.

### 11.3.2 Remote TLS/SSL Connection with x509 Certificate (qemu+tls or xen+tls)

Using TCP connections with TLS/SSL encryption and authentication via x509 certificates is much more complicated to set up than SSH, but it is a lot more scalable. Use this method if you need to manage several VM Host Servers with a varying number of administrators.

#### 11.3.2.1 Basic Concept

TLS (Transport Layer Security) encrypts the communication between two computers by using certificates. The computer starting the connection is always considered the “client”, using a “client certificate”, while the receiving computer is always considered the “server”, using a “server certificate”. This scenario applies, for example, if you manage your VM Host Servers from a central desktop.

If connections are initiated from both computers, each needs to have a client *and* a server certificate. This is the case, for example, if you migrate a VM Guest from one host to another.

Each x509 certificate has a matching private key file. Only the combination of certificate and private key file can identify itself correctly. To assure that a certificate was issued by the assumed owner, it is signed and issued by a central certificate called certificate authority (CA). Both the client and the server certificates must be issued by the same CA.

### Important: User Authentication

Using a remote TLS/SSL connection only ensures that two computers are allowed to communicate in a certain direction. Restricting access to certain users can indirectly be achieved on the client side by restricting access to the certificates. For more information, see [Section 11.3.2.5, “Restricting Access \(Security Considerations\)”](#).

`libvirt` also supports user authentication on the server with SASL. For more information, see [Section 11.3.2.6, “Central User Authentication with SASL for TLS Sockets”](#).

#### 11.3.2.2 Configuring the VM Host Server

The VM Host Server is the machine receiving connections. Therefore, the *server* certificates need to be installed. The CA certificate needs to be installed, too. When the certificates are in place, TLS support can be turned on for `libvirt`.

1. Create the server certificate and export it together with the CA certificate as described in [Section B.2, “Generating x509 Client/Server Certificates”](#).
2. Create the following directories on the VM Host Server:

```
mkdir -p /etc/pki/CA/ /etc/pki/libvirt/private/
```

Install the certificates as follows:

```
/etc/pki/CA/cacert.pem  
/etc/pki/libvirt/servercert.pem  
/etc/pki/libvirt/private/serverkey.pem
```

### Important: Restrict Access to Certificates

Make sure to restrict access to certificates as explained in [Section 11.3.2.5, “Restricting Access \(Security Considerations\)”](#).

3. Enable TLS support by enabling the relevant socket and restarting `libvirtd`:

```
tux > sudo systemctl stop libvirtd.service
tux > sudo systemctl enable --now libvirtd-tls.socket
tux > sudo systemctl start libvirtd.service
```

4. By default, `libvirt` uses the TCP port 16514 for accepting secure TLS connections. Open this port in the firewall.

### ! Important: Restarting `libvirtd` with TLS enabled

If you enable TLS for `libvirt`, the server certificates need to be in place, otherwise restarting `libvirtd` will fail. You also need to restart `libvirtd` in case you change the certificates.

#### 11.3.2.3 Configuring the Client and Testing the Setup

The client is the machine initiating connections. Therefore the *client* certificates need to be installed. The CA certificate needs to be installed, too.

1. Create the client certificate and export it together with the CA certificate as described in [Section B.2, "Generating x509 Client/Server Certificates"](#).
2. Create the following directories on the client:

```
mkdir -p /etc/pki/CA/ /etc/pki/libvirt/private/
```

Install the certificates as follows:

```
/etc/pki/CA/cacert.pem
/etc/pki/libvirt/clientcert.pem
/etc/pki/libvirt/private/clientkey.pem
```

### ! Important: Restrict Access to Certificates

Make sure to restrict access to certificates as explained in [Section 11.3.2.5, "Restricting Access \(Security Considerations\)"](#).

3. Test the client/server setup by issuing the following command. Replace `mercury.example.com` with the name of your VM Host Server. Specify the same fully qualified host name as used when creating the server certificate.

```
#QEMU/KVM
virsh -c qemu+tls://mercury.example.com/system list --all

#Xen
virsh -c xen+tls://mercury.example.com/system list --all
```

If your setup is correct, you will see a list of all VM Guests registered with `libvirt` on the VM Host Server.

#### 11.3.2.4 Enabling VNC for TLS/SSL connections

Currently, VNC communication over TLS is only supported by a few tools. Common VNC viewers such as `tightvnc` or `tigervnc` do not support TLS/SSL. The only supported alternative to Virtual Machine Manager and `virt-viewer` is `vinagre`.

##### 11.3.2.4.1 VNC over TLS/SSL: VM Host Server Configuration

To access the graphical console via VNC over TLS/SSL, you need to configure the VM Host Server as follows:

1. Open ports for the service `VNC` in your firewall.
2. Create a directory `/etc/pki/libvirt-vnc` and link the certificates into this directory as follows:

```
mkdir -p /etc/pki/libvirt-vnc && cd /etc/pki/libvirt-vnc
ln -s /etc/pki/CA/cacert.pem ca-cert.pem
ln -s /etc/pki/libvirt/servercert.pem server-cert.pem
ln -s /etc/pki/libvirt/private/serverkey.pem server-key.pem
```

3. Edit `/etc/libvirt/qemu.conf` and set the following parameters:

```
vnc_listen = "0.0.0.0"
vnc_tls = 1
vnc_tls_x509_verify = 1
```

#### 4. Restart the `libvirtd`:

```
root # systemctl restart libvirtd
```



### Important: VM Guests Need to be Restarted

The VNC TLS setting is only set when starting a VM Guest. Therefore, you need to restart all machines that have been running prior to making the configuration change.

#### 11.3.2.4.2 VNC over TLS/SSL: Client Configuration

The only action needed on the client side is to place the x509 client certificates in a location recognized by the client of choice. Unfortunately, each supported client—Virtual Machine Manager, **`virt-viewer`**, and **`vinagre`**—expects the certificates in a different location. However, Virtual Machine Manager and **`vinagre`** can either read from a system-wide location applying to all users, or from a per-user location.

##### Virtual Machine Manager (**`virt-manager`**)

To connect to the remote host, Virtual Machine Manager requires the setup explained in [Section 11.3.2.3, “Configuring the Client and Testing the Setup”](#). To be able to connect via VNC, the client certificates also need to be placed in the following locations:

##### System-wide location

```
/etc/pki/CA/cacert.pem  
/etc/pki/libvirt-vnc/clientcert.pem  
/etc/pki/libvirt-vnc/private/clientkey.pem
```

##### Per-user location

```
/etc/pki/CA/cacert.pem  
~/.pki/libvirt-vnc/clientcert.pem  
~/.pki/libvirt-vnc/private/clientkey.pem
```

##### **`virt-viewer`**

**`virt-viewer`** only accepts certificates from a system-wide location:

```
/etc/pki/CA/cacert.pem
```

```
/etc/pki/libvirt-vnc/clientcert.pem  
/etc/pki/libvirt-vnc/private/clientkey.pem
```



## Important: Restrict Access to Certificates

Make sure to restrict access to certificates as explained in [Section 11.3.2.5, “Restricting Access \(Security Considerations\)”](#).

### 11.3.2.5 Restricting Access (Security Considerations)

Each x509 certificate consists of two pieces: the public certificate and a private key. A client can only authenticate using both pieces. Therefore, any user that has read access to the client certificate and its private key can access your VM Host Server. On the other hand, an arbitrary machine equipped with the full server certificate can pretend to be the VM Host Server. Since this is probably not desirable, access to at least the private key files needs to be restricted as much as possible. The easiest way to control access to a key file is to use access permissions.

#### Server Certificates

Server certificates need to be readable for QEMU processes. On SUSE Linux Enterprise Server QEMU, processes started from `libvirt` tools are owned by `root`, so it is sufficient if the `root` can read the certificates:

```
chmod 700 /etc/pki/libvirt/private/  
chmod 600 /etc/pki/libvirt/private/serverkey.pem
```

If you change the ownership for QEMU processes in `/etc/libvirt/qemu.conf`, you also need to adjust the ownership of the key file.

#### System Wide Client Certificates

To control access to a key file that is available system-wide, restrict read access to a certain group, so that only members of that group can read the key file. In the following example, a group `libvirt` is created, and group ownership of the `clientkey.pem` file and its parent directory is set to `libvirt`. Afterward, the access permissions are restricted to owner and group. Finally the user `tux` is added to the group `libvirt`, and thus can access the key file.

```
CERTPATH="/etc/pki/libvirt/"  
# create group libvirt
```



```
groupadd libvirt
# change ownership to user root and group libvirt
chown root.libvirt $CERTPATH/private $CERTPATH/clientkey.pem
# restrict permissions
chmod 750 $CERTPATH/private
chmod 640 $CERTPATH/private/clientkey.pem
# add user tux to group libvirt
usermod --append --groups libvirt tux
```

## Per-User Certificates

User-specific client certificates for accessing the graphical console of a VM Guest via VNC need to be placed in the user's home directory in `~/.pki`. Contrary to SSH, for example, the VNC viewer using these certificates do not check the access permissions of the private key file. Therefore, it is solely the user's responsibility to make sure the key file is not readable by others.

### 11.3.2.5.1 Restricting Access from the Server Side

By default, every client that is equipped with appropriate client certificates may connect to a VM Host Server accepting TLS connections. Therefore, it is possible to use additional server-side authentication with SASL as described in [Section 11.1.1.3, “User name and Password Authentication with SASL”](#).

It is also possible to restrict access with a whitelist of DN (distinguished names), so only clients with a certificate matching a DN from the list can connect.

Add a list of allowed DN to `tls_allowed_dn_list` in `/etc/libvirt/libvirtd.conf`. This list may contain wild cards. Do not specify an empty list, since that would result in refusing all connections.

```
tls_allowed_dn_list = [
    "C=US,L=Provo,O=SUSE Linux Products GmbH,OU=*,CN=venus.example.com,EMAIL=*",
    "C=DE,L=Nuremberg,O=SUSE Linux Products GmbH,OU=Documentation,CN=*" ]
```

Get the distinguished name of a certificate with the following command:

```
certtool -i --infile /etc/pki/libvirt/clientcert.pem | grep "Subject:"
```

Restart `libvirtd` after having changed the configuration:

```
root # systemctl restart libvirtd
```

### 11.3.2.6 Central User Authentication with SASL for TLS Sockets

A direct user authentication via TLS is not possible—this is handled indirectly on each client via the read permissions for the certificates as explained in [Section 11.3.2.5, “Restricting Access \(Security Considerations\)”](#). However, if a central, server-based user authentication is needed, `libvirt` also allows to use SASL (Simple Authentication and Security Layer) on top of TLS for direct user authentication. See [Section 11.1.1.3, “User name and Password Authentication with SASL”](#) for configuration details.

### 11.3.2.7 Troubleshooting

#### 11.3.2.7.1 Virtual Machine Manager/`virsh` Cannot Connect to Server

Check the following in the given order:

Is it a firewall issue (TCP port 16514 needs to be open on the server)?

Is the client certificate (certificate and key) readable by the user that has started Virtual Machine Manager/`virsh`?

Has the same full qualified host name as in the server certificate been specified with the connection?

Is TLS enabled on the server (`listen_tls = 1`)?

Has `libvirtd` been restarted on the server?

#### 11.3.2.7.2 VNC Connection fails

Ensure that you can connect to the remote server using Virtual Machine Manager. If so, check whether the virtual machine on the server has been started with TLS support. The virtual machine's name in the following example is `sles`.

```
ps ax | grep qemu | grep "\-name sles" | awk -F" -vnc " '{ print FS $2 }'
```

If the output does not begin with a string similar to the following, the machine has not been started with TLS support and must be restarted.

```
-vnc 0.0.0.0:0,tls,x509verify=/etc/pki/libvirt
```

## 12 Managing Storage

When managing a VM Guest on the VM Host Server itself, you can access the complete file system of the VM Host Server to attach or create virtual hard disks or to attach existing images to the VM Guest. However, this is not possible when managing VM Guests from a remote host. For this reason, libvirt supports so called “Storage Pools”, which can be accessed from remote machines.



### Tip: CD/DVD ISO images

To be able to access CD/DVD ISO images on the VM Host Server from remote, they also need to be placed in a storage pool.

libvirt knows two different types of storage: volumes and pools.

#### Storage Volume

A storage volume is a storage device that can be assigned to a guest—a virtual disk or a CD/DVD/floppy image. Physically (on the VM Host Server) it can be a block device (a partition, a logical volume, etc.) or a file.

#### Storage Pool

A storage pool is a storage resource on the VM Host Server that can be used for storing volumes, similar to network storage for a desktop machine. Physically it can be one of the following types:

##### File System Directory (*dir*)

A directory for hosting image files. The files can be either one of the supported disk formats (raw, qcow2, or qed), or ISO images.

##### Physical Disk Device (*disk*)

Use a complete physical disk as storage. A partition is created for each volume that is added to the pool.

##### Pre-Formatted Block Device (*fs*)

Specify a partition to be used in the same way as a file system directory pool (a directory for hosting image files). The only difference to using a file system directory is that libvirt takes care of mounting the device.

### iSCSI Target (iscsi)

Set up a pool on an iSCSI target. You need to have been logged in to the volume once before, to use it with [libvirt](#). Use the YaST *iSCSI Initiator* to detect and log in to a volume, see *Book "Storage Administration Guide"* for details. Volume creation on iSCSI pools is not supported, instead each existing Logical Unit Number (LUN) represents a volume. Each volume/LUN also needs a valid (empty) partition table or disk label before you can use it. If missing, use [fdisk](#) to add it:

```
~ # fdisk -cu /dev/disk/by-path/ip-192.168.2.100:3260-iscsi-
iqn.2010-10.com.example:[...]-lun-2
Device contains neither a valid DOS partition table, nor Sun, SGI
or OSF disklabel
Building a new DOS disklabel with disk identifier 0xc15cdc4e.
Changes will remain in memory only, until you decide to write them.
After that, of course, the previous content won't be recoverable.

Warning: invalid flag 0x0000 of partition table 4 will be corrected by w(rite)

Command (m for help): w
The partition table has been altered!

Calling ioctl() to re-read partition table.
Syncing disks.
```

### LVM Volume Group (logical)

Use an LVM volume group as a pool. You may either use a predefined volume group, or create a group by specifying the devices to use. Storage volumes are created as partitions on the volume.



#### Warning: Deleting the LVM-Based Pool

When the LVM-based pool is deleted in the Storage Manager, the volume group is deleted as well. This results in a non-recoverable loss of all data stored on the pool!

### Multipath Devices (*mpath*)

At the moment, multipathing support is limited to assigning existing devices to the guests. Volume creation or configuring multipathing from within [libvirt](#) is not supported.

### Network Exported Directory (*netfs*)

Specify a network directory to be used in the same way as a file system directory pool (a directory for hosting image files). The only difference to using a file system directory is that `libvirt` takes care of mounting the directory.

### SCSI Host Adapter (*scsi*)

Use an SCSI host adapter in almost the same way as an iSCSI target. We recommend to use a device name from `/dev/disk/by-*` rather than `/dev/sdX`. The latter can change (for example, when adding or removing hard disks). Volume creation on iSCSI pools is not supported. Instead, each existing LUN (Logical Unit Number) represents a volume.



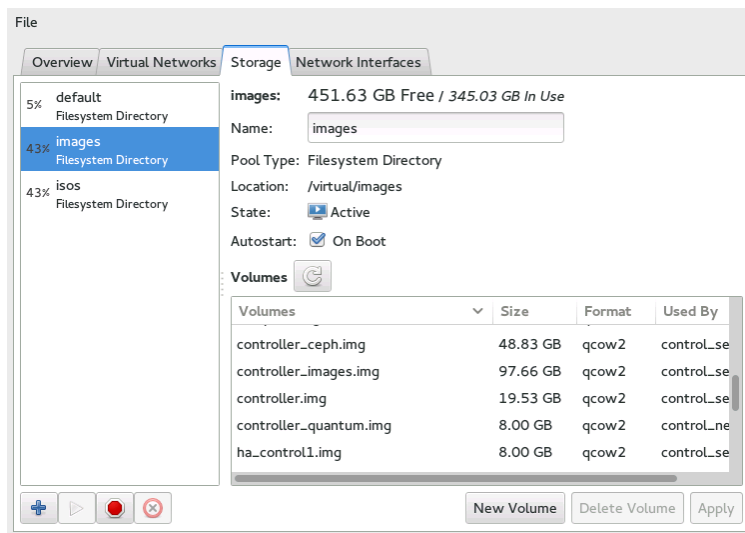
### Warning: Security Considerations

To avoid data loss or data corruption, do not attempt to use resources such as LVM volume groups, iSCSI targets, etc., that are also used to build storage pools on the VM Host Server. There is no need to connect to these resources from the VM Host Server or to mount them on the VM Host Server—`libvirt` takes care of this.

Do not mount partitions on the VM Host Server by label. Under certain circumstances it is possible that a partition is labeled from within a VM Guest with a name already existing on the VM Host Server.

## 12.1 Managing Storage with Virtual Machine Manager

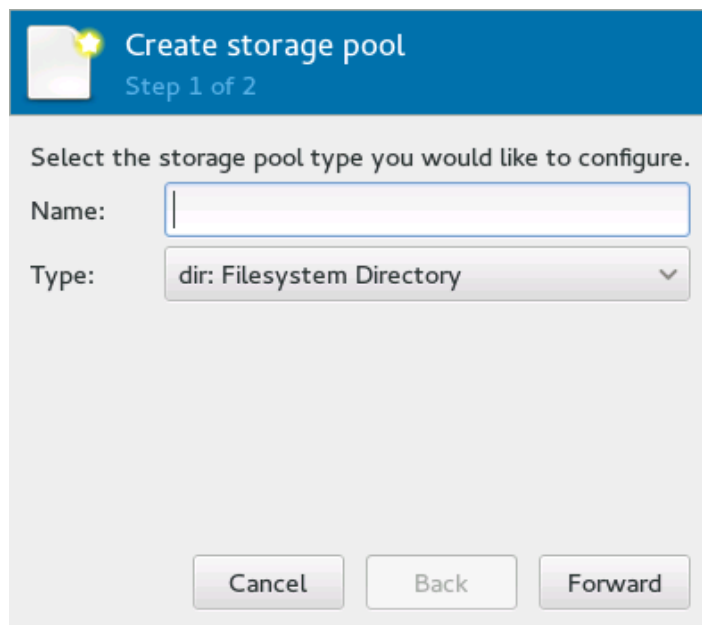
The Virtual Machine Manager provides a graphical interface—the Storage Manager—to manage storage volumes and pools. To access it, either right-click a connection and choose *Details*, or highlight a connection and choose *Edit > Connection Details*. Select the *Storage* tab.



### 12.1.1 Adding a Storage Pool

To add a storage pool, proceed as follows:

1. Click *Add* in the bottom left corner. The dialog *Add a New Storage Pool* appears.
2. Provide a *Name* for the pool (consisting of alphanumeric characters and `_ - .`) and select a *Type*. Proceed with *Forward*.



3. Specify the required details in the following window. The data that needs to be entered depends on the type of pool you are creating:

#### **Typedir**

- *Target Path:* Specify an existing directory.

#### **Typedisk**

- *Target Path:* The directory that hosts the devices. The default value `/dev` should usually fit.
- *Format:* Format of the device's partition table. Using `auto` should usually work. If not, get the required format by running the command `parted -l` on the VM Host Server.
- *Source Path:* Path to the device. It is recommended to use a device name from `/dev/disk/by-*` rather than the simple `/dev/sdX`, since the latter can change (for example, when adding or removing hard disks). You need to specify the path that resembles the whole disk, not a partition on the disk (if existing).
- *Build Pool:* Activating this option formats the device. Use with care—all data on the device will be lost!

#### **Typefs**

- *Target Path:* Mount point on the VM Host Server file system.
- *Format:* File system format of the device. The default value `auto` should work.
- *Source Path:* Path to the device file. It is recommended to use a device name from `/dev/disk/by-*` rather than `/dev/sdX`, because the latter can change (for example, when adding or removing hard disks).

#### **Typeiscsi**

Get the necessary data by running the following command on the VM Host Server:

```
iscsiadm --mode node
```

It will return a list of iSCSI volumes with the following format. The elements in bold text are required:

```
IP_ADDRESS:PORT,TPGT TARGET_NAME_(IQN)
```

- *Target Path*: The directory containing the device file. Use /dev/disk/by-path (default) or /dev/disk/by-id.
- *Host Name*: Host name or IP address of the iSCSI server.
- *Source Path*: The iSCSI target name (IQN).

### **Type***logical*

- *Target Path*: In case you use an existing volume group, specify the existing device path. When building a new LVM volume group, specify a device name in the /dev directory that does not already exist.
- *Source Path*: Leave empty when using an existing volume group. When creating a new one, specify its devices here.
- *Build Pool*: Only activate when creating a new volume group.

### **Type***mpath*

- *Target Path*: Support for multipathing is currently limited to making all multipath devices available. Therefore, specify an arbitrary string here that will then be ignored. The path is required, otherwise the XML parser will fail.

### **Type***netfs*

- *Target Path*: Mount point on the VM Host Server file system.
- *Host Name*: IP address or host name of the server exporting the network file system.
- *Source Path*: Directory on the server that is being exported.



## Typescsi

- *Target Path*: The directory containing the device file. Use /dev/disk/by-path (default) or /dev/disk/by-id.
- *Source Path*: Name of the SCSI adapter.



### Note: File Browsing

Using the file browser by clicking *Browse* is not possible when operating from remote.

4. Click *Finish* to add the storage pool.

## 12.1.2 Managing Storage Pools

Virtual Machine Manager's Storage Manager lets you create or delete volumes in a pool. You may also temporarily deactivate or permanently delete existing storage pools. Changing the basic configuration of a pool is currently not supported by SUSE.

### 12.1.2.1 Starting, Stopping and Deleting Pools

The purpose of storage pools is to provide block devices located on the VM Host Server that can be added to a VM Guest when managing it from remote. To make a pool temporarily inaccessible from remote, click *Stop* in the bottom left corner of the Storage Manager. Stopped pools are marked with *State: Inactive* and are grayed out in the list pane. By default, a newly created pool will be automatically started *On Boot* of the VM Host Server.

To start an inactive pool and make it available from remote again, click *Start* in the bottom left corner of the Storage Manager.



### Note: A Pool's State Does not Affect Attached Volumes

Volumes from a pool attached to VM Guests are always available, regardless of the pool's state (*Active* (stopped) or *Inactive* (started)). The state of the pool solely affects the ability to attach volumes to a VM Guest via remote management.

To permanently make a pool inaccessible, click *Delete* in the bottom left corner of the Storage Manager. You may only delete inactive pools. Deleting a pool does not physically erase its contents on VM Host Server—it only deletes the pool configuration. However, you need to be extra careful when deleting pools, especially when deleting LVM volume group-based tools:



### Warning: Deleting Storage Pools

Deleting storage pools based on *local* file system directories, local partitions or disks has no effect on the availability of volumes from these pools currently attached to VM Guests.

Volumes located in pools of type iSCSI, SCSI, LVM group or Network Exported Directory will become inaccessible from the VM Guest if the pool is deleted. Although the volumes themselves will not be deleted, the VM Host Server will no longer have access to the resources.

Volumes on iSCSI/SCSI targets or Network Exported Directory will become accessible again when creating an adequate new pool or when mounting/accessing these resources directly from the host system.

When deleting an LVM group-based storage pool, the LVM group definition will be erased and the LVM group will no longer exist on the host system. The configuration is not recoverable and all volumes from this pool are lost.

#### 12.1.2.2 Adding Volumes to a Storage Pool

Virtual Machine Manager lets you create volumes in all storage pools, except in pools of types Multipath, iSCSI, or SCSI. A volume in these pools is equivalent to a LUN and cannot be changed from within `libvirt`.

1. A new volume can either be created using the Storage Manager or while adding a new storage device to a VM Guest. In either case, select a storage pool from the left panel, then click *Create new volume*.
2. Specify a *Name* for the image and choose an image format.  
Note that SUSE currently only supports `raw`, `qcow2`, or `qed` images. The latter option is not available on LVM group-based pools.

Next to *Max Capacity*, specify the amount maximum size that the disk image is allowed to reach. Unless you are working with a `qcow2` image, you can also set an amount for *Allocation* that should be allocated initially. If both values differ, a sparse image file will be created which grows on demand.

For `qcow2` images, you can use a *Backing Store* (also called “backing file”) which constitutes a base image. The newly created `qcow2` image will then only record the changes that are made to the base image.

3. Start the volume creation by clicking *Finish*.

### 12.1.2.3 Deleting Volumes From a Storage Pool

Deleting a volume can only be done from the Storage Manager, by selecting a volume and clicking *Delete Volume*. Confirm with *Yes*.



#### Warning: Volumes Can Be Deleted Even While in Use

Volumes can be deleted even if they are currently used in an active or inactive VM Guest. There is no way to recover a deleted volume.

Whether a volume is used by a VM Guest is indicated in the *Used By* column in the Storage Manager.

## 12.2 Managing Storage with `virsh`

Managing storage from the command line is also possible by using `virsh`. However, creating storage pools is currently not supported by SUSE. Therefore, this section is restricted to documenting functions like starting, stopping and deleting pools and volume management.

A list of all `virsh` subcommands for managing pools and volumes is available by running `virsh help pool` and `virsh help volume`, respectively.

### 12.2.1 Listing Pools and Volumes

List all pools currently active by executing the following command. To also list inactive pools, add the option `--all`:

```
virsh pool-list --details
```

Details about a specific pool can be obtained with the `pool-info` subcommand:

```
virsh pool-info POOL
```

Volumes can only be listed per pool by default. To list all volumes from a pool, enter the following command.

```
virsh vol-list --details POOL
```

At the moment **virsh** offers no tools to show whether a volume is used by a guest or not. The following procedure describes a way to list volumes from all pools that are currently used by a VM Guest.

#### PROCEDURE 12.1: LISTING ALL STORAGE VOLUMES CURRENTLY USED ON A VM HOST SERVER

1. Create an XSLT style sheet by saving the following content to a file, for example, `~/libvirt/guest_storage_list.xml`:

```
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet version="1.0"
  xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
  <xsl:output method="text"/>
  <xsl:template match="text()"/>
  <xsl:strip-space elements="*" />
  <xsl:template match="disk">
    <xsl:text>  </xsl:text>
    <xsl:value-of select="(source/@file|source/@dev|source/@dir)[1]" />
    <xsl:text>&#10;</xsl:text>
  </xsl:template>
</xsl:stylesheet>
```

2. Run the following commands in a shell. It is assumed that the guest's XML definitions are all stored in the default location (`/etc/libvirt/qemu`). **xsltproc** is provided by the package `libxslt`.

```
SSHEET="$HOME/libvirt/guest_storage_list.xml"
cd /etc/libvirt/qemu
for FILE in *.xml; do
  basename $FILE .xml
  xsltproc $SSHEET $FILE
done
```

## 12.2.2 Starting, Stopping and Deleting Pools

Use the **virsh** pool subcommands to start, stop or delete a pool. Replace *P00L* with the pool's name or its UUID in the following examples:

### Stopping a Pool

```
virsh pool-destroy P00L
```



#### Note: A Pool's State Does not Affect Attached Volumes

Volumes from a pool attached to VM Guests are always available, regardless of the pool's state (*Active* (stopped) or *Inactive* (started)). The state of the pool solely affects the ability to attach volumes to a VM Guest via remote management.

### Deleting a Pool

```
virsh pool-delete P00L
```



#### Warning: Deleting Storage Pools

See [Warning: Deleting Storage Pools](#)

### Starting a Pool

```
virsh pool-start P00L
```

### Enable Autostarting a Pool

```
virsh pool-autostart P00L
```

Only pools that are marked to autostart will automatically be started if the VM Host Server reboots.

### Disable Autostarting a Pool

```
virsh pool-autostart P00L --disable
```

### 12.2.3 Adding Volumes to a Storage Pool

**virsh** offers two ways to add volumes to storage pools: either from an XML definition with `vol-create` and `vol-create-from` or via command line arguments with `vol-create-as`. The first two methods are currently not supported by SUSE, therefore this section focuses on the subcommand `vol-create-as`.

To add a volume to an existing pool, enter the following command:

```
virsh vol-create-as POOL ❶ NAME ❷ 12G --format ❸ raw|qcow2|qed ❹ --allocation 4G ❺
```

- ❶ Name of the pool to which the volume should be added
- ❷ Name of the volume
- ❸ Size of the image, in this example 12 gigabytes. Use the suffixes k, M, G, T for kilobyte, megabyte, gigabyte, and terabyte, respectively.
- ❹ Format of the volume. SUSE currently supports `raw`, `qcow2`, and `qed`.
- ❺ Optional parameter. By default **virsh** creates a sparse image file that grows on demand. Specify the amount of space that should be allocated with this parameter (4 gigabytes in this example). Use the suffixes k, M, G, T for kilobyte, megabyte, gigabyte, and terabyte, respectively.

When not specifying this parameter, a sparse image file with no allocation will be generated. To create a non-sparse volume, specify the whole image size with this parameter (would be `12G` in this example).

#### 12.2.3.1 Cloning Existing Volumes

Another way to add volumes to a pool is to clone an existing volume. The new instance is always created in the same pool as the original.

```
virsh vol-clone NAME_EXISTING_VOLUME ❶ NAME_NEW_VOLUME ❷ --pool POOL ❸
```

- ❶ Name of the existing volume that should be cloned
- ❷ Name of the new volume
- ❸ Optional parameter. `libvirt` tries to locate the existing volume automatically. If that fails, specify this parameter.

## 12.2.4 Deleting Volumes from a Storage Pool

To permanently delete a volume from a pool, use the subcommand `vol-delete`:

```
virsh vol-delete NAME --pool POOL
```

`--pool` is optional. `libvirt` tries to locate the volume automatically. If that fails, specify this parameter.



### Warning: No Checks Upon Volume Deletion

A volume will be deleted in any case, regardless of whether it is currently used in an active or inactive VM Guest. There is no way to recover a deleted volume.

Whether a volume is used by a VM Guest can only be detected by using by the method described in [Procedure 12.1, “Listing all Storage Volumes Currently Used on a VM Host Server”](#).

## 12.2.5 Attaching Volumes to a VM Guest

After you create a volume as described in [Section 12.2.3, “Adding Volumes to a Storage Pool”](#), you can attach it to a virtual machine and use it as a hard disk:

```
virsh attach-disk DOMAIN SOURCE_IMAGE_FILE TARGET_DISK_DEVICE
```

For example:

```
virsh attach-disk sles12sp3 /virt/images/example_disk.qcow2 sda2
```

To check if the new disk is attached, inspect the result of the `virsh dumpxml` command:

```
root # virsh dumpxml sles12sp3
[...]
<disk type='file' device='disk'>
  <driver name='qemu' type='raw'/>
  <source file='/virt/images/example_disk.qcow2'/>
  <backingStore/>
  <target dev='sda2' bus='scsi'/>
  <alias name='scsi0-0-0'/>
  <address type='drive' controller='0' bus='0' target='0' unit='0'/>
</disk>
[...]
```

### 12.2.5.1 Hotplug or Persistent Change

You can attach disks to both active and inactive domains. The attachment is controlled by the `--live` and `--config` options:

#### `--live`

Hotplugs the disk to an active domain. The attachment is not saved in the domain configuration. Using `--live` on an inactive domain is an error.

#### `--config`

Changes the domain configuration persistently. The attached disk is then available after the next domain start.

#### `--live --config`

Hotplugs the disk and adds it to the persistent domain configuration.



#### Tip: **virsh attach-device**

**virsh attach-device** is the more generic form of **virsh attach-disk**. You can use it to attach other types of devices to a domain.

### 12.2.6 Detaching Volumes from a VM Guest

To detach a disk from a domain, use **virsh detach-disk**:

```
root # virsh detach-disk DOMAIN TARGET_DISK_DEVICE
```

For example:

```
root # virsh detach-disk sles12sp3 sda2
```

You can control the attachment with the `--live` and `--config` options as described in [Section 12.2.5, “Attaching Volumes to a VM Guest”](#).



## 12.3 Locking Disk Files and Block Devices with `virtlockd`

Locking block devices and disk files prevents concurrent writes to these resources from different VM Guests. It provides protection against starting the same VM Guest twice, or adding the same disk to two different virtual machines. This will reduce the risk of a virtual machine's disk image becoming corrupted because of a wrong configuration.

The locking is controlled by a daemon called `virtlockd`. Since it operates independently from the `libvirtd` daemon, locks will endure a crash or a restart of `libvirtd`. Locks will even persist in the case of an update of the `virtlockd` itself, since it can re-execute itself. This ensures that VM Guests do *not* need to be restarted upon a `virtlockd` update. `virtlockd` is supported for KVM, QEMU, and Xen.

### 12.3.1 Enable Locking

Locking virtual disks is not enabled by default on SUSE Linux Enterprise Server. To enable and automatically start it upon rebooting, perform the following steps:

1. Edit `/etc/libvirt/qemu.conf` and set

```
lock_manager = "lockd"
```

2. Start the `virtlockd` daemon with the following command:

```
systemctl start virtlockd
```

3. Restart the `libvirtd` daemon with:

```
systemctl restart libvirtd
```

4. Make sure `virtlockd` is automatically started when booting the system:

```
systemctl enable virtlockd
```

## 12.3.2 Configure Locking

By default `virtlockd` is configured to automatically lock all disks configured for your VM Guests. The default setting uses a "direct" lockspace, where the locks are acquired against the actual file paths associated with the VM Guest `<disk>` devices. For example, `flock(2)` will be called directly on `/var/lib/libvirt/images/my-server/disk0.raw` when the VM Guest contains the following `<disk>` device:

```
<disk type='file' device='disk'>
  <driver name='qemu' type='raw' />
  <source file='/var/lib/libvirt/images/my-server/disk0.raw' />
  <target dev='vda' bus='virtio' />
</disk>
```

The `virtlockd` configuration can be changed by editing the file `/etc/libvirt/qemu-lockd.conf`. It also contains detailed comments with further information. Make sure to activate configuration changes by reloading `virtlockd`:

```
systemctl reload virtlockd
```



### Note: Locking Currently Only Available for All Disks

Currently, locking can only be activated globally, so that all virtual disks are locked. Support for locking selected disks is planned for future releases.

### 12.3.2.1 Enabling an Indirect Lockspace

The default configuration of `virtlockd` uses a "direct" lockspace. This means that the locks are acquired against the actual file paths associated with the `<disk>` devices.

If the disk file paths are not accessible to all hosts, `virtlockd` can be configured to allow an "indirect" lockspace. This means that a hash of the disk file path is used to create a file in the indirect lockspace directory. The locks are then held on these hash files instead of the actual disk file paths. Indirect lockspace is also useful if the file system containing the disk files does not support `fcntl()` locks. An indirect lockspace is specified with the `file_lockspace_dir` setting:

```
file_lockspace_dir = "/MY_LOCKSPACE_DIRECTORY"
```

### 12.3.2.2 Enable Locking on LVM or iSCSI Volumes

When wanting to lock virtual disks placed on LVM or iSCSI volumes shared by several hosts, locking needs to be done by UUID rather than by path (which is used by default). Furthermore, the lockspace directory needs to be placed on a shared file system accessible by all hosts sharing the volume. Set the following options for LVM and/or iSCSI:

```
lvm_lockspace_dir = "/MY_LOCKSPACE_DIRECTORY"
iscsi_lockspace_dir = "/MY_LOCKSPACE_DIRECTORY"
```

## 12.4 Online Resizing of Guest Block Devices

Sometimes you need to change—extend or shrink—the size of the block device used by your guest system. For example, when the disk space originally allocated is no longer enough, it is time to increase its size. If the guest disk resides on a *logical volume*, you can resize it while the guest system is running. This is a big advantage over an offline disk resizing (see the **virt-resize** command from the [Section 17.3, “Guestfs Tools”](#) package) as the service provided by the guest is not interrupted by the resizing process. To resize a VM Guest disk, follow these steps:

#### PROCEDURE 12.2: ONLINE RESIZING OF GUEST DISK

1. Inside the guest system, check the current size of the disk (for example /dev/vda).

```
root # fdisk -l /dev/vda
Disk /dev/sda: 160.0 GB, 160041885696 bytes, 312581808 sectors
Units = sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
```

2. On the host, resize the logical volume holding the /dev/vda disk of the guest to the required size, for example 200 GB.

```
root # lvresize -L 200G /dev/mapper/vg00-home
Extending logical volume home to 200 GiB
Logical volume home successfully resized
```

3. On the host, resize the block device related to the disk /dev/mapper/vg00-home of the guest. Note that you can find the DOMAIN\_ID with **virsh list**.

```
root # virsh blockresize --path /dev/vg00/home --size 200G DOMAIN_ID
Block device '/dev/vg00/home' is resized
```

4. Check that the new disk size is accepted by the guest.

```
root # fdisk -l /dev/vda
Disk /dev/sda: 200.0 GB, 200052357120 bytes, 390727260 sectors
Units = sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
```

## 12.5 Sharing Directories between Host and Guests (File System Pass-Through)

libvirt allows to share directories between host and guests using QEMU's file system pass-through (also called VirtFS) feature. Such a directory can be also be accessed by several VM Guests at once and therefore be used to exchange files between VM Guests.



### Note: Windows Guests and File System Pass-Through

Note that sharing directories between VM Host Server and Windows guests via File System Pass-Through does not work, because Windows lacks the drivers required to mount the shared directory.

To make a shared directory available on a VM Guest, proceed as follows:

1. Open the guest's console in Virtual Machine Manager and either choose *View > Details* from the menu or click *Show virtual hardware details* in the toolbar. Choose *Add Hardware > Filesystem* to open the *Filesystem Passthrough* dialog.
2. *Driver* allows you to choose between a *Handle* or *Path* base driver. The default setting is *Path*. *Mode* lets you choose the security model, which influences the way file permissions are set on the host. Three options are available:

#### *Passthrough* (Default)

Files on the file system are directly created with the client-user's credentials. This is very similar to what NFSv3 is using.

#### *Squash*

Same as *Passthrough*, but failure of privileged operations like chown are ignored. This is required when KVM is not run with root privileges.

### Mapped

Files are created with the file server's credentials (`qemu.qemu`). The user credentials and the client-user's credentials are saved in extended attributes. This model is recommended when host and guest domains should be kept completely isolated.

3. Specify the path to the directory on the VM Host Server with *Source Path*. Enter a string at *Target Path* that will be used as a tag to mount the shared directory. Note that the string of this field is a tag only, not a path on the VM Guest.
4. *Apply* the setting. If the VM Guest is currently running, you need to shut it down to apply the new setting (rebooting the guest is not sufficient).
5. Boot the VM Guest. To mount the shared directory, enter the following command:

```
sudo mount -t 9p -o trans=virtio,version=9p2000.L,rw TAG /MOUNT_POINT
```

To make the shared directory permanently available, add the following line to the `/etc/fstab` file:

```
TAG /MOUNT_POINT 9p trans=virtio,version=9p2000.L,rw 0 0
```

## 12.6 Using RADOS Block Devices with libvirt

RADOS Block Devices (RBD) store data in a Ceph cluster. They allow snapshotting, replication, and data consistency. You can use an RBD from your `libvirt`-managed VM Guests similarly to how you use other block devices.

Refer to [SUSE Enterprise Storage documentation \(https://documentation.suse.com/ses/html/ses-all/cha-ceph-libvirt.html\)](https://documentation.suse.com/ses/html/ses-all/cha-ceph-libvirt.html) for more details.

## 13 Managing Networks

This chapter describes common network configurations for a VM Host Server, including those supported natively by the VM Host Server and `libvirt`. The configurations are valid for all hypervisors supported by SUSE Linux Enterprise Server, such as KVM or Xen.

There are two common network configurations to provide a VM Guest with a network connection:

- A *network bridge* acting as a Layer 2 switch
- A *virtual network* managed by `libvirt` with Layer 3 forwarding enabled

### 13.1 Network Bridge

The network bridge configuration provides a Layer 2 switch for VM Guests, switching Layer 2 Ethernet packets between ports on the bridge based on MAC addresses associated with the ports. This gives the VM Guest Layer 2 access to the VM Host Server's network. This configuration is analogous to connecting the VM Guest's virtual Ethernet cable into a hub that is shared with the host and other VM Guests running on the host. The configuration is often referred to as *shared physical device*.

The network bridge configuration is the default configuration of SUSE Linux Enterprise Server when configured as a KVM or Xen hypervisor. It is the preferred configuration when you simply want to connect VM Guests to the VM Host Server's LAN.

#### 13.1.1 Managing Network Bridges with YaST

This section includes procedures to add or remove network bridges with YaST.

##### 13.1.1.1 Adding a Network Bridge

To add a network bridge on VM Host Server, follow these steps:

1. Start *YaST* > *System* > *Network Settings*.

2. Activate the *Overview* tab and click *Add*.
3. Select *Bridge* from the *Device Type* list and enter the bridge device interface name in the *Configuration Name* entry. Press the *Next* button to proceed.
4. In the *Address* tab, specify networking details such as DHCP/static IP address, subnet mask or host name.

Using *Dynamic Address* is only useful when also assigning a device to a bridge that is connected to a DHCP server.

If you intend to create a virtual bridge that has no connection to a real Ethernet device, use *Statically assigned IP Address*. In this case, it is a good idea to use addresses from the private IP address ranges, for example, 192.168.0.0/16, 172.16.0.0/12, or 10.0.0.0/8.

To create a bridge that should only serve as a connection between the different guests without connection to the host system, set the IP address to 0.0.0.0 and the subnet mask to 255.255.255.255. The network scripts handle this special address as an unset IP address.

5. Activate the *Bridged Devices* tab and activate the network devices you want to include in the network bridge.
6. Click *Next* to return to the *Overview* tab and confirm with *OK*. The new network bridge should now be active on VM Host Server.

#### 13.1.1.2 Deleting a Network Bridge

To delete an existing network bridge, follow these steps:

1. Start *YaST* > *System* > *Network Settings*.
2. Select the bridge device you want to delete from the list in the *Overview* tab.
3. Delete the bridge with *Delete* and confirm with *OK*.

#### 13.1.2 Managing Network Bridges from the Command Line

This section includes procedures to add or remove network bridges using the command line.

### 13.1.2.1 Adding a Network Bridge

To add a new network bridge device on VM Host Server, follow these steps:

1. Log in as root on the VM Host Server where you want to create a new network bridge.
2. Choose a name for the new bridge—virbr\_test in our example—and run

```
tux > sudo ip link add name VIRBR_TEST type bridge
```

3. Check if the bridge was created on VM Host Server:

```
tux > sudo bridge vlan  
[...]  
virbr_test 1 PVID Egress Untagged
```

virbr\_test is present, but is not associated with any physical network interface.

4. Bring the network bridge up and add a network interface to the bridge:

```
tux > sudo ip link set virbr_test up  
tux > sudo ip link set eth1 master virbr_test
```



#### Important: Network Interface Must Be Unused

You can only assign a network interface that is not yet used by other network bridge.

5. Optionally, enable STP (see [Spanning Tree Protocol \(https://en.wikipedia.org/wiki/Spanning\\_Tree\\_Protocol\)](https://en.wikipedia.org/wiki/Spanning_Tree_Protocol)):

```
tux > sudo bridge link set dev virbr_test cost 4
```

### 13.1.2.2 Deleting a Network Bridge

To delete an existing network bridge device on VM Host Server from the command line, follow these steps:

1. Log in as root on the VM Host Server where you want to delete an existing network bridge.
2. List existing network bridges to identify the name of the bridge to remove:

```
tux > sudo bridge vlan  
[...]
```



```
virbr_test 1 PVID Egress Untagged
```

3. Delete the bridge:

```
tux > sudo ip link delete dev virbr_test
```

### 13.1.3 Using VLAN Interfaces

Sometimes, it is necessary to create a private connection either between two VM Host Servers or between VM Guest systems. For example, to migrate VM Guest to hosts in a different network segment, or to create a private bridge that only VM Guest systems may connect to (even when running on different VM Host Server systems). An easy way to build such connections is to set up VLAN networks.

VLAN interfaces are commonly set up on the VM Host Server. They either interconnect the different VM Host Server systems, or they may be set up as a physical interface to an otherwise virtual-only bridge. It is even possible to create a bridge with a VLAN as a physical interface that has no IP address in the VM Host Server. That way, the guest systems have no possibility to access the host over this network.

Run the YaST module *System > Network Settings*. Follow this procedure to set up the VLAN device:


#### PROCEDURE 13.1: SETTING UP VLAN INTERFACES WITH YAST


1. Click *Add* to create a new network interface.
2. In the *Hardware Dialog*, select *Device Type VLAN*.
3. Change the value of *Configuration Name* to the ID of your VLAN. Note that VLAN ID 1 is commonly used for management purposes.
4. Click *Next*.
5. Select the interface that the VLAN device should connect to below *Real Interface for VLAN*. If the desired interface does not appear in the list, first set up this interface without an IP address.
6. Select the desired method for assigning an IP address to the VLAN device.
7. Click *Next* to finish the configuration.

It is also possible to use the VLAN interface as a physical interface of a bridge. This makes it possible to connect several VM Host Server-only networks and allows live migration of VM Guest systems that are connected to such a network.

YaST does not always allow setting no IP address. However, this may be a desired feature, especially if VM Host Server-only networks should be connected. In this case, use the special address `0.0.0.0` with netmask `255.255.255.255`. The system scripts handle this address as no IP address set.

## 13.2 Virtual Networks

`libvirt`-managed virtual networks are similar to bridged networks, but typically have no Layer 2 connection to the VM Host Server. Connectivity to the VM Host Server's physical network is accomplished with Layer 3 forwarding, which introduces additional packet processing on the VM Host Server as compared to a Layer 2 bridged network. Virtual networks also provide DHCP and DNS services for VM Guests. For more information on `libvirt`'s virtual networks see the *Network XML format* documentation at <https://libvirt.org/formatnetwork.html> .

A standard `libvirt` installation on SUSE Linux Enterprise Server already comes with a predefined virtual network named `default` that provides DHCP and DNS services for the network, along with connectivity to the VM Host Server's physical network using the network address translation (NAT) forwarding mode. Although it is predefined, the `default` virtual network must be explicitly enabled by the administrator. For more information on the forwarding modes supported by `libvirt` see the *Connectivity* section of the *Network XML format* documentation at <https://libvirt.org/formatnetwork.html#elementsConnect> .

`libvirt`-managed virtual networks can be used to satisfy a wide range of use-cases, but are commonly used on VM Host Servers that have a wireless connection or dynamic/sporadic network connectivity such as laptops. Virtual networks are also useful when the VM Host Server's network has limited IP addresses, allowing forwarding of packets between the virtual network and the VM Host Server's network. However, most server use-cases are better suited for the network bridge configuration, where VM Guests are connected to the VM Host Server's LAN.



### Warning: Enabling Forwarding Mode

Enabling forwarding mode in a `libvirt` virtual network enables forwarding in the VM Host Server by setting `/proc/sys/net/ipv4/ip_forward` and `/proc/sys/net/ipv6/conf/all/forwarding` to 1, which essentially turns the VM Host Server into a router.

Restarting the VM Host Server's network may reset the values and disable forwarding. To avoid this behavior, explicitly enable forwarding in the VM Host Server by editing the `/etc/sysctl.conf` file and adding:

```
net.ipv4.ip_forward = 1
```

```
net.ipv6.conf.all.forwarding = 1
```

## 13.2.1 Managing Virtual Networks with Virtual Machine Manager

You can define, configure, and operate virtual networks with Virtual Machine Manager.

### 13.2.1.1 Defining Virtual Networks

1. Start Virtual Machine Manager. In the list of available connections, right-click the name of the connection for which you need to configure the virtual network, and then select *Details*.
2. In the *Connection Details* window, click the *Virtual Networks* tab. You can see the list of all virtual networks available for the current connection. On the right, there are details of the selected virtual network.

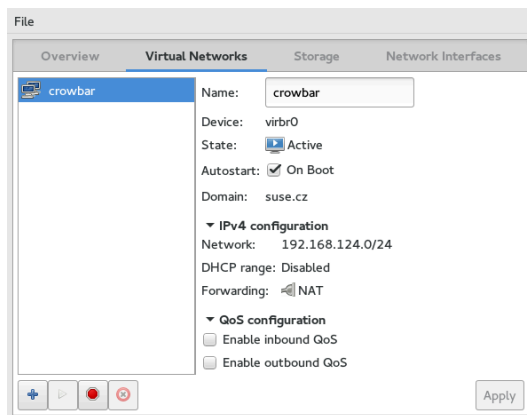


FIGURE 13.1: CONNECTION DETAILS

3. To add a new virtual network, click *Add*.
4. Specify a name for the new virtual network and click *Forward*.

Create virtual network  
Step 1 of 4

Choose a name for your virtual network:

Network Name:

Example: network1

FIGURE 13.2: CREATE VIRTUAL NETWORK

5. To specify an IPv4 network address space definition, activate the relevant option and type it into the *Network* text entry.

Create virtual network  
Step 2 of 4

Choose IPv4 address space for the virtual network:

☒ Enable IPv4 network address space definition

Network:

Hint: The network should be chosen from one of the IPv4 private address ranges. eg 10.0.0.0/8 or 192.168.0.0/16

Gateway:

Type: ?

☒ Enable DHCPv4

Start:

End:

☒ Enable Static Route Definition

to Network:

via Gateway:

FIGURE 13.3: CREATE VIRTUAL NETWORK

6. `libvirt` can provide your virtual network with a DHCP server. If you need it, activate *Enable DHCPv4*, then type the start and end IP address range of assignable addresses.
7. To enable static routing for the new virtual network, activate the relevant option and type the network and gateway addresses.
8. Click *Forward* to proceed.

9. To specify IPv6-related options—network address space, DHCPv6 server, or static route—activate *Enable IPv6 network address space definition* and activate the relevant options and fill in the relevant boxes.
10. Click *Forward* to proceed.
11. Select whether you want an isolated or forwarded virtual network.

**Create virtual network**  
Step 4 of 4

Connected to a physical network:

☐ Isolated virtual network

☒ Forwarding to physical network

Destination: Any physical device

Mode: NAT

☐ Enable IPv6 internal routing/networking

If an IPv6 network address is **not** specified, this will enable IPv6 internal routing between virtual machines. By default, IPv4 internal routing is enabled.

DNS Domain Name: vnet1

Cancel Back Finish

FIGURE 13.4: CREATE VIRTUAL NETWORK

For forwarded networks, specify the network interface to which the requests will be forwarded, and one of the forwarding modes: While *NAT* (network address translation) remaps the virtual network address space and allows sharing a single IP address, *Routed* forwards packets from the virtual network to the VM Host Server's physical network with no translation.

12. If you did not specify an IPv6 network address space definition earlier, you can enable IPv6 internal routing between virtual machines.
13. (*Optional*) Optionally, change the DNS domain name.
14. Click *Finish* to create the new virtual network. On the VM Host Server, a new virtual network bridge `virbrX` is available, which corresponds to the newly-created virtual network. You can check with `bridge link`. `libvirt` automatically adds iptables rules to allow traffic to/from guests attached to the new `virbrX` device.

### 13.2.1.2 Starting Virtual Networks

To start a virtual network that is temporarily stopped, follow these steps:

1. Start Virtual Machine Manager. In the list of available connections, right-click the name of the connection for which you need to configure the virtual network, and then select *Details*.
2. In the *Connection Details* window, click the *Virtual Networks* tab. You can see the list of all virtual networks available for the current connection.
3. To start the virtual network, click *Start*.

### 13.2.1.3 Stopping Virtual Networks

To stop an active virtual network, follow these steps:

1. Start Virtual Machine Manager. In the list of available connections, right-click the name of the connection for which you need to configure the virtual network, and then select *Details*.
2. In the *Connection Details* window, click the *Virtual Networks* tab. You can see the list of all virtual networks available for the current connection.
3. Select the virtual network to be stopped, then click *Stop*.

### 13.2.1.4 Deleting Virtual Networks

To delete a virtual network from VM Host Server, follow these steps:

1. Start Virtual Machine Manager. In the list of available connections, right-click the name of the connection for which you need to configure the virtual network, and then select *Details*.
2. In the *Connection Details* window, click the *Virtual Networks* tab. You can see the list of all virtual networks available for the current connection.
3. Select the virtual network to be deleted, then click *Delete*.

### 13.2.1.5 Obtaining IP Addresses with **nsswitch** for NAT Networks (in KVM)

- On VM Host Server, install `libvirt-nss`, which provides NSS support for `libvirt`:

```
tux > sudo zypper in libvirt-nss
```

- Add `libvirt` to `/etc/nsswitch.conf`:

```
...
hosts:  files libvirt mdns_minimal [NOTFOUND=return] dns
...
```

- If NSCD is running, restart it:

```
tux > sudo systemctl restart nscd
```

Now you can reach the guest system by name from the host.

The NSS module has limited functionality. It reads `/var/lib/libvirt/dnsmasq/*.status` files to find the host name and corresponding IP addresses in a JSON record describing each lease provided by `dnsmasq`. Host name translation can only be done on those VM Host Servers using a `libvirt`-managed bridged network backed by `dnsmasq`.

For more information, see [http://wiki.libvirt.org/page/NSS\\_module](http://wiki.libvirt.org/page/NSS_module).

## 13.2.2 Managing Virtual Networks with **virsh**

You can manage `libvirt`-provided virtual networks with the `virsh` command line tool. To view all network related `virsh` commands, run

```
tux > sudo virsh help network
Networking (help keyword 'network'):
net-autostart          autostart a network
    net-create          create a network from an XML file
    net-define          define (but don't start) a network from an XML
file
    net-destroy         destroy (stop) a network
    net-dumpxml         network information in XML
    net-edit            edit XML configuration for a network
    net-event           Network Events
    net-info            network information
    net-list            list networks
    net-name            convert a network UUID to network name
    net-start           start a (previously defined) inactive network
```

net-undefine	undefine an inactive network
net-update	update parts of an existing network's configuration
net-uuid	convert a network name to network UUID

To view brief help information for a specific `virsh` command, run `virsh help VIRSH_COMMAND`:

```
tux > sudo virsh help net-create
NAME
  net-create - create a network from an XML file

SYNOPSIS
  net-create <file>

DESCRIPTION
  Create a network.

OPTIONS
  [--file] <string>  file containing an XML network description
```

### 13.2.2.1 Creating a Network

To create a new *running* virtual network, run

```
tux > sudo virsh net-create VNET_DEFINITION.xml
```

The `VNET_DEFINITION.xml` XML file includes the definition of the virtual network that `libvirt` accepts.

To define a new virtual network without activating it, run

```
tux > sudo virsh net-define VNET_DEFINITION.xml
```

The following examples illustrate definitions of different types of virtual networks.

#### EXAMPLE 13.1: NAT BASED NETWORK

The following configuration allows VM Guests outgoing connectivity if it is available on VM Host Server. In the absence of VM Host Server networking, it allows guests to talk directly to each other.

```
<network>
<name>vnet_nated</name> ❶
<bridge name="virbr1"/> ❷
```



```

<forward mode="nat"/> ❸
<ip address="192.168.122.1" netmask="255.255.255.0"> ❹
  <dhcp>
    <range start="192.168.122.2" end="192.168.122.254"/> ❺
    <host mac="52:54:00:c7:92:da" name="host1.testing.com" \
      ip="192.168.1.23.101"/> ❻
    <host mac="52:54:00:c7:92:db" name="host2.testing.com" \
      ip="192.168.1.23.102"/>
    <host mac="52:54:00:c7:92:dc" name="host3.testing.com" \
      ip="192.168.1.23.103"/>
  </dhcp>
</ip>
</network>

```

- ❶ The name of the new virtual network.
- ❷ The name of the bridge device used to construct the virtual network. When defining a new network with a `<forward>` mode of "nat" or "route" (or an isolated network with no `<forward>` element), `libvirt` will automatically generate a unique name for the bridge device if none is given.
- ❸ Inclusion of the `<forward>` element indicates that the virtual network will be connected to the physical LAN. The `mode` attribute specifies the forwarding method. The most common modes are "nat" (default, network address translation), "route" (direct forwarding to the physical network, no address translation), and "bridge" (network bridge configured outside of `libvirt`). If the `<forward>` element is not specified, the virtual network will be isolated from other networks. For a complete list of forwarding modes, see <http://libvirt.org/formatnetwork.html#elementsConnect>.
- ❹ The IP address and netmask for the network bridge.
- ❺ Enable DHCP server for the virtual network, offering IP addresses ranging from the specified `start` and `end` attribute.
- ❻ The optional `<host>` elements specify hosts that will be given names and predefined IP addresses by the built-in DHCP server. Any IPv4 host element must specify the following: the MAC address of the host to be assigned a given name, the IP to be assigned to that host, and the name to be given to that host by the DHCP server. An IPv6 host element differs slightly from that for IPv4: there is no `mac` attribute since a MAC address has no defined meaning in IPv6. Instead, the `name` attribute is used to identify the host to be assigned the IPv6 address. For DHCPv6, the `name` is the plain name of the client host sent by the client to the server. Note that this method of assigning a specific IP address can also be used instead of the `mac` attribute for IPv4.

#### EXAMPLE 13.2: ROUTED NETWORK

The following configuration routes traffic from the virtual network to the LAN without applying any NAT. The IP address range must be preconfigured in the routing tables of the router on the VM Host Server network.

```
<network>
  <name>vnet_routed</name>
  <bridge name="virbr1"/>
  <forward mode="route" dev="eth1"/> ❶
  <ip address="192.168.122.1" netmask="255.255.255.0">
    <dhcp>
      <range start="192.168.122.2" end="192.168.122.254"/>
    </dhcp>
  </ip>
</network>
```

❶ The guest traffic may only go out via the eth1 network device on the VM Host Server.

#### EXAMPLE 13.3: ISOLATED NETWORK

This configuration provides a completely isolated private network. The guests can talk to each other, and to VM Host Server, but cannot reach any other machines on the LAN, as the `<forward>` element is missing in the XML description.

```
<network>
  <name>vnet_isolated</name>
  <bridge name="virbr3"/>
  <ip address="192.168.152.1" netmask="255.255.255.0">
    <dhcp>
      <range start="192.168.152.2" end="192.168.152.254"/>
    </dhcp>
  </ip>
</network>
```

#### EXAMPLE 13.4: USING AN EXISTING BRIDGE ON VM HOST SERVER

This configuration shows how to use an existing VM Host Server's network bridge br0. VM Guests are directly connected to the physical network. Their IP addresses will all be on the subnet of the physical network, and there will be no restrictions on incoming or outgoing connections.

```
<network>
  <name>host-bridge</name>
  <forward mode="bridge"/>
  <bridge name="br0"/>
</network>
```

### 13.2.2.2 Listing Networks

To list all virtual networks available to `libvirt`, run:

```
tux > sudo virsh net-list --all
```

Name	State	Autostart	Persistent
-----	-----	-----	-----
crowbar	active	yes	yes
vnet_nated	active	yes	yes
vnet_routed	active	yes	yes
vnet_isolated	inactive	yes	yes

To list available domains, run:

```
tux > sudo virsh list
```

Id	Name	State
-----	-----	-----
1	nated_sles12sp5	running
...		

To get a list of interfaces of a running domain, run `domifaddr DOMAIN`, or optionally specify the interface to limit the output to this interface. By default, it additionally outputs their IP and MAC addresses:

```
tux > sudo virsh domifaddr nated_sles12sp5 --interface vnet0 --source lease
```

Name	MAC address	Protocol	Address
-----	-----	-----	-----
vnet0	52:54:00:9e:0d:2b	ipv6	fd00:dead:beef:55::140/64
-	-	ipv4	192.168.100.168/24

To print brief information of all virtual interfaces associated with the specified domain, run:

```
tux > sudo virsh domiflist nated_sles12sp5
```

Interface	Type	Source	Model	MAC
-----	-----	-----	-----	-----
vnet0	network	vnet_nated	virtio	52:54:00:9e:0d:2b

### 13.2.2.3 Getting Details about a Network

To get detailed information about a network, run:

```
tux > sudo virsh net-info vnet_routed
```

```
Name:          vnet_routed
```

```
UUID:          756b48ff-d0c6-4c0a-804c-86c4c832a498
Active:        yes
Persistent:    yes
Autostart:     yes
Bridge:        virbr5
```

#### 13.2.2.4 Starting a Network

To start an inactive network that was already defined, find its name (or unique identifier, UUID) with:

```
tux > sudo virsh net-list --inactive
Name                State      Autostart    Persistent
-----
vnet_isolated       inactive  yes          yes
```

Then run:

```
tux > sudo virsh net-start vnet_isolated
Network vnet_isolated started
```

#### 13.2.2.5 Stopping a Network

To stop an active network, find its name (or unique identifier, UUID) with:

```
tux > sudo virsh net-list --inactive
Name                State      Autostart    Persistent
-----
vnet_isolated       active     yes          yes
```

Then run:

```
tux > sudo virsh net-destroy vnet_isolated
Network vnet_isolated destroyed
```

#### 13.2.2.6 Removing a Network

To remove the definition of an inactive network from VM Host Server permanently, run:

```
tux > sudo virsh net-undefine vnet_isolated
Network vnet_isolated has been undefined
```

## 14 Configuring Virtual Machines

Virtual Machine Manager's *Details* view offers in-depth information about the VM Guest's complete configuration and hardware equipment. Using this view, you can also change the guest configuration or add and modify virtual hardware. To access this view, open the guest's console in Virtual Machine Manager and either choose *View > Details* from the menu, or click *Show virtual hardware details* in the toolbar.

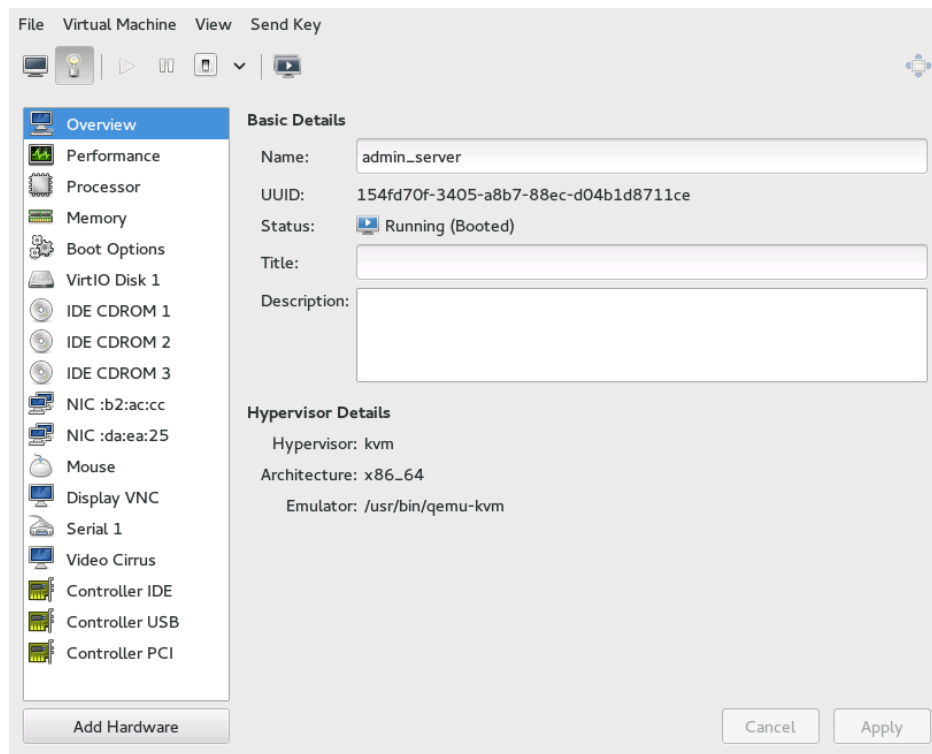


FIGURE 14.1: DETAILS VIEW OF A VM GUEST

The left panel of the window lists VM Guest overview and already installed hardware. After clicking an item in the list, you can access its detailed settings in the details view. You can change the hardware parameters to match your needs, then click *Apply* to confirm them. Some changes take effect immediately, while others need a reboot of the machine—and `virt-manager` warns you about that fact.

To remove installed hardware from a VM Guest, select the appropriate list entry in the left panel and then click *Remove* in the bottom right of the window.

To add new hardware, click *Add Hardware* below the left panel, then select the type of the hardware you want to add in the *Add New Virtual Hardware* window. Modify its parameters and confirm with *Finish*.

The following sections describe configuration options for the specific hardware type *being added*. They do not focus on modifying an existing piece of hardware as the options are identical.

## 14.1 Machine Setup

This section describes the setup of the virtualized processor and memory hardware. These components are vital to a VM Guest, therefore you cannot remove them. It also shows how to view the overview and performance information, and how to change boot options.

### 14.1.1 Overview

*Overview* shows basic details about VM Guest and the hypervisor.

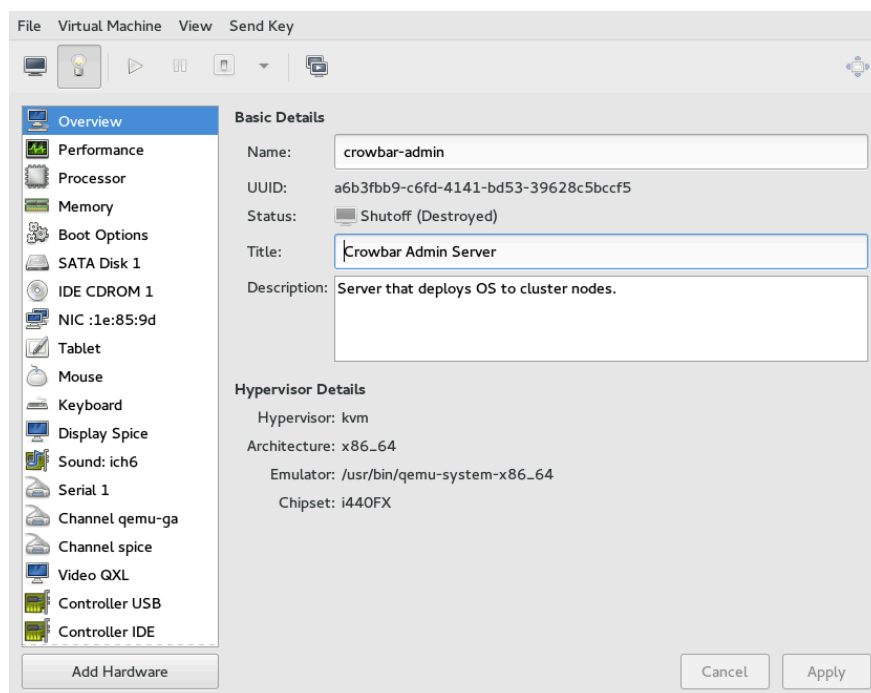


FIGURE 14.2: OVERVIEW DETAILS

*Name*, *Title*, and *Description* are editable and help you identify VM Guest in the *Virtual Machine Manager* list of machines.

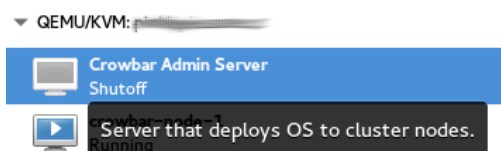


FIGURE 14.3: VM GUEST TITLE AND DESCRIPTION

*UUID* shows the universally unique identifier of the virtual machine, while *Status* shows its current status—*Running*, *Paused*, or *Shutoff*.

The *Hypervisor Details* section shows the hypervisor type, CPU architecture, used emulator, and chipset type. None of the hypervisor parameters can be changed.

## 14.1.2 Performance

*Performance* shows regularly updated charts of CPU and memory usage, and disk and network I/O.

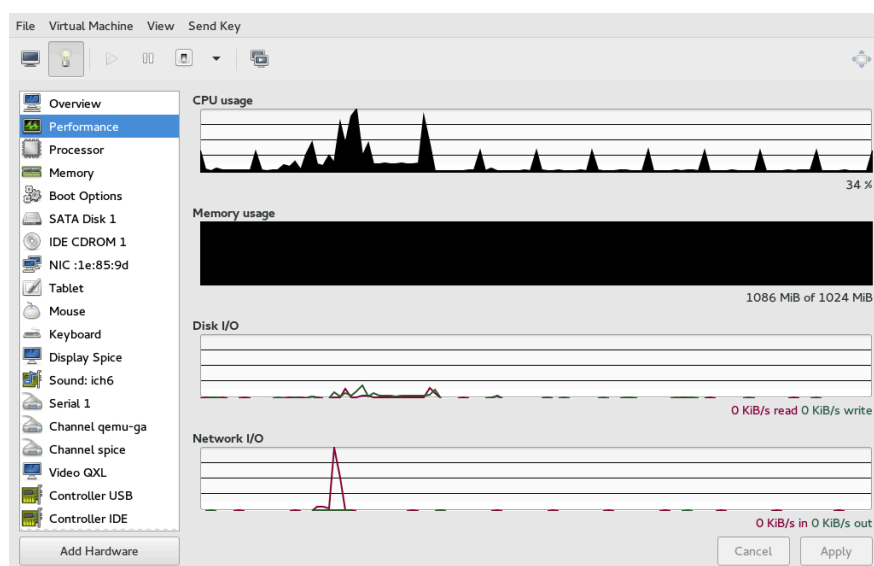


FIGURE 14.4: PERFORMANCE



### Tip: Enabling Disabled Charts

Not all the charts in the *Graph* view are enabled by default. To enable these charts, go to *File > View Manager*, then select *Edit > Preferences > Polling*, and check the charts that you want to see regularly updated.

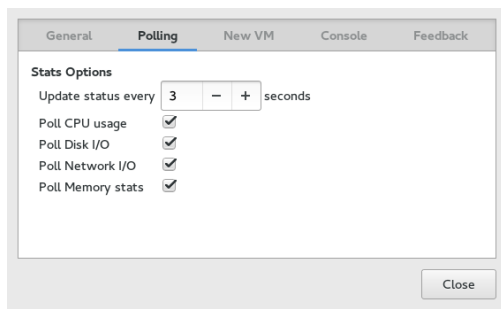


FIGURE 14.5: STATISTICS CHARTS

### 14.1.3 Processor

*Processor* includes detailed information about VM Guest processor configuration.

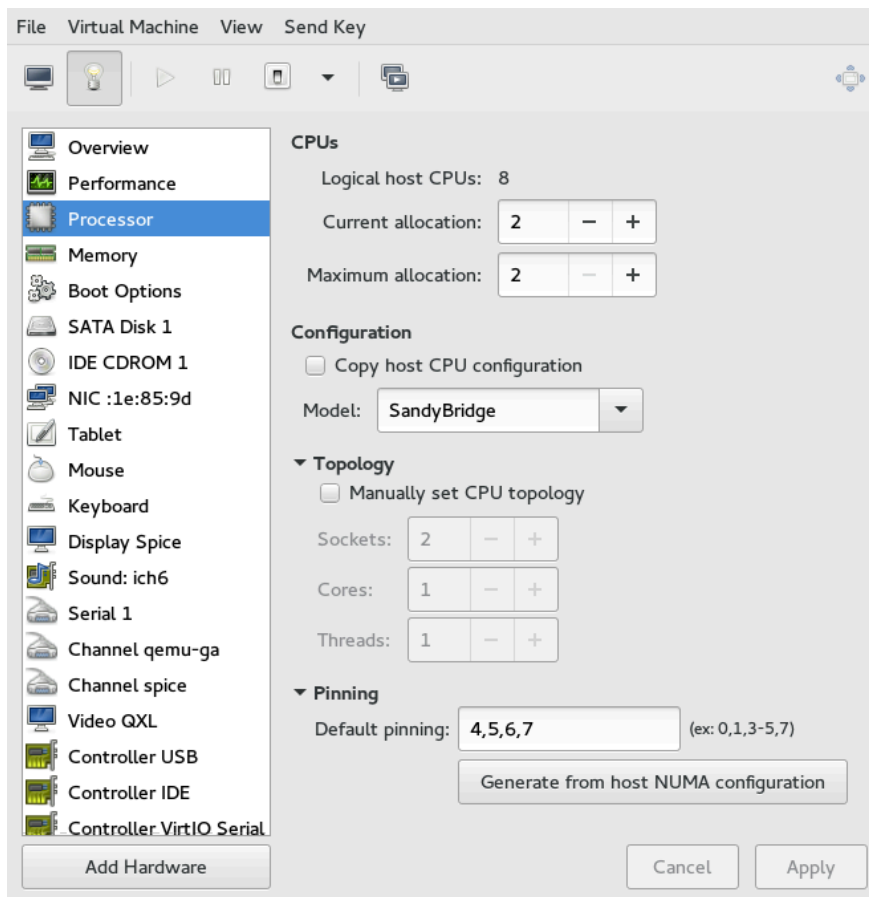


FIGURE 14.6: PROCESSOR VIEW

In the *CPUs* section, you can configure several parameters related to the number of allocated CPUs.



### Logical host CPUs

The real number of CPUs installed on VM Host Server.

### Current allocation

The number of currently allocated CPUs. You can hotplug more CPUs by increasing this value up to the *Maximum allocation* value.

### Maximum allocation

Maximum number of allocatable CPUs for the current session. Any change to this value will take effect after the next VM Guest reboot.

The *Configuration* section lets you configure the CPU model and topology.

When activated, the *Copy host CPU configuration* option uses the host CPU model for VM Guest. Otherwise you need to specify the CPU model from the drop-down box.

After you activate *Manually set CPU topology*, you can specify a custom number of sockets, cores and threads for the CPU.

## 14.1.4 Memory

*Memory* contains information about the memory that is available to VM Guest.

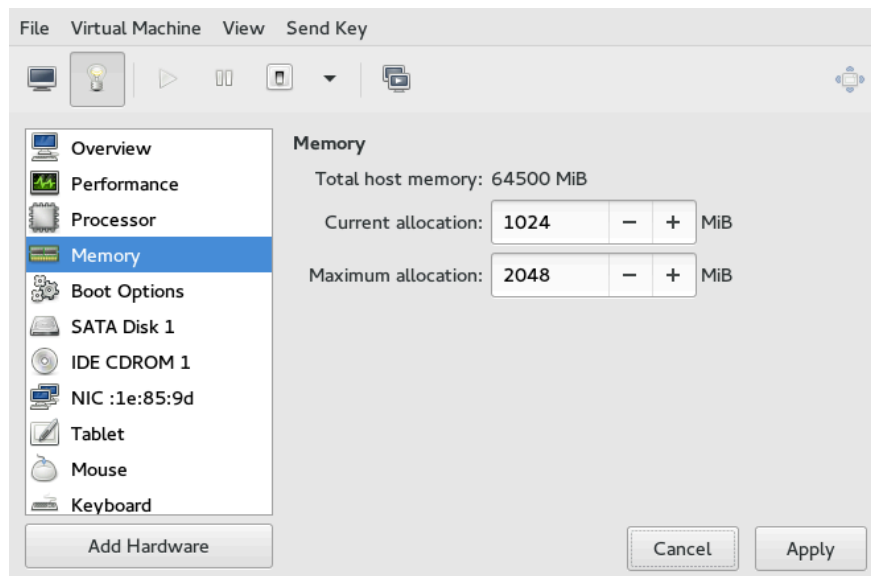


FIGURE 14.7: MEMORY VIEW

### Total host memory

Total amount of memory installed on VM Host Server.

### Current allocation

The amount of memory currently available to VM Guest. You can hotplug more memory by increasing this value up to the value of *Maximum allocation*.

### Maximum allocation

The maximum value to which you can hotplug the currently available memory. Any change to this value will take effect after the next VM Guest reboot.

## 14.1.5 Boot Options

*Boot Options* introduces options affecting the VM Guest boot process.

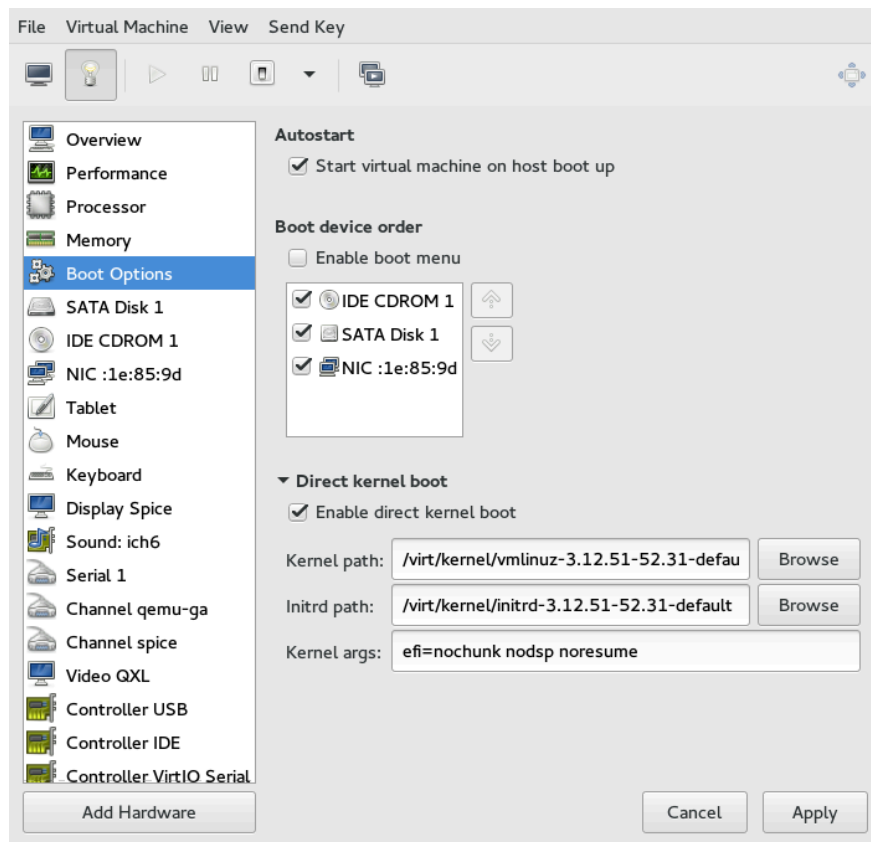


FIGURE 14.8: BOOT OPTIONS

In the *Autostart* section, you can specify whether the virtual machine should automatically start during the VM Host Server boot phase.

In the *Boot device order*, activate the devices that will be used for booting VM Guest. You can change their order with the up and down arrow buttons on the right side of the list. To choose from a list of bootable devices on VM Guest start, activate *Enable boot menu*.

To boot a different kernel than the one on the boot device, activate *Enable direct kernel boot* and specify the paths to the alternative kernel and initrd placed on the VM Host Server file system. You can also specify kernel arguments that will be passed to the loaded kernel.

## 14.2 Storage

This section gives you a detailed description of configuration options for storage devices. It includes both hard disks and removable media, such as USB or CD-ROM drives.

### PROCEDURE 14.1: ADDING A NEW STORAGE DEVICE

1. Click *Add Hardware* below the left panel, then select *Storage* from the *Add New Virtual Hardware* window.

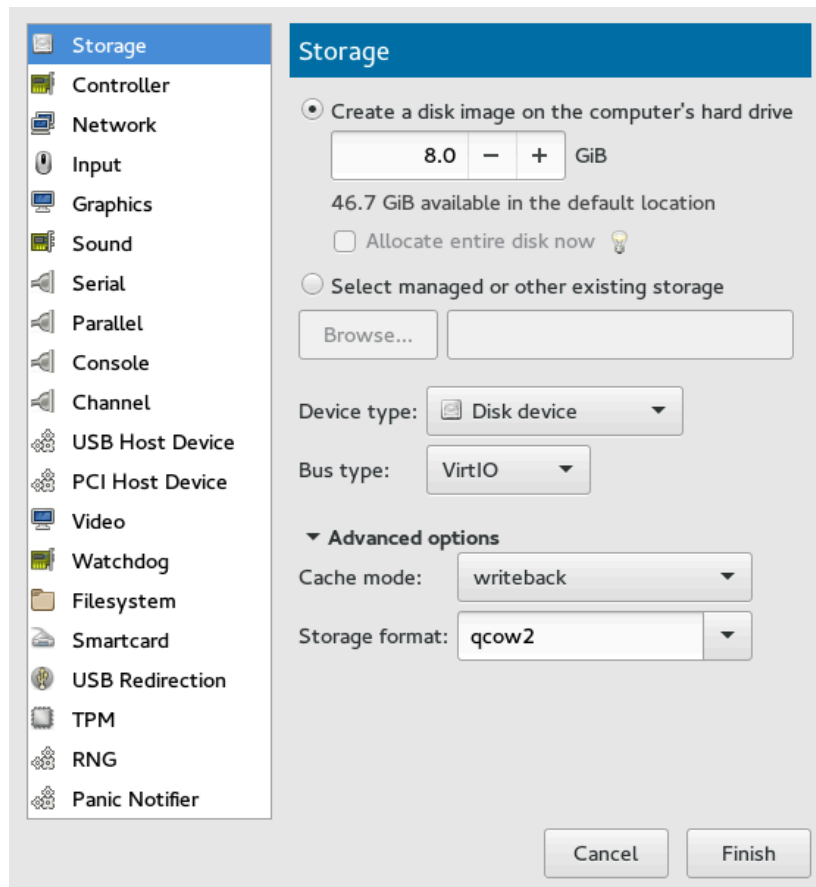


FIGURE 14.9: ADD A NEW STORAGE

2. To create a qcow2 disk image in the default location, activate *Create a disk image for the virtual machine* and specify its size in gigabytes.

To gain more control over the disk image creation, activate *Select or create custom storage* and click *Manage* to manage storage pools and images. The window *Choose Storage Volume* opens which has almost identical functionality as the *Storage* tab described in [Section 12.1, “Managing Storage with Virtual Machine Manager”](#).



### Tip: Supported Storage Formats

SUSE only supports the following storage formats: raw, qcow2, and qed.

3. After you manage to create and specify the disk image file, specify the *Device type*. It can be one of the following options:
  - *Disk device*
  - *CDROM device*: Does not allow using *Create a disk image for the virtual machine*.
  - *Floppy device*: Does not allow using *Create a disk image for the virtual machine*.
  - *LUN Passthrough*: Required to use an existing SCSI storage directly without adding it into a storage pool.
4. Select the *Bus type* for your device. The list of available options depends on the device type you selected in the previous step. The types based on *VirtIO* use paravirtualized drivers.
5. In the *Advanced options* section, select the preferred *Cache mode*. For more information on cache modes, see [Chapter 15, Disk Cache Modes](#).
6. Confirm your settings with *Finish*. A new storage device appears in the left panel.

## 14.3 Controllers

This section focuses on adding and configuring new controllers.

### PROCEDURE 14.2: ADDING A NEW CONTROLLER

1. Click *Add Hardware* below the left panel, then select *Controller* from the *Add New Virtual Hardware* window.

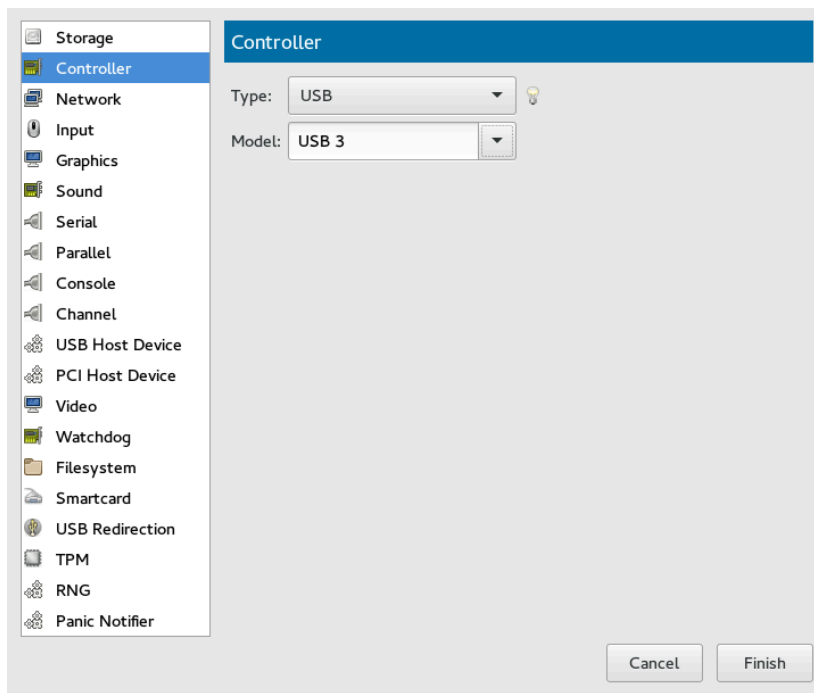


FIGURE 14.10: ADD A NEW CONTROLLER

2. Select the type of the controller. You can choose from *IDE*, *Floppy*, *SCSI*, *SATA*, *VirtIO Serial* (paravirtualized), *USB*, or *CCID* (smart card devices).
3. Optionally, in the case of a USB or SCSI controller, select a controller model.
4. Confirm your settings with *Finish*. A new controller appears in the left panel.

## 14.4 Networking

This section describes how to add and configure new network devices.

### PROCEDURE 14.3: ADDING A NEW NETWORK DEVICE

1. Click *Add Hardware* below the left panel, then select *Network* from the *Add New Virtual Hardware* window.

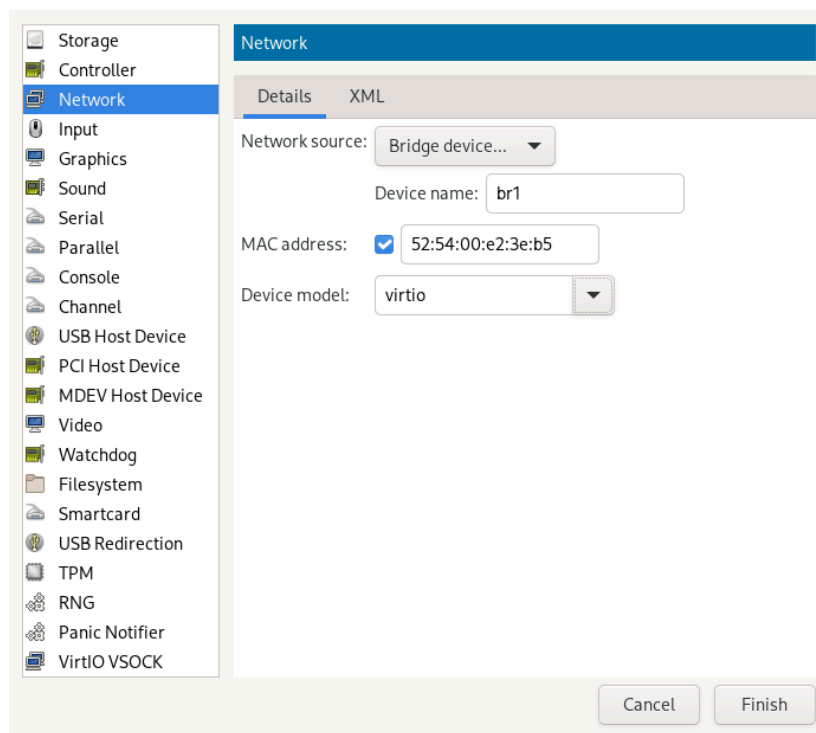


FIGURE 14.11: ADD A NEW CONTROLLER

2. From the *Network source* list, select the source for the network connection. The list includes VM Host Server's available physical network interfaces, network bridges, or network bonds. You can also assign the VM Guest to an already defined virtual network. See [Chapter 13, Managing Networks](#) for more information on setting up virtual networks with Virtual Machine Manager.
3. Specify a *MAC address* for the network device. While Virtual Machine Manager pre-fills a random value for your convenience, it is recommended to supply a MAC address appropriate for your network environment to avoid network conflicts.
4. Select a device model from the list. You can either leave the *Hypervisor default*, or specify one of *e1000*, *rtl8139*, or *virtio* models. Note that *virtio* uses paravirtualized drivers.
5. Confirm your settings with *Finish*. A new network device appears in the left panel.

## 14.5 Enabling Seamless and Synchronized Mouse Pointer Movement

When you click within a VM Guest's console with the mouse, the pointer is captured by the console window and cannot be used outside the console unless it is explicitly released (by pressing **Alt** – **Ctrl** ). To prevent the console from grabbing the key and to enable seamless pointer movement between host and guest instead, add a tablet to the VM Guest.

Adding a tablet has the additional advantage of synchronizing the mouse pointer movement between VM Host Server and VM Guest when using a graphical environment on the guest. With no tablet configured on the guest, you will often see two pointers with one dragging behind the other.

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View > Details*.
2. Click *Add Hardware* and choose *Input* and then *EvTouch USB Graphics Tablet* in the pop-up window. Proceed with *Finish*.
3. If the guest is running, you will be asked whether to enable the tablet after the next reboot. Confirm with *Yes*.
4. When you start or restart the VM Guest, the tablet becomes available in the VM Guest.

## 14.6 Adding a CD/DVD-ROM Device with Virtual Machine Manager

KVM supports CD or DVD-ROMs in VM Guest either by directly accessing a physical drive on the VM Host Server or by accessing ISO images. To create an ISO image from an existing CD or DVD, use **dd**:

```
dd if=/dev/CD_DVD_DEVICE of=my_distro.iso bs=2048
```

To add a CD/DVD-ROM device to your VM Guest, proceed as follows:

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View > Details*.

2. Click *Add Hardware* and choose *Storage* in the pop-up window.
3. Change the *Device Type* to *IDE CDROM*.
4. Select *Select or create custom storage*.
  - a. To assign the device to a physical medium, enter the path to the VM Host Server's CD/DVD-ROM device (for example, `/dev/cdrom`) next to *Manage*. Alternatively, use *Manage* to open a file browser and then click *Browse Local* to select the device. Assigning the device to a physical medium is only possible when the Virtual Machine Manager was started on the VM Host Server.
  - b. To assign the device to an existing image, click *Manage* to choose an image from a storage pool. If the Virtual Machine Manager was started on the VM Host Server, alternatively choose an image from another location on the file system by clicking *Browse Local*. Select an image and close the file browser with *Choose Volume*.
5. Save the new virtualized device with *Finish*.
6. Reboot the VM Guest to make the new device available. For more information, see [Section 14.8, "Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager"](#).

## 14.7 Adding a Floppy Device with Virtual Machine Manager

Currently KVM only supports the use of floppy disk images—using a physical floppy drive is not supported. Create a floppy disk image from an existing floppy using **dd**:

```
dd if=/dev/fd0 of=/var/lib/libvirt/images/floppy.img
```

To create an empty floppy disk image use one of the following commands:

### Raw Image

```
dd if=/dev/zero of=/var/lib/libvirt/images/floppy.img bs=512 count=2880
```

### FAT Formatted Image

```
mkfs.msdos -C /var/lib/libvirt/images/floppy.img 1440
```



To add a floppy device to your VM Guest, proceed as follows:

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View > Details*.
2. Click *Add Hardware* and choose *Storage* in the pop-up window.
3. Change the *Device Type* to *Floppy Disk*.
4. Choose *Select or create custom storage* and click *Manage* to choose an existing image from a storage pool. If Virtual Machine Manager was started on the VM Host Server, alternatively choose an image from another location on the file system by clicking *Browse Local*. Select an image and close the file browser with *Choose Volume*.
5. Save the new virtualized device with *Finish*.
6. Reboot the VM Guest to make the new device available. For more information, see [Section 14.8, “Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager”](#).

## 14.8 Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager

Whether you are using the VM Host Server's physical CD/DVD-ROM device or an ISO/floppy image: Before you can change the media or image of an existing device in the VM Guest, you first need to disconnect the media from the guest.

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View > Details*.
2. Choose the Floppy or CD/DVD-ROM device and “eject” the medium by clicking *Disconnect*.
3. To “insert” a new medium, click *Connect*.
  - a. If using the VM Host Server's physical CD/DVD-ROM device, first change the media in the device (this may require unmounting it on the VM Host Server before it can be ejected). Then choose *CD-ROM or DVD* and select the device from the drop-down box.
  - b. If you are using an ISO image, choose *ISO image Location* and select an image by clicking *Manage*. When connecting from a remote host, you may only choose images from existing storage pools.

4. Click *OK* to finish. The new media can now be accessed in the VM Guest.

## 14.9 Editing VM Configuration with **virsh**

The configuration of a VM is stored in an XML file in `/etc/libvirt/qemu/` and looks like this:

EXAMPLE 14.1: EXAMPLE XML CONFIGURATION FILE

```
<domain type='kvm'>
  <name>sles15</name>
  <uuid>ab953e2f-9d16-4955-bb43-1178230ee625</uuid>
  <memory unit='KiB'>2097152</memory>
  <currentMemory unit='KiB'>2097152</currentMemory>
  <vcpu placement='static'>2</vcpu>
  <os>
    <type arch='x86_64' machine='pc-i440fx-2.11'>hvm</type>
  </os>
  <features>...</features>
  <cpu mode='custom' match='exact' check='partial'>
    <model fallback='allow'>Skylake-Client-IBRS</model>
  </cpu>
  <clock>...</clock>
  <on_poweroff>destroy</on_poweroff>
  <on_reboot>restart</on_reboot>
  <on_crash>destroy</on_crash>
  <pm>
    <suspend-to-mem enabled='no' />
    <suspend-to-disk enabled='no' />
  </pm>
  <devices>
    <emulator>/usr/bin/qemu-system-x86_64</emulator>
    <disk type='file' device='disk'>...</disk>
  </devices>
  ...
</domain>
```

If you want to edit the configuration of a VM Guest, check if it is offline:

```
tux > sudo virsh list --inactive
```

If your VM Guest is in this list, you can safely edit its configuration:

```
tux > sudo virsh edit NAME_OF_VM_GUEST
```

Before saving the changes, **virsh** validates your input against a RelaxNG schema.

## 14.10 Changing the Machine Type with **virsh**

By default, when installing with the **virt-install** tool, the machine type for VM Guest is *pc-i440fx*. The machine type is stored in the VM Guest's xml configuration file in /etc/libvirt/qemu/ in the tag type:

```
<type arch='x86_64' machine='pc-i440fx-2.3'>hvm</type>
```

As an example, the following procedure shows how to change this value to the machine type q35. q35 is an Intel\* chipset. It includes *PCIe*, supports up to 12 USB ports, and has support for *SATA* and *IOMMU*. IRQ routing has also been improved.

1. Check whether your VM Guest is inactive:

```
virsh list --inactive
Id      Name                                State
-----
-       sles11                               shut off
```

2. Edit the configuration for this VM Guest:

```
virsh edit sles11
```

3. Change the value of the machine attribute:

```
<type arch='x86_64' machine='pc-q35-2.0'>hvm</type>
```

4. Restart the VM Guest.

```
root # virsh start sles11
```

5. Check that the machine type has changed. Log in to the VM Guest as root and run the following command:

```
root # dmidecode | grep Product
Product Name: Standard PC (Q35 + ICH9, 2009)
```



## Tip: Machine Type Update Recommendations

Whenever the QEMU version on the host system is upgraded (for example, when upgrading the VM Host Server to a new service pack), upgrade the machine type of the VM Guests to the latest available version. To check, use the command `qemu-system-x86_64 -M help` on the VM Host Server.

The default machine type `pc-i440fx`, for example, is regularly updated. If your VM Guest still runs with a machine type of `pc-i440fx-1.X`, an update to `pc-i440fx-2.X` is strongly recommended. This allows taking advantage of the most recent updates and corrections in machine definitions, and ensures better future compatibility.

## 14.11 Assigning a Host PCI Device to a VM Guest

You can directly assign host-PCI devices to guests (PCI pass-through). When the PCI device is assigned to one VM Guest, it cannot be used on the host or by another VM Guest unless it is re-assigned. A prerequisite for this feature is a VM Host Server configuration as described in *Important: Requirements for VFIO and SR-IOV*.

### 14.11.1 Adding a PCI Device with Virtual Machine Manager

The following procedure describes how to add a PCI device to a VM Guest using Virtual Machine Manager:

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View > Details*.
2. Click *Add Hardware* and choose the *PCI Host Device* category in the left panel. A list of available PCI devices appears in the right part of the window.

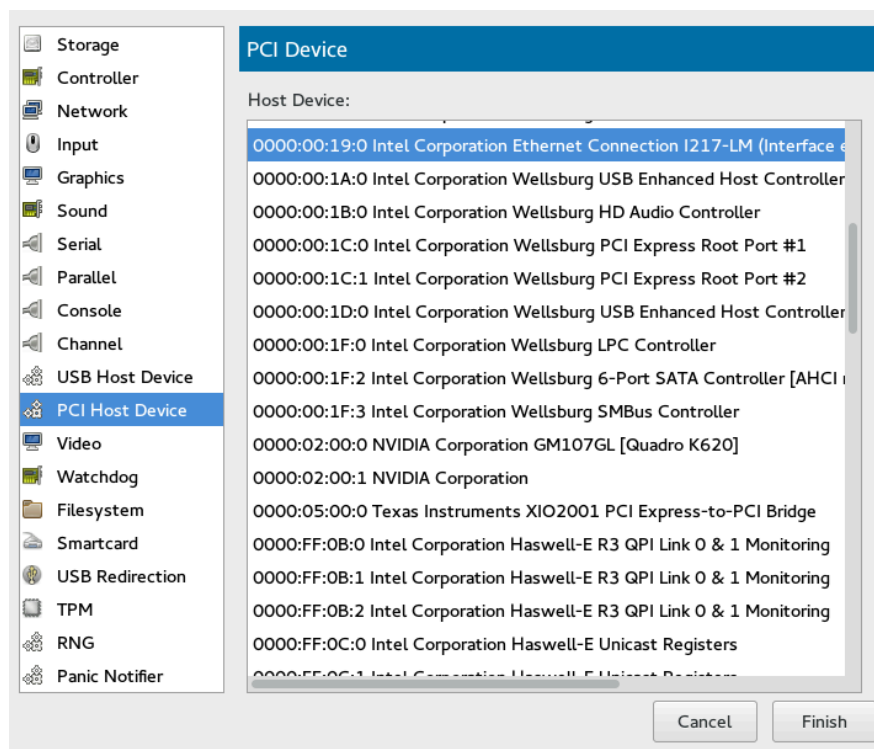


FIGURE 14.12: ADDING A PCI DEVICE

- From the list of available PCI devices, choose the one you want to pass to the guest. Confirm with *Finish*.



### Tip: Assigning a PCI Device Requires a VM Guest Shutdown

Although it is possible to assign a PCI device to a running VM Guest as described above, the device will not become available until you shut down the VM Guest and reboot it afterward.

## 14.11.2 Adding a PCI Device with **virsh**

To assign a PCI device to VM Guest with **virsh**, follow these steps:

- Identify the host PCI device to assign to the guest. In the following example, we are assigning a DEC network card to the guest:

```
tux > sudo lspci -nn
[...]
```

```
03:07.0 Ethernet controller [0200]: Digital Equipment Corporation DECchip \
21140 [FasterNet] [1011:0009] (rev 22)
[...]
```

Note down the device ID (03:07.0 in this case).

2. Gather detailed information about the device using `virsh nodedev-dumpxml ID`. To get the ID, you need to replace colon and period in the device ID (03:07.0) with underscore and prefix the result with “pci\_0000\_” (pci\_0000\_03\_07\_0).

```
tux > virsh nodedev-dumpxml pci_0000_03_07_0
<device>
  <name>pci_0000_03_07_0</name>
  <path>/sys/devices/pci0000:00/0000:00:14.4/0000:03:07.0</path>
  <parent>pci_0000_00_14_4</parent>
  <driver>
    <name>tulip</name>
  </driver>
  <capability type='pci'>
    <domain>0</domain>
    <bus>3</bus>
    <slot>7</slot>
    <function>0</function>
    <product id='0x0009'>DECchip 21140 [FasterNet]</product>
    <vendor id='0x1011'>Digital Equipment Corporation</vendor>
    <numa node='0' />
  </capability>
</device>
```

Note down the values for domain, bus, and function.

3. Detach the device from the host system prior to attaching it to VM Guest.

```
tux > virsh nodedev-detach pci_0000_03_07_0
Device pci_0000_03_07_0 detached
```



### Tip: Multi-Function PCI Devices

When using a multi-function PCI device that does not support FLR (function level reset) or PM (power management) reset, you need to detach all its functions from the VM Host Server. The whole device must be reset for security reasons. `libvirt` will refuse to assign the device if one of its functions is still in use by the VM Host Server or another VM Guest.

4. Convert the domain, bus, slot, and function value from decimal to hexadecimal, and prefix with `0x` to tell the system that the value is hexadecimal. In our example, domain = 0, bus = 3, slot = 7, and function = 0. Their hexadecimal values are:

```
tux > printf %x 0
0
tux > printf %x 3
3
tux > printf %x 7
7
```

This results in domain = 0x0000, bus = 0x03, slot = 0x07 and function = 0x00.

5. Run **virsh edit** on your domain, and add the following device entry in the `<devices>` section using the values from the previous step:

```
<hostdev mode='subsystem' type='pci' managed='yes'>
  <source>
    <address domain='0x0000' bus='0x03' slot='0x07' function='0x00' />
  </source>
</hostdev>
```



### Tip: managed Compared to unmanaged

`libvirt` recognizes two modes for handling PCI devices: they can be either managed or unmanaged. In the managed case, `libvirt` handles all details of unbinding the device from the existing driver if needed, resetting the device, binding it to `vfio-pci` before starting the domain, etc. When the domain is terminated or the device is removed from the domain, `libvirt` will unbind from `vfio-pci` and rebind to the original driver in the case of a managed device. If the device is unmanaged, the user must ensure all of these management aspects of the device are done before assigning it to a domain, and after the device is no longer used by the domain.

In the example above, the `managed='yes'` option means that the device is managed. To switch the device mode to unmanaged, set `managed='no'` in the listing above. If you do so, you need to take care of the related driver with the **virsh nodedev-detach** and **virsh nodedev-reattach** commands. That means you need to run **virsh nodedev-detach pci\_0000\_03\_07\_0** prior to starting the VM Guest

to detach the device from the host. In case the VM Guest is not running, you can make the device available for the host by running `virsh nodedev-reattach pci_0000_03_07_0`.

6. Shut down the VM Guest and restart it to make the assigned PCI device available.



#### Tip: SELinux

If you are running SELinux on your VM Host Server, you need to disable it prior to starting the VM Guest with

```
setsebool -P virt_use_sysfs 1
```

## 14.12 Assigning a Host USB Device to a VM Guest

Analogous to assigning host PCI devices (see [Section 14.11, “Assigning a Host PCI Device to a VM Guest”](#)), you can directly assign host USB devices to guests. When the USB device is assigned to one VM Guest, it cannot be used on the host or by another VM Guest unless it is re-assigned.

### 14.12.1 Adding a USB Device with Virtual Machine Manager

To assign a host USB device to VM Guest using Virtual Machine Manager, follow these steps:

1. Double-click a VM Guest entry in the Virtual Machine Manager to open its console and switch to the *Details* view with *View > Details*.
2. Click *Add Hardware* and choose the *USB Host Device* category in the left panel. A list of available USB devices appears in the right part of the window.



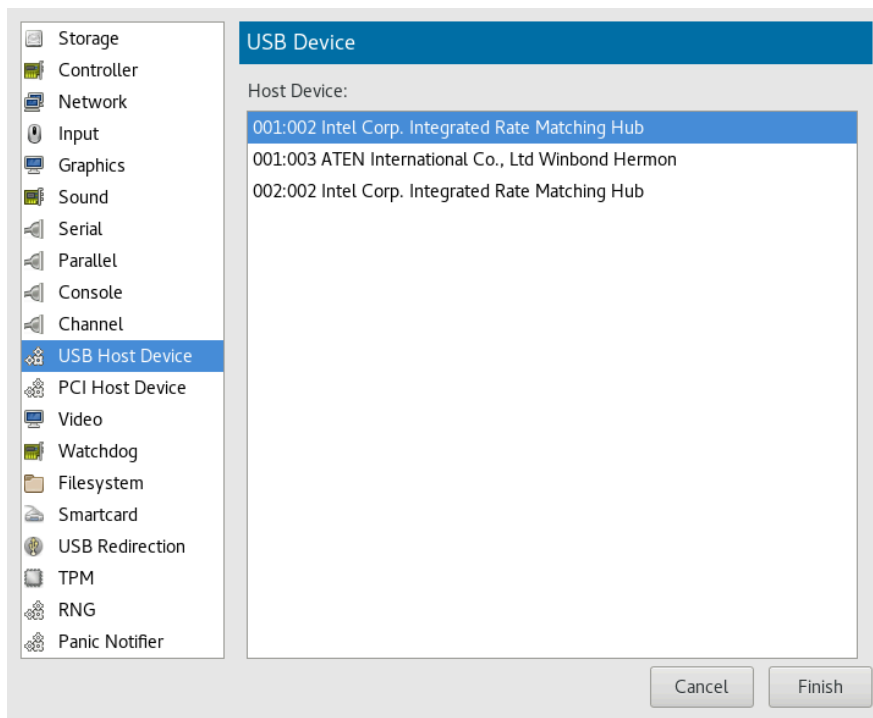


FIGURE 14.13: ADDING A USB DEVICE

3. From the list of available USB devices, choose the one you want to pass to the guest. Confirm with *Finish*. The new USB device appears in the left pane of the *Details* view.



### Tip: USB Device Removal

To remove the host USB device assignment, click it in the left pane of the *Details* view and confirm with *Remove*.

## 14.12.2 Adding a USB Device with **virsh**

To assign a USB device to VM Guest using **virsh**, follow these steps:

1. Identify the host USB device to assign to the guest:

```
tux > sudo lsusb
[...]
Bus 001 Device 003: ID 0557:2221 ATEN International Co., Ltd Winbond Hermon
[...]
```

Note down the vendor and product IDs. In our example, the vendor ID is 0557 and the product ID is 2221.

2. Run **virsh edit** on your domain, and add the following device entry in the `<devices>` section using the values from the previous step:

```
<hostdev mode='subsystem' type='usb'>
  <source startupPolicy='optional'>
    <vendor id='0557' />
    <product id='2221' />
  </source>
</hostdev>
```



### Tip: Vendor/Product or Device's Address

Instead of defining the host device with `<vendor/>` and `<product/>` IDs, you can use the `<address/>` element as described for host PCI devices in [Section 14.11.2](#), *"Adding a PCI Device with **virsh**"*.

3. Shut down the VM Guest and restart it to make the assigned USB device available.



### Tip: SELinux

If you are running SELinux on your VM Host Server, you need to disable it prior to starting the VM Guest with

```
setsebool -P virt_use_sysfs 1
```

## 14.13 Adding SR-IOV Devices

Single Root I/O Virtualization (*SR-IOV*) capable *PCIe* devices can replicate their resources, so they appear to be multiple devices. Each of these "pseudo-devices" can be assigned to a VM Guest.

*SR-IOV* is an industry specification that was created by the Peripheral Component Interconnect Special Interest Group (PCI-SIG) consortium. It introduces physical functions (PF) and virtual functions (VF). PFs are full *PCIe* functions used to manage and configure the device. PFs also can move data. VFs lack the configuration and management part—they only can move data and a reduced set of configuration functions. Since VFs do not have all *PCIe* functions, the host

operating system or the *Hypervisor* must support *SR-IOV* to be able to access and initialize VFs. The theoretical maximum for VFs is 256 per device (consequently the maximum for a dual-port Ethernet card would be 512). In practice this maximum is much lower, since each VF consumes resources.

### 14.13.1 Requirements

The following requirements must be met to be able to use *SR-IOV*:

- An *SR-IOV*-capable network card (as of SUSE Linux Enterprise Server 12 SP5, only network cards support *SR-IOV*)
- An AMD64/Intel 64 host supporting hardware virtualization (AMD-V or Intel VT-x), see *Section 7.3, “KVM Hardware Requirements”* for more information
- A chipset that supports device assignment (AMD-Vi or Intel VT-d)
- libvirt-0.9.10 or better
- *SR-IOV* drivers must be loaded and configured on the host system
- A host configuration that meets the requirements listed at *Important: Requirements for VFIO and SR-IOV*
- A list of the PCI addresses of the VF(s) that will be assigned to VM Guests



#### Tip: Checking if a Device is SR-IOV-Capable

The information whether a device is SR-IOV-capable can be obtained from its PCI descriptor by running `lspci`. A device that supports *SR-IOV* reports a capability similar to the following:

```
Capabilities: [160 v1] Single Root I/O Virtualization (SR-IOV)
```



#### Note: Adding an SR-IOV Device at VM Guest Creation

Before adding an SR-IOV device to a VM Guest when initially setting it up, the VM Host Server already needs to be configured as described in *Section 14.13.2, “Loading and Configuring the SR-IOV Host Drivers”*.

## 14.13.2 Loading and Configuring the SR-IOV Host Drivers

To be able to access and initialize VFs, an SR-IOV-capable driver needs to be loaded on the host system.

1. Before loading the driver, make sure the card is properly detected by running `lspci`. The following example shows the `lspci` output for the dual-port Intel 82576NS network card:

```
tux > sudo /sbin/lspci | grep 82576
01:00.0 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
(rev 01)
01:00.1 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
(rev 01)
04:00.0 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
(rev 01)
04:00.1 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
(rev 01)
```

In case the card is not detected, it is likely that the hardware virtualization support in the BIOS/EFI has not been enabled.

2. Check whether the `SR-IOV` driver is already loaded by running `lsmod`. In the following example a check for the `igb` driver (for the Intel 82576NS network card) returns a result. That means the driver is already loaded. If the command returns nothing, the driver is not loaded.

```
tux > sudo /sbin/lsmod | egrep "^igb "
igb                185649  0
```

3. Skip this step if the driver is already loaded.

If the `SR-IOV` driver is not yet loaded, the non-`SR-IOV` driver needs to be removed first, before loading the new driver. Use `rmmod` to unload a driver. The following example unloads the non-`SR-IOV` driver for the Intel 82576NS network card:

```
sudo /sbin/rmmod igbvf
```

Load the `SR-IOV` driver subsequently using the `modprobe` command—the VF parameter (`max_vfs`) is mandatory:

```
sudo /sbin/modprobe igb max_vfs=8
```

Or load the driver via SYSFS:

Find the PCI ID of the physical NIC by listing Ethernet devices:

```
tux > sudo lspci | grep Eth
06:00.0 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
06:00.1 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
```

To enable VFs, echo the number of desired VFs to load to the `sriov_numvfs` parameter:

```
tux > sudo echo 1 > /sys/bus/pci/devices/0000:06:00.1/sriov_numvfs
```

Verify that the VF NIC was loaded:

```
tux > sudo lspci | grep Eth
06:00.0 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
06:00.1 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
06:08.0 Ethernet controller: Emulex Corporation OneConnect NIC (Skyhawk) (rev 10)
```

Obtain the maximum number of VFs available:

```
tux > sudo lspci -vvv -s 06:00.1 | grep 'Initial VFs'
Initial VFs: 32, Total VFs: 32, Number of VFs: 0,
Function Dependency Link: 01
```

4. Create a `before.service` file which loads VF via SYSFS on boot:

```
[Unit]
Before=
After=network-online.target
[Service]
Type=oneshot
RemainAfterExit=true
ExecStart=/bin/bash -c "echo 1 > /sys/bus/pci/devices/0000:06:00.1/sriov_numvfs"
# beware, executable is run directly, not through a shell, check the man pages
# systemd.service and systemd.unit for full syntax
[Install]
# target in which to start the service
WantedBy=multi-user.target
#WantedBy=graphical.target
```

And copy it to `/etc/systemd/system`.

Additionally, it is required to create another service file (after-local.service) pointing to /etc/init.d/after.local script that detaches the NIC prior to starting the VM, otherwise the VM would fail to start:

```
[Unit]
Description=/etc/init.d/after.local Compatibility
After=libvirtd.service
Requires=libvirtd.service
[Service]
Type=oneshot
ExecStart=/etc/init.d/after.local
RemainAfterExit=true

[Install]
WantedBy=multi-user.target
```

And copy it to /etc/systemd/system.

```
#!/bin/sh
#
# Copyright (c) 2010 SuSE LINUX Products GmbH, Germany. All rights reserved.
# ...
virsh nodedev-detach pci_0000_06_08_0
```

Then save it as /etc/init.d/after.local.

5. Reboot the machine and check if the SR-IOV driver is loaded by re-running the **lspci** command from the first step of this procedure. If the SR-IOV driver was loaded successfully you should see additional lines for the VFs:

```
01:00.0 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
(rev 01)
01:00.1 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
(rev 01)
01:10.0 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
01:10.1 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
01:10.2 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
[...]
04:00.0 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
(rev 01)
04:00.1 Ethernet controller: Intel Corporation 82576NS Gigabit Network Connection
(rev 01)
04:10.0 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
04:10.1 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
04:10.2 Ethernet controller: Intel Corporation 82576 Virtual Function (rev 01)
```

### 14.13.3 Adding a VF Network Device to an Existing VM Guest

When the *SR-IOV* hardware is properly set up on the VM Host Server, you can add VFs to VM Guests. To do so, you need to collect some data first.

**Note:** The following procedure is using example data. Make sure to replace it by appropriate data from your setup.

1. Use the `virsh nodedev-list` command to get the PCI address of the VF you want to assign and its corresponding PF. Numerical values from the `lspci` output shown in [Section 14.13.2, "Loading and Configuring the SR-IOV Host Drivers"](#) (for example `01:00.0` or `04:00.1`) are transformed by adding the prefix "pci\_0000\_" and by replacing colons and dots with underscores. So a PCI ID listed as "04:00.0" by `lspci` is listed as "pci\_0000\_04\_00\_0" by `virsh`. The following example lists the PCI IDs for the second port of the Intel 82576NS network card:

```
tux > sudo virsh nodedev-list | grep 0000_04_
pci_0000_04_00_0
pci_0000_04_00_1
pci_0000_04_10_0
pci_0000_04_10_1
pci_0000_04_10_2
pci_0000_04_10_3
pci_0000_04_10_4
pci_0000_04_10_5
pci_0000_04_10_6
pci_0000_04_10_7
pci_0000_04_11_0
pci_0000_04_11_1
pci_0000_04_11_2
pci_0000_04_11_3
pci_0000_04_11_4
pci_0000_04_11_5
```

The first two entries represent the PFs, whereas the other entries represent the VFs.

2. Get more data that will be needed by running the command `virsh nodedev-dumpxml` on the PCI ID of the VF you want to add:

```
tux > sudo virsh nodedev-dumpxml pci_0000_04_10_0
```

```

<device>
  <name>pci_0000_04_10_0</name>
  <parent>pci_0000_00_02_0</parent>
  <capability type='pci'>
    <domain>0</domain>
    <bus>4</bus>
    <slot>16</slot>
    <function>0</function>
    <product id='0x10ca'>82576 Virtual Function</product>
    <vendor id='0x8086'>Intel Corporation</vendor>
    <capability type='phys_function'>
      <address domain='0x0000' bus='0x04' slot='0x00' function='0x0' />
    </capability>
  </capability>
</device>

```

The following data is needed for the next step:

- <domain>0</domain>
- <bus>4</bus>
- <slot>16</slot>
- <function>0</function>

3. Create a temporary XML file (for example `/tmp/vf-interface.xml` containing the data necessary to add a VF network device to an existing VM Guest. The minimal content of the file needs to look like the following:

```

<interface type='hostdev'>❶
  <source>
    <address type='pci' domain='0' bus='11' slot='16' function='0'2/>❷
  </source>
</interface>

```

- ❶ VFs do not get a fixed MAC address; it changes every time the host reboots. When adding network devices the “traditional” way with `<hostdev>`, it would require to reconfigure the VM Guest's network device after each reboot of the host, because of the MAC address change. To avoid this kind of problem, libvirt introduced the “`interface type='hostdev'`” directive, which sets up network-specific data *before* assigning the device.
- ❷ Specify the data you acquired in the previous step here.



4. In case a device is already attached to the host, it cannot be attached to a guest. To make it available for guests, detach it from the host first:

```
virsh nodedev-detach pci_0000_04_10_0
```

5. Last, add the VF interface to an existing VM Guest:

```
virsh attach-device GUEST /tmp/vf-interface.xml --OPTION
```

GUEST needs to be replaced by the domain name, ID or UUID of the VM Guest and --OPTION can be one of the following:

--persistent

This option will always add the device to the domain's persistent XML. In addition, if the domain is running, it will be hotplugged.

--config

This option will only affect the persistent XML, even if the domain is running. The device will only show up in the guest on next boot.

--live

This option will only affect a running domain. If the domain is inactive, the operation will fail. The device is not persisted in the XML and will not be available in the guest on next boot.

--current

This option affects the current state of the domain. If the domain is inactive, the device is added to the persistent XML and will be available on next boot. If the domain is active, the device is hotplugged but not added to the persistent XML.

To detach a VF interface, use the virsh detach-device command, which also takes the options listed above.

#### 14.13.4 Dynamic Allocation of VFs from a Pool

If you define the PCI address of a VF into a guest's configuration statically as described in [Section 14.13.3, "Adding a VF Network Device to an Existing VM Guest"](#), it is hard to migrate such guest to another host. The host must have identical hardware in the same location on the PCI bus, or the guest configuration must be modified prior to each start.

Another approach is to create a `libvirt` network with a device pool that contains all the VFs of an *SR-IOV* device. The guest then references this network, and each time it is started, a single VF is dynamically allocated to it. When the guest is stopped, the VF is returned to the pool, available for another guest.

#### 14.13.4.1 Defining Network with Pool of VFs on VM Host Server

The following example of network definition creates a pool of all VFs for the *SR-IOV* device with its physical function (PF) at the network interface `eth0` on the host:

```
<network>
  <name>passthrough</name>
  <forward mode='hostdev' managed='yes'>
    <pf dev='eth0' />
  </forward>
</network>
```

To use this network on the host, save the above code to a file, for example `/tmp/passthrough.xml`, and execute the following commands. Remember to replace `eth0` with the real network interface name of your *SR-IOV* device's PF:

```
virsh net-define /tmp/passthrough.xml
virsh net-autostart passthrough
virsh net-start passthrough
```

#### 14.13.4.2 Configuring VM Guest to Use VF from the Pool

The following example of guest device interface definition uses a VF of the *SR-IOV* device from the pool created in [Section 14.13.4.1, “Defining Network with Pool of VFs on VM Host Server”](#). `libvirt` automatically derives the list of all VFs associated with that PF the first time the guest is started.

```
<interface type='network'>
  <source network='passthrough'>
</interface>
```

To verify the list of associated VFs, run `virsh net-dumpxml passthrough` on the host after the first guest that uses the network with the pool of VFs starts.

```
<network connections='1'>
```

```

<name>passthrough</name>
<uuid>a6a26429-d483-d4ed-3465-4436ac786437</uuid>
<forward mode='hostdev' managed='yes'>
  <pf dev='eth0' />
  <address type='pci' domain='0x0000' bus='0x02' slot='0x10' function='0x1' />
  <address type='pci' domain='0x0000' bus='0x02' slot='0x10' function='0x3' />
  <address type='pci' domain='0x0000' bus='0x02' slot='0x10' function='0x5' />
  <address type='pci' domain='0x0000' bus='0x02' slot='0x10' function='0x7' />
  <address type='pci' domain='0x0000' bus='0x02' slot='0x11' function='0x1' />
  <address type='pci' domain='0x0000' bus='0x02' slot='0x11' function='0x3' />
  <address type='pci' domain='0x0000' bus='0x02' slot='0x11' function='0x5' />
</forward>
</network>

```

## 14.14 Using Macvtap to Share VM Host Server Network Interfaces

Macvtap provides direct attachment of a VM Guest virtual interface to a host network interface. The macvtap-based interface extends the VM Host Server network interface and has its own MAC address on the same Ethernet segment. Typically, this is used to make both the VM Guest and the VM Host Server show up directly on the switch that the VM Host Server is connected to.



### Note: Macvtap Cannot Be Used with a Linux Bridge

Macvtap cannot be used with network interfaces already connected to a Linux bridge. Before attempting to create the macvtap interface, remove the interface from the bridge.



### Note: VM Guest to VM Host Server Communication with Macvtap

When using macvtap, a VM Guest can communicate with other VM Guests, and with other external hosts on the network. But it cannot communicate with the VM Host Server on which the VM Guest runs. This is the defined behavior of macvtap, because of the way the VM Host Server's physical Ethernet is attached to the macvtap bridge. Traffic from the VM Guest into that bridge that is forwarded to the physical interface cannot be bounced back up to the VM Host Server's IP stack. Similarly, traffic from the VM Host Server's IP stack that is sent to the physical interface cannot be bounced back up to the macvtap bridge for forwarding to the VM Guest.

Virtual network interfaces based on macvtap are supported by libvirt by specifying an interface type of `direct`. For example:

```
<interface type='direct'>
  <mac address='aa:bb:cc:dd:ee:ff' />
  <source dev='eth0' mode='bridge' />
  <model type='virtio' />
</interface>
```

The operation mode of the macvtap device can be controlled with the `mode` attribute. The following list shows its possible values and a description for each:

- `vepa`: All VM Guest packets are sent to an external bridge. Packets whose destination is a VM Guest on the same VM Host Server as where the packet originates from are sent back to the VM Host Server by the VEPA capable bridge (today's bridges are typically not VEPA capable).
- `bridge`: Packets whose destination is on the same VM Host Server as where they originate from are directly delivered to the target macvtap device. Both origin and destination devices need to be in `bridge` mode for direct delivery. If either one of them is in `vepa` mode, a VEPA capable bridge is required.
- `private`: All packets are sent to the external bridge and will only be delivered to a target VM Guest on the same VM Host Server if they are sent through an external router or gateway and that device sends them back to the VM Host Server. This procedure is followed if either the source or destination device is in private mode.
- `passthrough`: A special mode that gives more power to the network interface. All packets will be forwarded to the interface, allowing virtio VM Guests to change the MAC address or set promiscuous mode to bridge the interface or create VLAN interfaces on top of it. Note that a network interface is not shareable in `passthrough` mode. Assigning an interface to a VM Guest will disconnect it from the VM Host Server. For this reason SR-IOV virtual functions are often assigned to the VM Guest in `passthrough` mode.

## 14.15 Managing Guest Memory Allocation (Xen only)

**libvirt** now includes support for adjusting memory allocation per guest with **virsh**. Xen paravirtual devices connect to the `xenbus` controller, which is analogous to a physical device bus such as a PCI controller. Xen's `max_grant_frames` attribute sets how many frames, which are analogous to memory, are allocated to the `xenbus` controller for each guest.

The default is 32, and this can be increased as needed, up to the amount set for dom0, or decreased. How much is enough? This depends on the number of devices and workload demand, such as a saturated network interface or heavy I/O. Use **xen-diag** to see your current used and maximum `max_grant_frames` values for dom0 and your guests. The guests must be running:

```
tux > sudo virsh list
 Id   Name           State
-----
 0    Domain-0       running
 3    sle15sp1       running

tux > sudo xen-diag gnttab_query_size 0
domid=0: nr_frames=1, max_nr_frames=256

tux > sudo xen-diag gnttab_query_size 3
domid=3: nr_frames=3, max_nr_frames=32
```

The `sle15sp1` guest is using only 3 frames out of 32. If you are seeing performance issues, and log entries that point to insufficient frames, increase the value with **virsh**. Look for the `<controller type='xenbus'>` line in the guest's configuration file and add the `maxGrantFrames` control element:

```
tux > sudo virsh edit sle15sp1
<controller type='xenbus' index='0' maxGrantFrames='40' />
```

Save your changes and restart the guest. Now it should show your change:

```
tux > sudo xen-diag gnttab_query_size 3
domid=3: nr_frames=3, max_nr_frames=40
```

See the *Controllers* section of the libvirt *Domain XML format* manual at <https://libvirt.org/format-domain.html#elementsControllers> for more information.

## 14.16 Disabling a Memory Balloon Device

Memory Balloon has become a default option for KVM. The device will be added to the VM Guest explicitly, so you do not need to add this element in the VM Guest's XML configuration. However, if you want to disable Memory Balloon in the VM Guest for any reason, you need to set `model='none'` as shown below:

```
<devices>
```

```
<memballoon model='none' />
</device>
```

## 14.17 Configuring Multiple Monitors (Dual Head)

`libvirt` supports a dual head configuration to display the video output of the VM Guest on multiple monitors.



### Important: No Support for Xen

The Xen hypervisor does not support dual head configuration.

#### PROCEDURE 14.4: CONFIGURING DUAL HEAD

1. While the virtual machine is running, verify that the `xf86-video-qxl` package is installed in the VM Guest:

```
tux > rpm -q xf86-video-qxl
```

2. Shut down the VM Guest and start editing its configuration XML as described in [Section 14.9, “Editing VM Configuration with `virsh`”](#).
3. Verify that the model of the virtual graphics card is 'qxl':

```
<video>
  <model type='qxl' ... />
```

4. Increase the `heads` parameter in the graphics card model specification from the default 1 to 2, for example:

```
<video>
  <model type='qxl' ram='65536' vram='65536' vgamem='16384' heads='2' primary='yes' />
  <alias name='video0' />
  <address type='pci' domain='0x0000' bus='0x00' slot='0x01' function='0x0' />
</video>
```

5. Configure the virtual machine to use the Spice display instead of VNC:

```
<graphics type='spice' port='5916' autoport='yes' listen='0.0.0.0'>
  <listen type='address' address='0.0.0.0' />
</graphics>
```

6. Start the virtual machine and connect to its display with **virt-viewer**, for example:

```
tux > virt-viewer --connect qemu+ssh://USER@VM_HOST/system
```

7. From the list of VMs, select the one whose configuration you have modified and confirm with *Connect*.
8. After the graphical subsystem (Xorg) loads in the VM Guest, select *View > Displays > Display 2* to open a new window with the second monitor's output.

# III Hypervisor-Independent Features

- 15 Disk Cache Modes **156**
- 16 VM Guest Clock Settings **160**
- 17 libguestfs **162**



## 15 Disk Cache Modes

### 15.1 Disk Interface Cache Modes

Hypervisors allow for various storage caching strategies to be specified when configuring a VM Guest. Each guest disk interface can have one of the following cache modes specified: *writethrough*, *writeback*, *none*, *directsync*, or *unsafe*. If no cache mode is specified, an appropriate default cache mode is used. These cache modes influence how host-based storage is accessed, as follows:

- Read/write data may be cached in the host page cache.
- The guest's storage controller is informed whether a write cache is present, allowing for the use of a flush command.
- Synchronous write mode may be used, in which write requests are reported complete only when committed to the storage device.
- Flush commands (generated by the guest storage controller) may be ignored for performance reasons.

If a disorderly disconnection between the guest and its storage occurs, the cache mode in use will affect whether data loss occurs. The cache mode can also affect disk performance significantly. Additionally, some cache modes are incompatible with live migration, depending on several factors. There are no simple rules about what combination of cache mode, disk image format, image placement, or storage sub-system is best. The user should plan each guest's configuration carefully and experiment with various configurations to determine the optimal performance.

### 15.2 Description of Cache Modes

#### cache mode unspecified

In older QEMU versions, not specifying a cache mode meant that *writethrough* would be used as the default. With modern versions—as shipped with SUSE Linux Enterprise Server—the various guest storage interfaces have been fixed to handle *writeback* or *writethrough* semantics more correctly. This allows for the default caching mode to be switched to *writeback*. The guest driver for each of ide, scsi, and virtio have within their power to

disable the write back cache, causing the caching mode used to revert to *writethrough*. The typical guest's storage drivers will maintain the default caching mode as *writeback*, however.

#### **writethrough**

This mode causes the hypervisor to interact with the disk image file or block device with O\_DSYNC semantics. Writes are reported as completed only when the data has been committed to the storage device. The host page cache is used in what can be termed a writethrough caching mode. The guest's virtual storage adapter is informed that there is no writeback cache, so the guest would not need to send down flush commands to manage data integrity. The storage behaves as if there is a writethrough cache.

#### **writeback**

This mode causes the hypervisor to interact with the disk image file or block device with neither O\_DSYNC nor O\_DIRECT semantics. The host page cache is used and writes are reported to the guest as completed when they are placed in the host page cache. The normal page cache management will handle commitment to the storage device. Additionally, the guest's virtual storage adapter is informed of the writeback cache, so the guest would be expected to send down flush commands as needed to manage data integrity. Analogous to a raid controller with RAM cache.

#### **none**

This mode causes the hypervisor to interact with the disk image file or block device with O\_DIRECT semantics. The host page cache is bypassed and I/O happens directly between the hypervisor user space buffers and the storage device. Because the actual storage device may report a write as completed when placed in its write queue only, the guest's virtual storage adapter is informed that there is a writeback cache. The guest would be expected to send down flush commands as needed to manage data integrity. Performance-wise, it is equivalent to direct access to your host's disk.

#### **unsafe**

This mode is similar to the writeback mode discussed above. The key aspect of this “unsafe” mode, is that all flush commands from the guests are ignored. Using this mode implies that the user has accepted the trade-off of performance over risk of data loss in case of a host failure. Useful, for example, during guest installation, but not for production workloads.

## directsync

This mode causes the hypervisor to interact with the disk image file or block device with both `O_DSYNC` and `O_DIRECT` semantics. This means, writes are reported as completed only when the data has been committed to the storage device, and when it is also desirable to bypass the host page cache. Like *writethrough*, it is helpful to guests that do not send flushes when needed. It was the last cache mode added, completing the possible combinations of caching and direct access semantics.

## 15.3 Data Integrity Implications of Cache Modes

### writethrough, none, directsync

These are the safest modes, and considered equally safe, given that the guest operating system is “modern and well behaved”, which means that it uses flushes as needed. If you have a suspect guest, use *writethrough*, or *directsync*. Note that some file systems are not compatible with `none` or `directsync`, as they do not support `O_DIRECT`, which these cache modes rely on.

### writeback

This mode informs the guest of the presence of a write cache, and relies on the guest to send flush commands as needed to maintain data integrity within its disk image. This is a common storage design which is completely accounted for within modern file systems. This mode exposes the guest to data loss in the unlikely case of a host failure, because there is a window of time between the time a write is reported as completed, and that write being committed to the storage device.

### unsafe

This mode is similar to *writeback* caching except for the following: the guest flush commands are ignored, nullifying the data integrity control of these flush commands, and resulting in a higher risk of data loss because of host failure. The name “unsafe” should serve as a warning that there is a much higher potential for data loss because of a host failure than with the other modes. As the guest terminates, the cached data is flushed at that time.

## 15.4 Performance Implications of Cache Modes

The choice to make full use of the page cache, or to write through it, or to bypass it altogether can have dramatic performance implications. Other factors that influence disk performance include the capabilities of the actual storage system, what disk image format is used, the potential size of the page cache and the IO scheduler used. Additionally, not flushing the write cache increases performance, but with risk, as noted above. As a general rule, high-end systems typically perform best with the cache mode `none`, because of the reduced data copying that occurs. The potential benefit of having multiple guests share the common host page cache, the ratio of reads to writes, and the use of AIO mode `native` (see below) should also be considered.

## 15.5 Effect of Cache Modes on Live Migration

The caching of storage data and metadata restricts the configurations that support live migration. Currently, only `raw`, `qcow2` and `qed` image formats can be used for live migration. If a clustered file system is used, all cache modes support live migration. Otherwise the only cache mode that supports live migration on read/write shared storage is `none`.

The `libvirt` management layer includes checks for migration compatibility based on several factors. If the guest storage is hosted on a clustered file system, is read-only or is marked shareable, then the cache mode is ignored when determining if migration can be allowed. Otherwise `libvirt` will not allow migration unless the cache mode is set to `none`. However, this restriction can be overridden with the “unsafe” option to the migration APIs, which is also supported by `virsh`, as for example in

```
virsh migrate --live --unsafe
```



### Tip

The cache mode `none` is required for the AIO mode setting `native`. If another cache mode is used, then the AIO mode will silently be switched back to the default `threads`. The guest flush within the host is implemented using `fdatsync()`.

## 16 VM Guest Clock Settings

Keeping the correct time in a VM Guest is one of the more difficult aspects of virtualization. Keeping the correct time is especially important for network applications and is also a prerequisite to do a live migration of a VM Guest.



### Tip: Timekeeping on the VM Host Server

It is strongly recommended to ensure the VM Host Server keeps the correct time as well, for example, by using NTP (see Book “Administration Guide”, Chapter 26 “Time Synchronization with NTP” for more information).

## 16.1 KVM: Using `kvm_clock`

KVM provides a paravirtualized clock which is supported via the `kvm_clock` driver. It is strongly recommended to use `kvm_clock`.

Use the following command inside a VM Guest running Linux to check whether the driver `kvm_clock` has been loaded:

```
tux > sudo dmesg | grep kvm-clock
[ 0.000000] kvm-clock: cpu 0, msr 0:7d3a81, boot clock
[ 0.000000] kvm-clock: cpu 0, msr 0:1206a81, primary cpu clock
[ 0.012000] kvm-clock: cpu 1, msr 0:1306a81, secondary cpu clock
[ 0.160082] Switching to clocksource kvm-clock
```

To check which clock source is currently used, run the following command in the VM Guest. It should output `kvm-clock`:


```
tux > cat /sys/devices/system/clocksource/clocksource0/current_clocksource
```



### Important: `kvm-clock` and NTP

When using `kvm-clock`, it is recommended to use NTP in the VM Guest, as well. Using NTP on the VM Host Server is also recommended.

### 16.1.1 Other Timekeeping Methods

The paravirtualized `kvm-clock` is currently not for Windows\* operating systems. For Windows\*, use the `Windows Time Service Tools` for time synchronization (see <http://technet.microsoft.com/en-us/library/cc773263%28WS.10%29.aspx>  for more information).

## 16.2 Xen Virtual Machine Clock Settings

With Xen 4, the independent wallclock setting `/proc/sys/xen/independent_wallclock` used for time synchronization between Xen host and guest was removed. A new configuration option `tsc_mode` was introduced. It specifies a method of utilizing the *timestamp counter* to synchronize the guest time with the Xen server. Its default value '0' handles the vast majority of hardware and software environments.

For more details on `tsc_mode`, see the `xen-tscmode` manual page (`man 7 xen-tscmode`).

## 17 libguestfs

*Virtual Machines* consist of disk images and definition files. Manually accessing and manipulating these guest components (outside of normal hypervisor processes) is possible, but inherently dangerous and risks compromising data integrity. libguestfs is a C library and a corresponding set of tools designed for safely accessing and modifying *Virtual Machine* disk images—outside of normal hypervisor processes, but without the risk normally associated with manual editing.

### 17.1 VM Guest Manipulation Overview

#### 17.1.1 VM Guest Manipulation Risk

As disk images and definition files are simply another type of file in a Linux environment, it is possible to use many tools to access, edit and write to these files. When used correctly, such tools can be an important part of guest administration. However, even correct usage of these tools is not without risk. Risks that should be considered when manually manipulating guest disk images include:

- *Data Corruption*: Concurrently accessing images, by the host machine or another node in a cluster, can cause changes to be lost or data corruption to occur if virtualization protection layers are bypassed.
- *Security*: Mounting disk images as loop devices requires root access. While an image is loop mounted, other users and processes can potentially access the disk contents.
- *Administrator Error*: Bypassing virtualization layers correctly requires advanced understanding of virtual components and tools. Failing to isolate the images or failing to clean up properly after changes have been made can lead to further problems once back in virtualization control.

## 17.1.2 libguestfs Design

libguestfs C library has been designed to safely and securely create, access and modify virtual machine (VM Guest) disk images. It also provides additional language bindings: for Perl (<https://libguestfs.org/guestfs-perl.3.html>), Python (<https://libguestfs.org/guestfs-python.3.html>), PHP (only for 64-bit machines), and Ruby (<https://libguestfs.org/guestfs-ruby.3.html>). libguestfs can access VM Guest disk images without needing root and with multiple layers of defense against rogue disk images.

libguestfs provides many tools designed for accessing and modifying VM Guest disk images and contents. These tools provide such capabilities as: viewing and editing files inside guests, scripting changes to VM Guests, monitoring disk used/free statistics, creating guests, doing V2V or P2V migrations, performing backups, cloning VM Guests, formatting disks, and resizing disks.



### Warning: Best Practices

You must not use libguestfs tools on live virtual machines. Doing so will probably result in disk corruption in the VM Guest. libguestfs tools try to stop you from doing this, but cannot catch all cases.

However most command have the `--ro` (read-only) option. With this option, you can attach a command to a live virtual machine. The results might be strange or inconsistent at times but you will not risk disk corruption.

## 17.2 Package Installation

libguestfs is shipped through 4 packages:

- `libguestfs0`: which provides the main C library
- `guestfs-data`: which contains the appliance files used when launching images (stored in `/usr/lib64/guestfs`)
- `guestfs-tools`: the core guestfs tools, man pages, and the `/etc/libguestfs-tools.conf` configuration file.
- `guestfs-winsupport`: provides support for Windows file guests in the guestfs tools. This package only needs to be installed to handle Windows guests, for example when converting a Windows guest to KVM.



To install guestfs tools on your system run:

```
zypper in guestfs-tools
```

## 17.3 Guestfs Tools

### 17.3.1 Modifying Virtual Machines

The set of tools found within the guestfs-tools package is used for accessing and modifying virtual machine disk images. This functionality is provided through a familiar shell interface with built-in safeguards which ensure image integrity. Guestfs tools shells expose all capabilities of the guestfs API, and create an appliance on the fly using the packages installed on the machine and the files found in `/usr/lib4/guestfs`.

### 17.3.2 Supported File Systems and Disk Images

Guestfs tools support various file systems including:

- Ext2, Ext3, Ext4
- Xfs
- Btrfs

Multiple disk image formats are also supported:

- raw
- qcow2



#### Warning: Unsupported File System

Guestfs may also support Windows\* file systems (VFAT, NTFS), BSD\* and Apple\* file systems, and other disk image formats (VMDK, VHDX...). However, these file systems and disk image formats are unsupported on SUSE Linux Enterprise.

### 17.3.3 virt-rescue

**virt-rescue** is similar to a rescue CD, but for virtual machines, and without the need for a CD. virt-rescue presents users with a rescue shell and some simple recovery tools which can be used to examine and correct problems within a virtual machine or disk image.

```
tux > virt-rescue -a sles.qcow2
Welcome to virt-rescue, the libguestfs rescue shell.

Note: The contents of / are the rescue appliance.
You need to mount the guest's partitions under /sysroot
before you can examine them. A helper script for that exists:
mount-rootfs-and-do-chroot.sh /dev/sda2

><rescue>
[ 67.194384] EXT4-fs (sda1): mounting ext3 file system
using the ext4 subsystem
[ 67.199292] EXT4-fs (sda1): mounted filesystem with ordered data
mode. Opts: (null)
mount: /dev/sda1 mounted on /sysroot.
mount: /dev bound on /sysroot/dev.
mount: /dev/pts bound on /sysroot/dev/pts.
mount: /proc bound on /sysroot/proc.
mount: /sys bound on /sysroot/sys.
Directory: /root
Thu Jun 5 13:20:51 UTC 2014
(none):~ #
```

You are now running the VM Guest in rescue mode:

```
(none):~ # cat /etc/fstab
devpts /dev/pts          devpts mode=0620,gid=5 0 0
proc   /proc                proc   defaults                0 0
sysfs  /sys                  sysfs  noauto                  0 0
debugfs /sys/kernel/debug debugfs noauto                  0 0
usbfs  /proc/bus/usb          usbfs  noauto                  0 0
tmpfs  /run                  tmpfs  noauto                  0 0
/dev/disk/by-id/ata-QEMU_HARDDISK_QM00001-part1 / ext3 defaults 1 1
```

### 17.3.4 virt-resize

**virt-resize** is used to resize a virtual machine disk, making it larger or smaller overall, and resizing or deleting any partitions contained within.

## Full step-by-step example: How to expand a virtual machine disk

1. First, with virtual machine powered off, determine the size of the partitions available on this virtual machine:

```
tux > virt-filesystems --long --parts --blkdevs -h -a sles.qcow2
```

Name	Type	MBR	Size	Parent
/dev/sda1	partition	83	16G	/dev/sda
/dev/sda	device	-	16G	-

2. **virt-resize** cannot do in-place disk modifications—there must be sufficient space to store the resized output disk. Use the **truncate** command to create a file of suitable size:

```
tux > truncate -s 32G outdisk.img
```

3. Use **virt-resize** to resize the disk image. **virt-resize** requires two mandatory parameters for the input and output images:

```
tux > virt-resize --expand /dev/sda1 sles.qcow2 outdisk.img  
Examining sles.qcow2 ...  
*****  
  
Summary of changes:  
  
/dev/sda1: This partition will be resized from 16,0G to 32,0G. The  
filesystem ext3 on /dev/sda1 will be expanded using the 'resize2fs'  
method.  
  
*****  
  
Setting up initial partition table on outdisk.img ...  
Copying /dev/sda1 ...  
● 84%  
[██████████████████████████████████████████████████████████████] 00:03  
Expanding /dev/sda1 using the 'resize2fs' method ...  
  
Resize operation completed with no errors. Before deleting the old  
disk, carefully check that the resized disk boots and works correctly.
```

- #### 4. Confirm the image was resized properly:

```
tux > virt-filesystems --long --parts --blkdevs -h -a outdisk.img
```

Name	Type	MBR	Size	Parent
/dev/sda1	partition	83	32G	/dev/sda
/dev/sda	device	-	32G	-

5. Bring up the VM Guest using the new disk image and confirm correct operation before deleting the old image.

## 17.3.5 Other virt-\* Tools

There are guestfs tools to simplify administrative tasks—such as viewing and editing files, or obtaining information on the virtual machine.

### 17.3.5.1 virt-filesystems

This tool is used to report information regarding file systems, partitions, and logical volumes in a disk image or virtual machine.

```
tux > virt-filesystems -l -a sles.qcow2
Name      Type      VFS  Label  Size      Parent
/dev/sda1 filesystem ext3  -      17178820608 -
```

### 17.3.5.2 virt-ls

**virt-ls** lists file names, file sizes, checksums, extended attributes and more from a virtual machine or disk image. Multiple directory names can be given, in which case the output from each is concatenated. To list directories from a libvirt guest, use the **-d** option to specify the name of the guest. For a disk image, use the **-a** option.

```
tux > virt-ls -h -lR -a sles.qcow2 /var/log/
d 0755      776 /var/log
- 0640      0 /var/log/NetworkManager
- 0644     23K /var/log/Xorg.0.log
- 0644     23K /var/log/Xorg.0.log.old
d 0700     482 /var/log/YaST2
- 0644     512 /var/log/YaST2/_dev_vda
- 0644      59 /var/log/YaST2/arch.info
- 0644     473 /var/log/YaST2/config_diff_2017_05_03.log
- 0644     5.1K /var/log/YaST2/curl_log
- 0644     1.5K /var/log/YaST2/disk_vda.info
- 0644     1.4K /var/log/YaST2/disk_vda.info-1
[...]
```

### 17.3.5.3 **virt-cat**

**virt-cat** is a command line tool to display the contents of a file that exists in the named virtual machine (or disk image). Multiple file names can be given, in which case they are concatenated together. Each file name must be a full path, starting at the root directory (starting with '/').

```
tux > virt-cat -a sles.qcow2 /etc/fstab
devpts /dev/pts devpts mode=0620,gid=5 0 0
proc   /proc     proc   defaults      0 0
```

### 17.3.5.4 **virt-df**

**virt-df** is a command line tool to display free space on virtual machine file systems. Unlike other tools, it does not only display the size of disk allocated to a virtual machine, but can look inside disk images to show how much space is actually being used.

```
tux > virt-df -a sles.qcow2
Filesystem                                1K-blocks      Used Available Use%
sles.qcow2:/dev/sda1                      16381864      520564   15022492  4%
```

### 17.3.5.5 **virt-edit**

**virt-edit** is a command line tool capable of editing files that reside in the named virtual machine (or disk image).

### 17.3.5.6 **virt-tar-in/out**

**virt-tar-in** unpacks an uncompressed TAR archive into a virtual machine disk image or named libvirt domain. **virt-tar-out** packs a virtual machine disk image directory into a TAR archive.

```
tux > virt-tar-out -a sles.qcow2 /home homes.tar
```

### 17.3.5.7 **virt-copy-in/out**

**virt-copy-in** copies files and directories from the local disk into a virtual machine disk image or named libvirt domain. **virt-copy-out** copies files and directories out of a virtual machine disk image or named libvirt domain.

```
tux > virt-copy-in -a sles.qcow2 data.tar /tmp/
virt-ls -a sles.qcow2 /tmp/
.ICE-unix
.X11-unix
data.tar
```

### 17.3.5.8 virt-log

**virt-log** shows the log files of the named libvirt domain, virtual machine or disk image. If the package `guestfs-winsupport` is installed it can also show the event log of a Windows virtual machine disk image.

```
tux > virt-log -a windows8.qcow2
<?xml version="1.0" encoding="utf-8" standalone="yes" ?>
<Events>
<Event xmlns="http://schemas.microsoft.com/win/2004/08/events/event"><System><Provider
  Name="EventLog"></Provider>
<EventID Qualifiers="32768">6011</EventID>
<Level>4</Level>
<Task>0</Task>
<Keywords>0x0080000000000000</Keywords>
<TimeCreated SystemTime="2014-09-12 05:47:21"></TimeCreated>
<EventRecordID>1</EventRecordID>
<Channel>System</Channel>
<Computer>windows-uj49s6b</Computer>
<Security UserID=""></Security>
</System>
<EventData><Data><string>WINDOWS-UJ49S6B</string>
<string>WIN-KG190623QG4</string>
</Data>
<Binary></Binary>
</EventData>
</Event>

...
```

### 17.3.6 guestfish

**guestfish** is a shell and command line tool for examining and modifying virtual machine file systems. It uses `libguestfs` and exposes all of the functionality of the `guestfs` API.

Examples of usage:

```
tux > guestfish -a disk.img <<EOF
run
list-filesystems
EOF
```

```
guestfish
```

```
Welcome to guestfish, the guest filesystem shell for
editing virtual machine filesystems and disk images.
```

```
Type: 'help' for help on commands
      'man' to read the manual
      'quit' to quit the shell
```

```
><fs> add sles.qcow2
><fs> run
><fs> list-filesystems
/dev/sda1: ext3
><fs> mount /dev/sda1 /
cat /etc/fstab
devpts /dev/pts          devpts mode=0620,gid=5 0 0
proc   /proc              proc   defaults                0 0
sysfs  /sys                sysfs  noauto                  0 0
debugfs /sys/kernel/debug debugfs noauto                  0 0
usbfs  /proc/bus/usb        usbfs  noauto                  0 0
tmpfs  /run                tmpfs  noauto                  0 0
/dev/disk/by-id/ata-QEMU_HARDDISK_QM000001-part1 / ext3 defaults 1 1
```

### 17.3.7 Converting a Physical Machine into a KVM Guest

Libguestfs provides tools to help converting Xen virtual machines or physical machines into KVM guests. The Xen to KVM conversion scenario is covered by the *Article “Xen to KVM Migration Guide”*. The following section will cover a special use case: converting a bare metal machine into a KVM one.

Converting a physical machine into a KVM one is not yet supported in SUSE Linux Enterprise Server. This feature is released as a technology preview only.

Converting a physical machine requires collecting information about it and transmitting this to a conversion server. This is achieved by running a live system prepared with **virt-p2v** and **kiwi** tools on the machine.

1. Install the needed packages with the command:

```
root # zypper in virt-p2v kiwi-desc-isoboot
```



## Note

These steps will document how to create an ISO image to create a bootable DVD. Alternatively, you can create a PXE boot image instead; for more information about building PXE images with KIWI NG, see [`man virt-p2v-make-kiwi`](#).

2. Create a KIWI NG configuration:

```
tux > virt-p2v-make-kiwi -o /tmp/p2v.kiwi
```

The `-o` defines where to create the KIWI NG configuration.

3. Edit the `config.xml` file in the generated configuration if needed. For example, in `config.xml` adjust the keyboard layout of the live system.
4. Build the ISO image with `kiwi`:

```
tux > kiwi --build /tmp/p2v.kiwi ❶ \
    -d /tmp/build ❷ \
    --ignore-repos \
    --add-repo http://URL/T0/SLE/REPOSITORIES ❸ \
    --type iso
```

- ❶ The directory where the KIWI NG configuration was generated in the previous step.
- ❷ The directory where KIWI NG will place the generated ISO image and other intermediary build results.
- ❸ The URLs to the package repositories as found with `zypper lr -d`.  
Use one `--add-repo` parameter per repository.

5. Burn the ISO on a DVD or a USB stick. With such a medium, boot the machine to be converted.
6. After the system is started, you will be asked for the connection details of the *conversion server*. This server is a machine with the `virt-v2v` package installed.  
If the network setup is more complex than a DHCP client, click the *Configure network* button to open the YaST network configuration dialog.



Click the *Test connection* button to allow moving to the next page of the wizard.

7. Select the disks and network interfaces to be converted and define the VM data like the amount of allocated CPUs, memory and the Virtual Machine name.



### Note

If not defined, the created disk image format will be *raw* by default. This can be changed by entering the desired format in the *Output format* field.

There are two possibilities to generate the virtual machine: either using the *local* or the *libvirt* output. The first one will place the Virtual Machine disk image and configuration in the path defined in the *Output storage* field. These can then be used to define a new libvirt-handled guest using [virsh](#). The second method will create a new libvirt-handled guest with the disk image placed in the pool defined in the *Output storage* field.

Click *Start conversion* to start it.

## 17.4 Troubleshooting

### 17.4.1 Btrfs-related Problems

When using the `guestfs` tools on an image with Btrfs root partition (the default with SUSE Linux Enterprise Server) the following error message may be displayed:

```
tux > virt-ls -a /path/to/sles12sp2.qcow2 /
virt-ls: multi-boot operating systems are not supported
```

If using `guestfish -i` option, remove this option and instead use the commands `'run'` followed by `'list-file systems'`. You can then mount filesystems you want by hand using the `'mount'` or `'mount-ro'` command.

If using `guestmount -i`, remove this option and choose the filesystem(s) you want to see by manually adding `'-m'` option(s). Use `'virt-file systems'` to see what filesystems are available.

If using other `virt` tools, multi-boot operating systems won't work with these tools. Use the `guestfish` equivalent commands (see the `virt` tool manual page).

This is usually caused by the presence of snapshots in the guests. In this case guestfs does not know which snapshot to bootstrap. To force the use of a snapshot, use the `-m` parameter as follows:

```
tux > virt-ls -m /dev/sda2::subvol=@/.snapshots/2/snapshot -a /path/to/sles12sp2.qcow2 /
```

## 17.4.2 Environment

When troubleshooting problems within a libguestfs appliance, the environment variable `LIBGUESTFS_DEBUG=1` can be used to enable debug messages. To output each command/API call in a format that is similar to guestfish commands, use the environment variable `LIBGUESTFS_TRACE=1`.

## 17.4.3 libguestfs-test-tool

**libguestfs-test-tool** is a test program that checks if basic libguestfs functionality is working. It will print a large amount of diagnostic messages and details of the guestfs environment, then create a test image and try to start it. If it runs to completion successfully, the following message should be seen near the end:

```
===== TEST FINISHED OK =====
```

## 17.5 External References

- [libguestfs.org](https://libguestfs.org) (<https://libguestfs.org>) ↗
- [libguestfs FAQ](https://libguestfs.org/guestfs-faq.1.html) (<https://libguestfs.org/guestfs-faq.1.html>) ↗

## IV Managing Virtual Machines with Xen

- 18 Setting Up a Virtual Machine Host **175**
- 19 Virtual Networking **187**
- 20 Managing a Virtualization Environment **196**
- 21 Block Devices in Xen **202**
- 22 Virtualization: Configuration Options and Settings **206**
- 23 Administrative Tasks **215**
- 24 XenStore: Configuration Database Shared between Domains **223**
- 25 Xen as a High-Availability Virtualization Host **228**

## 18 Setting Up a Virtual Machine Host

This section documents how to set up and use SUSE Linux Enterprise Server 12 SP5 as a virtual machine host.

Usually, the hardware requirements for the Dom0 are the same as those for the SUSE Linux Enterprise Server operating system. Additional CPU, disk, memory, and network resources should be added to accommodate the resource demands of all planned VM Guest systems.



### Tip: Resources

Remember that VM Guest systems, like physical machines, perform better when they run on faster processors and have access to more system memory.

The virtual machine host requires several software packages and their dependencies to be installed. To install all necessary packages, run *YaST Software Management*, select *View > Patterns* and choose *Xen Virtual Machine Host Server* for installation. The installation can also be performed with YaST using the module *Virtualization > Install Hypervisor and Tools*.

After the Xen software is installed, restart the computer and, on the boot screen, choose the newly added option with the Xen kernel.

Updates are available through your update channel. To be sure to have the latest updates installed, run *YaST Online Update* after the installation has finished.

### 18.1 Best Practices and Suggestions

When installing and configuring the SUSE Linux Enterprise Server operating system on the host, be aware of the following best practices and suggestions:

- If the host should always run as Xen host, run *YaST System > Boot Loader* and activate the Xen boot entry as default boot section.

- In YaST, click *System > Boot Loader*.
- Change the default boot to the *Xen* label, then click *Set as Default*.
- Click *Finish*.
- For best performance, only the applications and processes required for virtualization should be installed on the virtual machine host.
- When using both iSCSI and OCFS2 to host Xen images, the latency required for OCFS2 default timeouts in SUSE Linux Enterprise Server may not be met. To reconfigure this timeout, run `systemctl configure o2cb` or edit `O2CB_HEARTBEAT_THRESHOLD` in the system configuration.
- If you intend to use a watchdog device attached to the Xen host, use only one at a time. It is recommended to use a driver with actual hardware integration over a generic software one.



### Note: Hardware monitoring

The Dom0 kernel is running virtualized, so tools like `irqbalance` or `lscpu` do not reflect the real hardware characteristics.



### Important: Trusted boot not supported by Xen

Trusted boot (Tboot) is not supported by Xen. To ensure that the Xen host boots correctly, verify that the *Enable Trusted Boot Support* option is deactivated in the GRUB 2 configuration dialog.

## 18.2 Managing Dom0 memory

When the host is set up, a percentage of system memory is reserved for the hypervisor, and all remaining memory is automatically allocated to Dom0.

A better solution is to set a default amount of memory for Dom0, so the memory can be allocated appropriately to the hypervisor. An adequate amount would be 20 percent of the total system memory up to 4 GiB. A recommended minimum amount would be 512 MiB



## Warning: Minimum amount of Memory

The minimum amount of memory heavily depends on how many VM Guest(s) the host should handle. So be sure you have enough memory to support all your VM Guests. If the value is too low, the host system may hang when multiple VM Guests use most of the memory.

### 18.2.1 Setting a Maximum Amount of Memory

1. Determine the amount of memory to set for Dom0.
2. At Dom0, type `xl info` to view the amount of memory that is available on the machine. The memory that is currently allocated by Dom0 can be determined with the command `xl list`.
3. Run *YaST* > *Boot Loader*.
4. Select the Xen section.
5. In *Additional Xen Hypervisor Parameters*, add `dom0_mem=MEM_AMOUNT` where *MEM\_AMOUNT* is the maximum amount of memory to allocate to Dom0. Add K, M, or G, to specify the size, for example, `dom0_mem=768M`.
6. Restart the computer to apply the changes.



## Warning: Xen Dom0 Memory

When using the XL tool stack and the `dom0_mem=` option for the Xen hypervisor in GRUB 2 you need to disable `xl autoballoon` in `etc/xen/xl.conf`. Otherwise launching VMs will fail with errors about not being able to balloon down Dom0. So add `autoballoon=0` to `xl.conf` if you have the `dom0_mem=` option specified for Xen. Also see [Xen dom0 memory \(http://wiki.xen.org/wiki/Xen\\_Best\\_Practices#Xen\\_dom0\\_dedicated\\_memory\\_and\\_preventing\\_dom0\\_memory\\_balloonning\)](http://wiki.xen.org/wiki/Xen_Best_Practices#Xen_dom0_dedicated_memory_and_preventing_dom0_memory_balloonning) ↗

## 18.3 Network Card in Fully Virtualized Guests

In a fully virtualized guest, the default network card is an emulated Realtek network card. However, it is also possible to use the split network driver to run the communication between Dom0 and a VM Guest. By default, both interfaces are presented to the VM Guest, because the drivers of some operating systems require both to be present.

When using SUSE Linux Enterprise Server, only the paravirtualized network cards are available for the VM Guest by default. The following network options are available:

### emulated

To use an emulated network interface like an emulated Realtek card, specify `type=ioemu` in the `vif` device section of the domain `xl` configuration. An example configuration would look like:

```
vif = [ 'type=ioemu,mac=00:16:3e:5f:48:e4,bridge=br0' ]
```

Find more details about the `xl` configuration in the `xl.conf` man page [`man 5 xl.conf`](#).

### paravirtualized

When you specify `type=vif` and do not specify a model or type, the paravirtualized network interface is used:

```
vif = [ 'type=vif,mac=00:16:3e:5f:48:e4,bridge=br0,backen=0' ]
```

### emulated and paravirtualized

If the administrator should be offered both options, simply specify both type and model. The `xl` configuration would look like:

```
vif = [ 'type=ioemu,mac=00:16:3e:5f:48:e4,model=rtl8139,bridge=br0' ]
```

In this case, one of the network interfaces should be disabled on the VM Guest.

## 18.4 Starting the Virtual Machine Host

If virtualization software is correctly installed, the computer boots to display the GRUB 2 boot loader with a `Xen` option on the menu. Select this option to start the virtual machine host.



## Warning

When booting a Xen system, you might observe error messages in the `/var/log/messages` log file or `systemd` journal of dom0 similar to following:

```
isst_if_mbox_pci: probe of 0000:ff:1e.1 failed with error -5
isst_if_pci: probe of 0000:fe:00.1 failed with error -5
```

Ignore them as they are harmless and are caused by the fact that the ISST driver does not provide any power or frequency scaling feature for virtual machines.



## Note: Xen and Kdump

In Xen, the hypervisor manages the memory resource. If you need to reserve system memory for a recovery kernel in Dom0, this memory needs to be reserved by the hypervisor. Thus, it is necessary to add `crashkernel=size` to the `GRUB_CMDLINE_XEN_DEFAULT` variable in the `/etc/default/grub` file, save it and run the following command:

```
tux > sudo grub2-mkconfig -o /boot/grub2/grub.cfg
```

For more information on the `crashkernel` parameter, see Book “*System Analysis and Tuning Guide*”, Chapter 17 “*Kexec and Kdump*”, Section 17.4 “*Calculating crashkernel Allocation Size*”.

If the *Xen* option is not on the GRUB 2 menu, review the steps for installation and verify that the GRUB 2 boot loader has been updated. If the installation has been done without selecting the Xen pattern, run the *YaST Software Management*, select the filter *Patterns* and choose *Xen Virtual Machine Host Server* for installation.

After booting the hypervisor, the Dom0 virtual machine starts and displays its graphical desktop environment. If you did not install a graphical desktop, the command line environment appears.



## Tip: Graphics problems

Sometimes it may happen that the graphics system does not work properly. In this case, add `vga=ask` to the boot parameters. To activate permanent settings, use `vga=mode-0x???` where `???` is calculated as `0x100 + VESA mode` from [https://en.wikipedia.org/wiki/VESA\\_BIOS\\_Extensions](https://en.wikipedia.org/wiki/VESA_BIOS_Extensions), for example, `vga=mode-0x361`.



Before starting to install virtual guests, make sure that the system time is correct. To do this, configure NTP (Network Time Protocol) on the controlling domain:

1. In YaST select *Network Services > NTP Configuration*.
2. Select the option to automatically start the NTP daemon during boot. Provide the IP address of an existing NTP time server, then click *Finish*.



### Note: Time Services on Virtual Guests

Hardware clocks commonly are not very precise. All modern operating systems try to correct the system time compared to the hardware time by means of an additional time source. To get the correct time on all VM Guest systems, also activate the network time services on each respective guest or make sure that the guest uses the system time of the host. For more about Independent Wallclocks in SUSE Linux Enterprise Server see [Section 16.2, “Xen Virtual Machine Clock Settings”](#).

For more information about managing virtual machines, see [Chapter 20, Managing a Virtualization Environment](#).

## 18.5 PCI Pass-Through

To take full advantage of VM Guest systems, it is sometimes necessary to assign specific PCI devices to a dedicated domain. When using fully virtualized guests, this functionality is only available if the chipset of the system supports this feature, and if it is activated from the BIOS. This feature is available from both AMD\* and Intel\*. For AMD machines, the feature is called *IOMMU*; in Intel speak, this is *VT-d*. Note that Intel-VT technology is not sufficient to use this feature for fully virtualized guests. To make sure that your computer supports this feature, ask your supplier specifically to deliver a system that supports PCI Pass-Through.

### LIMITATIONS

- Certain graphics drivers use highly optimized ways to access DMA. This is not supported, and thus using graphics cards may be difficult.
- When accessing PCI devices behind a *PCIe* bridge, all the PCI devices must be assigned to a single guest. This limitation does not apply to *PCIe* devices.
- Guests with dedicated PCI devices cannot be migrated live to a different host.

The configuration of PCI Pass-Through is twofold. First, the hypervisor must be informed at boot time that a PCI device should be available for reassigning. Second, the PCI device must be assigned to the VM Guest.

## 18.5.1 Configuring the Hypervisor for PCI Pass-Through

1. Select a device to reassign to a VM Guest. To do this, run `lspci` and read the device number. For example, if `lspci` contains the following line:

```
06:01.0 Ethernet controller: Digital Equipment Corporation DECchip 21142/43 (rev 41)
```

In this case, the PCI number is `(06:01.0)`.

2. Specify a module dependency to ensure that `xen_pciback` is the first module to control the device. Add the file named `/etc/modprobe.d/50-e1000e.conf` with the following content:

```
install e1000e /sbin/modprobe xen_pciback ; /sbin/modprobe \  
--first-time --ignore-install e1000e
```

3. Instruct the `xen_pciback` module to control the device using the 'hide' option. Edit or create `/etc/modprobe.d/50-xen-pciback.conf` with the following content:

```
options xen_pciback hide=(06:01.0)
```

4. Reboot the system.
5. Check if the device is in the list of assignable devices with the command

```
xl pci-assignable-list
```

### 18.5.1.1 Dynamic Assignment with xl

To avoid restarting the host system, you can use dynamic assignment with `xl` to use PCI Pass-Through.

Begin by making sure that `dom0` has the `pciback` module loaded:

```
modprobe pciback
```

Then make a device assignable by using `xl pci-assignable-add`. For example, to make the device `06:01.0` available for guests, run the command:

```
xl pci-assignable-add 06:01.0
```

## 18.5.2 Assigning PCI Devices to VM Guest Systems

There are several possibilities to dedicate a PCI device to a VM Guest:

Adding the device while installing:

During installation, add the `pci` line to the configuration file:

```
pci=['06:01.0']
```

Hotplugging PCI devices to VM Guest systems

The command `xl` can be used to add or remove PCI devices on the fly. To add the device with number `06:01.0` to a guest with name `sles12` use:

```
xl pci-attach sles12 06:01.0
```

Adding the PCI device to Xend

To add the device to the guest permanently, add the following snippet to the guest configuration file:

```
pci = [ '06:01.0,power_mgmt=1,permissive=1' ]
```

After assigning the PCI device to the VM Guest, the guest system must care for the configuration and device drivers for this device.

## 18.5.3 VGA Pass-Through

Xen 4.0 and newer supports VGA graphics adapter pass-through on fully virtualized VM Guests. The guest can take full control of the graphics adapter with high-performance full 3D and video acceleration.

### LIMITATIONS

- VGA Pass-Through functionality is similar to PCI Pass-Through and as such also requires *IOMMU* (or Intel VT-d) support from the mainboard chipset and BIOS.

- Only the primary graphics adapter (the one that is used when you power on the computer) can be used with VGA Pass-Through.
- VGA Pass-Through is supported only for fully virtualized guests. Paravirtual guests (PV) are not supported.
- The graphics card cannot be shared between multiple VM Guests using VGA Pass-Through—you can dedicate it to one guest only.

To enable VGA Pass-Through, add the following settings to your fully virtualized guest configuration file:

```
gfx_passthru=1
pci=['yy:zz.n']
```

where `yy:zz.n` is the PCI controller ID of the VGA graphics adapter as found with `lspci -v` on Dom0.

## 18.5.4 Troubleshooting

In some circumstances, problems may occur during the installation of the VM Guest. This section describes some known problems and their solutions.

### During boot, the system hangs

The software I/O translation buffer allocates a large chunk of low memory early in the bootstrap process. If the requests for memory exceed the size of the buffer it usually results in a hung boot process. To check if this is the case, switch to console 10 and check the output there for a message similar to

```
kernel: PCI-DMA: Out of SW-IOMMU space for 32768 bytes at device 000:01:02.0
```

In this case, you need to increase the size of the `swiotlb`. Add `swiotlb=VALUE` (where `VALUE` is specified as the number of slab entries) on the command line of Dom0. The number can be adjusted up or down to find the optimal size for the machine.






### Note: swiotlb a PV guest

The `swiotlb=force` kernel parameter is required for DMA access to work for PCI devices on a PV guest. For more information about IOMMU and the `swiotlb` option see the file `boot-options.txt` from the package `kernel-source`.

## 18.5.5 For More Information

There are several resources on the Internet that provide interesting information about PCI Pass-Through:

- [https://wiki.xenproject.org/wiki/VTd\\_HowTo](https://wiki.xenproject.org/wiki/VTd_HowTo) 
- <http://software.intel.com/en-us/articles/intel-virtualization-technology-for-directed-io-vt-d-enhancing-intel-platforms-for-efficient-virtualization-of-io-devices/> 
- [http://support.amd.com/TechDocs/48882\\_IOMMU.pdf](http://support.amd.com/TechDocs/48882_IOMMU.pdf) 

## 18.6 USB Pass-Through

There are two methods for passing through individual host USB devices to a guest. The first is via an emulated USB device controller, the second is using PVUSB.

### 18.6.1 Identify the USB Device

Before you can pass through a USB device to the VM Guest, you need to identify it on the VM Host Server. Use the **lsusb** command to list the USB devices on the host system:

```
root # lsusb
Bus 001 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 002 Device 003: ID 0461:4d15 Primax Electronics, Ltd Dell Optical Mouse
Bus 002 Device 001: ID 1d6b:0001 Linux Foundation 1.1 root hub
```

To pass through the Dell mouse, for example, specify either the device tag in the form vendor\_id:device\_id (0461:4d15) or the bus address in the form bus.device (2.3). Remember to remove leading zeros, otherwise xl would interpret the numbers as octal values.

### 18.6.2 Emulated USB Device

In emulated USB, the device model (QEMU) presents an emulated USB controller to the guest. The USB device is then controlled from Dom0 while USB commands are translated between the VM Guest and the host USB device. This method is only available to fully virtualized domains (HVM).

Enable the emulated USB hub with the `usb=1` option. Then specify devices among the list of devices in the config file along with other emulated devices by using `host:USBID`. For example:

```
usb=1
usbdevice=['tablet','host:2.3','host:0424:460']
```

### 18.6.3 Paravirtualized PVUSB

PVUSB is a new high performance method for USB Pass-Through from dom0 to the virtualized guests. PVUSB supports both USB 2.0 and USB 1.1 devices. PVUSB uses paravirtualized front-end and back-end interfaces. With PVUSB, there are two ways to add USB devices to a guest:

- via the configuration file at domain creation time
- via hotplug while the VM is running

PVUSB uses a paravirtualized front- and back-end interface. PVUSB supports USB 1.1 and USB 2.0, and it works for both PV and HVM guests. To use PVUSB, you need `usbfront` in your guest OS, and `usbback` in dom0 or `usb` back-end in `qemu`. On SUSE Linux Enterprise Server, the USB back-end comes with `qemu`.

As of Xen 4.7, **xl** PVUSB support and hotplug support is introduced.

In the configuration file, specify USB controllers and USB host devices with `usbctrl` and `usbdev`. For example, in case of HVM guests:

```
usbctrl=['type=qusb,version=2,ports=4', 'type=qusb,version=1,ports=4', ]
usbdev=['hostbus=2, hostaddr=1, controller=0,port=1', ]
```



#### Note

It is important to specify `type=qusb` for the controller of HVM guests.

To manage hotplugging PVUSB devices, use the `usbctrl-attach`, `usbctrl-detach`, `usb-list`, `usbdev-attach` and `usb-detach` subcommands. For example:

Create a USB controller which is version USB 1.1 and has 8 ports:

```
root # xl usbctrl-attach test_vm version=1 ports=8 type=qusb
```

Find the first available controller:port in the domain, and attach USB device whose busnum:devnum is 2:3 to it; you can also specify controller and port:

```
root # xl usbdev-attach test_vm hostbus=2 hostaddr=3
```

Show all USB controllers and USB devices in the domain:

```
root # xl usb-list test_vm
Devid  Type   BE  state usb-ver ports
0      qusb   0   1     1      8
  Port 1: Bus 002 Device 003
  Port 2:
  Port 3:
  Port 4:
  Port 5:
  Port 6:
  Port 7:
  Port 8:
```

Detach the USB device under controller 0 port 1:

```
root # xl usbdev-detach test_vm 0 1
```

Remove the USB controller with the indicated dev\_id, and all USB devices under it:

```
root # xl usbctrl-detach test_vm dev_id
```

For more information, see [https://wiki.xenproject.org/wiki/Xen\\_USB\\_Passthrough](https://wiki.xenproject.org/wiki/Xen_USB_Passthrough) .

## 19 Virtual Networking

A VM Guest system needs some means to communicate either with other VM Guest systems or with a local network. The network interface to the VM Guest system is made of a split device driver, which means that any virtual Ethernet device has a corresponding network interface in Dom0. This interface is set up to access a virtual network that is run in Dom0. The bridged virtual network is fully integrated into the system configuration of SUSE Linux Enterprise Server and can be configured with YaST.

When installing a Xen VM Host Server, a bridged network configuration will be proposed during normal network configuration. The user can choose to change the configuration during the installation and customize it to the local needs.

If desired, Xen VM Host Server can be installed after performing a default Physical Server installation using the `Install Hypervisor and Tools` module in YaST. This module will prepare the system for hosting virtual machines, including invocation of the default bridge networking proposal.

In case the necessary packages for a Xen VM Host Server are installed manually with `rpm` or `zypper`, the remaining system configuration needs to be done by the administrator manually or with YaST.

The network scripts that are provided by Xen are not used by default in SUSE Linux Enterprise Server. They are only delivered for reference but disabled. The network configuration that is used in SUSE Linux Enterprise Server is done by means of the YaST system configuration similar to the configuration of network interfaces in SUSE Linux Enterprise Server.

For more general information about managing network bridges, see [Section 13.1, “Network Bridge”](#).

### 19.1 Network Devices for Guest Systems

The Xen hypervisor can provide different types of network interfaces to the VM Guest systems. The preferred network device should be a paravirtualized network interface. This yields the highest transfer rates with the lowest system requirements. Up to eight network interfaces may be provided for each VM Guest.



Systems that are not aware of paravirtualized hardware may not have this option. To connect systems to a network that can only run fully virtualized, several emulated network interfaces are available. The following emulations are at your disposal:

- Realtek 8139 (PCI). This is the default emulated network card.
- AMD PCnet32 (PCI)
- NE2000 (PCI)
- NE2000 (ISA)
- Intel e100 (PCI)
- Intel e1000 and its variants e1000-82540em, e1000-82544gc, e1000-82545em (PCI)

All these network interfaces are software interfaces. Because every network interface must have a unique MAC address, an address range has been assigned to XenSource that can be used by these interfaces.



### Tip: Virtual Network Interfaces and MAC Addresses

The default configuration of MAC addresses in virtualized environments creates a random MAC address that looks like 00:16:3E:xx:xx:xx. Normally, the amount of available MAC addresses should be big enough to get only unique addresses. However, if you have a very big installation, or to make sure that no problems arise from random MAC address assignment, you can also manually assign these addresses.

For debugging or system management purposes, it may be useful to know which virtual interface in Dom0 is connected to which Ethernet device in a running guest. This information may be read from the device naming in Dom0. All virtual devices follow the rule vif<domain number>.<interface\_number>.

For example, if you want to know the device name for the third interface (eth2) of the VM Guest with id 5, the device in Dom0 would be vif5.2. To obtain a list of all available interfaces, run the command **ip a**.

The device naming does not contain any information about which bridge this interface is connected to. However, this information is available in Dom0. To get an overview about which interface is connected to which bridge, run the command `brctl show`. The output may look like the following:

```
# brctl show
```

bridge name	bridge id	STP enabled	interfaces
br0	8000.001cc0309083	no	eth0 vif2.1
br1	8000.000476f060cc	no	eth1 vif2.0
br2	8000.000000000000	no	

In this example, there are three configured bridges: `br0`, `br1` and `br2`. Currently, `br0` and `br1` each have a real Ethernet device added: `eth0` and `eth1`, respectively. There is one VM Guest running with the ID 2 that has two Ethernet devices available. `eth0` on the VM Guest is bridged with `eth1` on the VM Host Server and `eth1` on the VM Guest is connected to `eth0` on the VM Host Server. The third bridge with the name `br2` is not connected to any VM Guest nor any real Ethernet device.

## 19.2 Host-Based Routing in Xen

Xen can be set up to use host-based routing in the controlling Dom0. Unfortunately, this is not yet well supported from YaST and requires quite an amount of manual editing of configuration files. Thus, this is a task that requires an advanced administrator.

The following configuration will only work when using fixed IP addresses. Using DHCP is not practicable with this procedure, because the IP address must be known to both, the VM Guest and the VM Host Server system.

The easiest way to create a routed guest is to change the networking from a bridged to a routed network. As a requirement to the following procedures, a VM Guest with a bridged network setup must be installed. For example, the VM Host Server is named `earth` with the IP `192.168.1.20`, and the VM Guest has the name `alice` with the IP `192.168.1.21`.

### PROCEDURE 19.1: CONFIGURING A ROUTED IPV4 VM GUEST

1. Make sure that `alice` is shut down. Use `xl` commands to shut down and check.

2. Prepare the network configuration on the VM Host Server earth:

- a. Create a hotplug interface that will be used to route the traffic. To accomplish this, create a file named `/etc/sysconfig/network/ifcfg-alice.0` with the following content:

```
NAME="Xen guest alice"
BOOTPROTO="static"
STARTMODE="hotplug"
```

- b. Edit the file `/etc/sysconfig/SuSEfirewall2` and add the following configurations:

- Add `alice.0` to the devices in `FW_DEV_EXT`:

```
FW_DEV_EXT="br0 alice.0"
```

- Switch on the routing in the firewall:

```
FW_ROUTE="yes"
```

- Tell the firewall which address should be forwarded:

```
FW_FORWARD="192.168.1.21/32,0/0"
```

- Finally, restart the firewall with the command:

```
sudo systemctl restart SuSEfirewall2
```

- c. Add a static route to the interface of `alice`. To accomplish this, add the following line to the end of `/etc/sysconfig/network/routes`:

```
192.168.1.21 - - alice.0
```

- d. To make sure that the switches and routers that the VM Host Server is connected to know about the routed interface, activate `proxy_arp` on `earth`. Add the following lines to `/etc/sysctl.conf`:

```
net.ipv4.conf.default.proxy_arp = 1
net.ipv4.conf.all.proxy_arp = 1
```

- e. Activate all changes with the commands:

```
sudo systemctl restart systemd-sysctl wicked
```

3. Proceed with configuring the Xen configuration of the VM Guest by changing the vif interface configuration for `alice` as described in [Section 20.1, “XL—Xen Management Tool”](#). Make the following changes to the text file you generate during the process:

- a. Remove the snippet

```
bridge=br0
```

- b. And add the following one:

```
vifname=vifalice.0
```

or

```
vifname=vifalice.0=emu
```

for a fully virtualized domain.

- c. Change the script that is used to set up the interface to the following:

```
script=/etc/xen/scripts/vif-route-ifup
```

- d. Activate the new configuration and start the VM Guest.

4. The remaining configuration tasks must be accomplished from inside the VM Guest.

- a. Open a console to the VM Guest with `xl console DOMAIN` and log in.
- b. Check that the guest IP is set to `192.168.1.21`.
- c. Provide VM Guest with a host route and a default gateway to the VM Host Server. Do this by adding the following lines to `/etc/sysconfig/network/routes`:

```
192.168.1.20 - - eth0
default 192.168.1.20 - -
```

5. Finally, test the network connection from the VM Guest to the world outside and from the network to your VM Guest.

## 19.3 Creating a Masqueraded Network Setup

Creating a masqueraded network setup is quite similar to the routed setup. However, there is no `proxy_arp` needed, and some firewall rules are different. To create a masqueraded network to a guest dolly with the IP address 192.168.100.1 where the host has its external interface on `br0`, proceed as follows. For easier configuration, only the already installed guest is modified to use a masqueraded network:

### PROCEDURE 19.2: CONFIGURING A MASQUERADED IPV4 VM GUEST

1. Shut down the VM Guest system with `xl shutdown DOMAIN`.
2. Prepare the network configuration on the VM Host Server:
  - a. Create a hotplug interface that will be used to route the traffic. To accomplish this, create a file named `/etc/sysconfig/network/ifcfg-dolly.0` with the following content:

```
NAME="Xen guest dolly"
BOOTPROTO="static"
STARTMODE="hotplug"
```

- b. Edit the file `/etc/sysconfig/SuSEfirewall2` and add the following configurations:

- Add dolly.0 to the devices in FW\_DEV\_DMZ:

```
FW_DEV_DMZ="dolly.0"
```

- Switch on the routing in the firewall:

```
FW_ROUTE="yes"
```

- Switch on masquerading in the firewall:

```
FW_MASQUERADE="yes"
```

- Tell the firewall which network should be masqueraded:

```
FW_MASQ_NETS="192.168.100.1/32"
```

- Remove the networks from the masquerading exceptions:

```
FW_NOMASQ_NETS=""
```

- Finally, restart the firewall with the command:

```
sudo systemctl restart SuSEfirewall2
```

- c. Add a static route to the interface of dolly. To accomplish this, add the following line to the end of `/etc/sysconfig/network/routes`:

```
192.168.100.1 - - dolly.0
```

- d. Activate all changes with the command:

```
sudo systemctl restart wicked
```

### 3. Proceed with configuring the Xen configuration of the VM Guest.

- a. Change the vif interface configuration for dolly as described in [Section 20.1, "XL—Xen Management Tool"](#).

- b. Remove the entry:

```
bridge=br0
```

- c. And add the following one:

```
vifname=vifdolly.0
```

- d. Change the script that is used to set up the interface to the following:

```
script=/etc/xen/scripts/vif-route-ifup
```

- e. Activate the new configuration and start the VM Guest.

### 4. The remaining configuration tasks need to be accomplished from inside the VM Guest.

- a. Open a console to the VM Guest with `xl console DOMAIN` and log in.

- b. Check whether the guest IP is set to 192.168.100.1.

- c. Provide VM Guest with a host route and a default gateway to the VM Host Server. Do this by adding the following lines to `/etc/sysconfig/network/routes`:

```
192.168.1.20 - - eth0
default 192.168.1.20 - -
```

5. Finally, test the network connection from the VM Guest to the outside world.

## 19.4 Special Configurations

There are many network configuration possibilities available to Xen. The following configurations are not activated by default:

### 19.4.1 Bandwidth Throttling in Virtual Networks

With Xen, you may limit the network transfer rate a virtual guest may use to access a bridge. To configure this, you need to modify the VM Guest configuration as described in [Section 20.1, “XL—Xen Management Tool”](#).

In the configuration file, first search for the device that is connected to the virtual bridge. The configuration looks like the following:

```
vif = [ 'mac=00:16:3e:4f:94:a9,bridge=br0' ]
```

To add a maximum transfer rate, add a parameter `rate` to this configuration as in:

```
vif = [ 'mac=00:16:3e:4f:94:a9,bridge=br0,rate=100Mb/s' ]
```

Note that the rate is either `Mb/s` (megabits per second) or `MB/s` (megabytes per second). In the above example, the maximum transfer rate of the virtual interface is 100 megabits. By default, there is no limitation to the bandwidth of a guest to the virtual bridge.

It is even possible to fine-tune the behavior by specifying the time window that is used to define the granularity of the credit replenishment:

```
vif = [ 'mac=00:16:3e:4f:94:a9,bridge=br0,rate=100Mb/s@20ms' ]
```

## 19.4.2 Monitoring the Network Traffic

To monitor the traffic on a specific interface, the little application `iftop` is a nice program that displays the current network traffic in a terminal.

When running a Xen VM Host Server, you need to define the interface that is monitored. The interface that Dom0 uses to get access to the physical network is the bridge device, for example `br0`. This, however, may vary on your system. To monitor all traffic to the physical interface, run a terminal as `root` and use the command:

```
iftop -i br0
```

To monitor the network traffic of a special network interface of a specific VM Guest, supply the correct virtual interface. For example, to monitor the first Ethernet device of the domain with id 5, use the command:

```
ftop -i vif5.0
```

To quit `iftop`, press the key `Q`. More options and possibilities are available in the manual page `man 8 iftop`.



## 20 Managing a Virtualization Environment

Apart from using the recommended `libvirt` library (*Part II, “Managing Virtual Machines with libvirt”*), you can manage Xen guest domains with the `xl` tool from the command line.

### 20.1 XL—Xen Management Tool

The `xl` program is a tool for managing Xen guest domains. It is part of the `xen-tools` package. `xl` is based on the LibXenlight library, and can be used for general domain management, such as domain creation, listing, pausing, or shutting down. Usually you need to be `root` to execute `xl` commands.



#### Note

`xl` can only manage running guest domains specified by their configuration file. If a guest domain is not running, you cannot manage it with `xl`.



#### Tip

To allow users to continue to have managed guest domains in the way the obsolete `xm` command allowed, we now recommend using `libvirt`'s `virsh` and `virt-manager` tools. For more information, see *Part II, “Managing Virtual Machines with libvirt”*.

`xl` operations rely upon `xenstored` and `xenconsoled` services. Make sure you start

```
systemctl start xencore
```

at boot time to initialize all the daemons required by `xl`.



#### Tip: Set up a xenbr0 Network Bridge in the Host Domain

In the most common network configuration, you need to set up a bridge in the host domain named `xenbr0` to have a working network for the guest domains.

The basic structure of every `xl` command is:

```
xl <subcommand> [options] domain_id
```

where `<subcommand>` is the `xl` command to run, `domain_id` is the ID number assigned to a domain or the name of the virtual machine, and **`OPTIONS`** indicates subcommand-specific options.

For a complete list of the available `xl` subcommands, run `xl help`. For each command, there is a more detailed help available that is obtained with the extra parameter `--help`. More information about the respective subcommands is available in the manual page of `xl`.

For example, the `xl list --help` displays all options that are available to the list command. As an example, the `xl list` command displays the status of all virtual machines.

```
# xl list
```

Name	ID	Mem	VCPUs	State	Time(s)
Domain-0	0	457	2	r-----	2712.9
sles12	7	512	1	-b-----	16.3
opensuse		512	1		12.9

The *State* information indicates if a machine is running, and in which state it is. The most common flags are `r` (running) and `b` (blocked) where blocked means it is either waiting for IO, or sleeping because there is nothing to do. For more details about the state flags, see `man 1 xl`.

Other useful `xl` commands include:

- `xl create` creates a virtual machine from a given configuration file.
- `xl reboot` reboots a virtual machine.
- `xl destroy` immediately terminates a virtual machine.
- `xl block-list` displays all virtual block devices attached to a virtual machine.

### 20.1.1 Guest Domain Configuration File

When operating domains, `xl` requires a domain configuration file for each domain. The default directory to store such configuration files is `/etc/xen/`.

A domain configuration file is a plain text file. It consists of several `KEY = VALUE` pairs. Some keys are mandatory, some are general and apply to any guest, and some apply only to a specific guest type (para or fully virtualized). A value can either be a `"string"` surrounded by single or double quotes, a number, a boolean value, or a list of several values enclosed in brackets `[ value1, value2, ... ]`.

EXAMPLE 20.1: GUEST DOMAIN CONFIGURATION FILE: `/etc/xen/sled12.cfg`

```
name= "sled12"
```

```
builder = "hvm"
vncviewer = 1
memory = 512
disk = [ '/var/lib/xen/images/sled12.raw,,hda', '/dev/cdrom,,hdc,cdrom' ]
vif = [ 'mac=00:16:3e:5f:48:e4,model=rtl8139,bridge=br0' ]
boot = "n"
```

To start such domain, run `xl create /etc/xen/sled12.cfg`.

## 20.2 Automatic Start of Guest Domains

To make a guest domain start automatically after the host system boots, follow these steps:

1. Create the domain configuration file if it does not exist, and save it in the `/etc/xen/` directory, for example `/etc/xen/domain_name.cfg`.
2. Make a symbolic link of the guest domain configuration file in the `auto/` subdirectory.

```
ln -s /etc/xen/domain_name.cfg /etc/xen/auto/domain_name.cfg
```

3. On the next system boot, the guest domain defined in `domain_name.cfg` will be started.

## 20.3 Event Actions

In the guest domain configuration file, you can define actions to be performed on a predefined set of events. For example, to tell the domain to restart itself after it is powered off, include the following line in its configuration file:

```
on_poweroff="restart"
```

A list of predefined events for a guest domain follows:

### LIST OF EVENTS

#### `on_poweroff`

Specifies what should be done with the domain if it shuts itself down.

#### `on_reboot`

Action to take if the domain shuts down with a reason code requesting a reboot.

### **on\_watchdog**

Action to take if the domain shuts down because of a Xen watchdog timeout.

### **on\_crash**

Action to take if the domain crashes.

For these events, you can define one of the following actions:

#### **LIST OF RELATED ACTIONS**

### **destroy**

Destroy the domain.

### **restart**

Destroy the domain and immediately create a new domain with the same configuration.

### **rename-restart**

Rename the domain that terminated, and then immediately create a new domain with the same configuration as the original.

### **preserve**

Keep the domain. It can be examined, and later destroyed with **xl destroy**.

### **coredump-destroy**

Write a core dump of the domain to /var/xen/dump/NAME and then destroy the domain.

### **coredump-restart**

Write a core dump of the domain to /var/xen/dump/NAME and then restart the domain.

## **20.4 Time Stamp Counter**

The Time Stamp Counter (TSC) may be specified for each domain in the guest domain configuration file (for more information, see [Section 20.1.1, “Guest Domain Configuration File”](#)).

With the tsc\_mode setting, you specify whether rdtsc instructions are executed “natively” (fast, but TSC-sensitive applications may sometimes run incorrectly) or emulated (always run correctly, but performance may suffer).

### **tsc\_mode=0 (default)**

Use this to ensure correctness while providing the best performance possible—for more information, see <https://xenbits.xen.org/docs/4.3-testing/misc/tscmode.txt> [↗](#).

### tsc\_mode=1 (always emulate)

Use this when TSC-sensitive apps are running and worst-case performance degradation is known and acceptable.

### tsc\_mode=2 (never emulate)

Use this when all applications running in this VM are TSC-resilient and highest performance is required.

### tsc\_mode=3 (PVRDTSCP)

High-TSC-frequency applications may be paravirtualized (modified) to obtain both correctness and highest performance—any unmodified applications must be TSC-resilient.

For background information, see <https://xenbits.xen.org/docs/4.3-testing/misc/tscmode.txt> [↗](#).

## 20.5 Saving Virtual Machines

### PROCEDURE 20.1: SAVE A VIRTUAL MACHINE'S CURRENT STATE

1. Make sure the virtual machine to be saved is running.
2. In the host environment, enter

```
xl save ID STATE-FILE
```

where *ID* is the virtual machine ID you want to save, and *STATE-FILE* is the name you specify for the memory state file. By default, the domain will no longer be running after you create its snapshot. Use -c to keep it running even after you create the snapshot.

## 20.6 Restoring Virtual Machines

### PROCEDURE 20.2: RESTORE A VIRTUAL MACHINE'S CURRENT STATE

1. Make sure the virtual machine to be restored has not been started since you ran the save operation.
2. In the host environment, enter

```
xl restore STATE-FILE
```

where STATE-FILE is the previously saved memory state file. By default, the domain will be running after it is restored. To pause it after the restore, use -p.

## 20.7 Virtual Machine States

A virtual machine's state can be displayed by viewing the results of the xl list command, which abbreviates the state using a single character.

- r - running - The virtual machine is currently running and consuming allocated resources.
- b - blocked - The virtual machine's processor is not running and not able to run. It is either waiting for I/O or has stopped working.
- p - paused - The virtual machine is paused. It does not interact with the hypervisor but still maintains its allocated resources, such as memory.
- s - shutdown - The guest operating system is in the process of being shut down, rebooted, or suspended, and the virtual machine is being stopped.
- c - crashed - The virtual machine has crashed and is not running.
- d - dying - The virtual machine is in the process of shutting down or crashing.

## 21 Block Devices in Xen

### 21.1 Mapping Physical Storage to Virtual Disks

The disk(s) specification for a Xen domain in the domain configuration file is as straightforward as the following example:

```
disk = [ 'format=raw,vdev=hdc,access=ro,devtype=cdrom,target=/root/image.iso' ]
```

It defines a disk block device based on the `/root/image.iso` disk image file. The disk will be seen as `hdc` by the guest, with read-only (`ro`) access. The type of the device is `cdrom` with `raw` format.

The following example defines an identical device, but using simplified positional syntax:

```
disk = [ '/root/image.iso,raw,hdc,ro,cdrom' ]
```

You can include more disk definitions in the same line, each one separated by a comma. If a parameter is not specified, then its default value is taken:

```
disk = [ '/root/image.iso,raw,hdc,ro,cdrom', '/dev/vg/guest-volume,,hda','...' ]
```

#### LIST OF PARAMETERS

##### target

Source block device or disk image file path.

##### format

The format of the image file. Default is `raw`.

##### vdev

Virtual device as seen by the guest. Supported values are `hd[x]`, `xvd[x]`, `sd[x]` etc. See </usr/share/doc/packages/xen/misc/vbd-interface.txt> for more details. This parameter is mandatory.

##### access

Whether the block device is provided to the guest in read-only or read-write mode. Supported values are `ro` or `r` for read-only, and `rw` or `w` for read/write access. Default is `ro` for `devtype=cdrom`, and `rw` for other device types.

##### devtype

Qualifies virtual device type. Supported value is `cdrom`.

### backendtype

The back-end implementation to use. Supported values are `phy`, `tap`, and `qdisk`. Normally this option should not be specified as the back-end type is automatically determined.

### script

Specifies that `target` is not a normal host path, but rather information to be interpreted by the executable program. The specified script file is looked for in `/etc/xen/scripts` if it does not point to an absolute path. These scripts are normally called `block-<script_name>`.

For more information about specifying virtual disks, see </usr/share/doc/packages/xen/misc/xl-disk-configuration.txt>.

## 21.2 Mapping Network Storage to Virtual Disk

Similar to mapping a local disk image (see [Section 21.1, “Mapping Physical Storage to Virtual Disks”](#)), you can map a network disk as a virtual disk as well.

The following example shows mapping of an RBD (RADOS Block Device) disk with multiple Ceph monitors and cephx authentication enabled:

```
disk = [ 'vdev=hdc, backendtype=qdisk, \
target=rbd:libvirt-pool/new-libvirt-image:\
id=libvirt:key=AQDsPwtW8JoXJBAAyLPQe7MhCC+JPkI3QuhaAw==:auth_supported=cephx;none:\
mon_host=137.65.135.205\\:6789;137.65.135.206\\:6789;137.65.135.207\\:6789' ]
```

Following is an example of an NBD (Network Block Device) disk mapping:

```
disk = [ 'vdev=hdc, backendtype=qdisk, target=nbd:151.155.144.82:5555' ]
```

## 21.3 File-Backed Virtual Disks and Loopback Devices

When a virtual machine is running, each of its file-backed virtual disks consumes a loopback device on the host. By default, the host allows up to 64 loopback devices to be consumed.

To simultaneously run more file-backed virtual disks on a host, you can increase the number of available loopback devices by adding the following option to the host's `/etc/modprobe.conf.local` file.



```
options loop max_loop=x
```

where x is the maximum number of loopback devices to create.

Changes take effect after the module is reloaded.



### Tip

Enter `rmmod loop` and `modprobe loop` to unload and reload the module. In case `rmmod` does not work, unmount all existing loop devices or reboot the computer.

## 21.4 Resizing Block Devices

While it is always possible to add new block devices to a VM Guest system, it is sometimes more desirable to increase the size of an existing block device. In case such a system modification is already planned during deployment of the VM Guest, some basic considerations should be done:

- Use a block device that may be increased in size. LVM devices and file system images are commonly used.
- Do not partition the device inside the VM Guest, but use the main device directly to apply the file system. For example, use `/dev/xvdb` directly instead of adding partitions to `/dev/xvdb`.
- Make sure that the file system to be used can be resized. Sometimes, for example with Ext3, some features must be switched off to be able to resize the file system. A file system that can be resized online and mounted is `XFS`. Use the command `xfs_growfs` to resize that file system after the underlying block device has been increased in size. For more information about `XFS`, see `man 8 xfs_growfs`.

When resizing an LVM device that is assigned to a VM Guest, the new size is automatically known to the VM Guest. No further action is needed to inform the VM Guest about the new size of the block device.

When using file system images, a loop device is used to attach the image file to the guest. For more information about resizing that image and refreshing the size information for the VM Guest, see [Section 23.2, “Sparse Image Files and Disk Space”](#).

## 21.5 Scripts for Managing Advanced Storage Scenarios

There are scripts that can help with managing advanced storage scenarios such as disk environments provided by dmmd (“device mapper—multi disk”) including LVM environments built upon a software RAID set, or a software RAID set built upon an LVM environment. These scripts are part of the xen-tools package. After installation, they can be found in /etc/xen/scripts:

- block-dmmd
- block-drbd-probe
- block-npiv

The scripts allow for external commands to perform some action, or series of actions of the block devices prior to serving them up to a guest.

These scripts could formerly only be used with xl or libxl using the disk configuration syntax script=. They can now be used with libvirt by specifying the base name of the block script in the <source> element of the disk. For example:

```
<source dev='dmmd:md;/dev/md0;lvm;/dev/vgxen/lv-vm01' />
```

## 22 Virtualization: Configuration Options and Settings

The documentation in this section, describes advanced management tasks and configuration options that might help technology innovators implement leading-edge virtualization solutions. It is provided as a courtesy and does not imply that all documented options and tasks are supported by Novell, Inc.

### 22.1 Virtual CD Readers

Virtual CD readers can be set up when a virtual machine is created or added to an existing virtual machine. A virtual CD reader can be based on a physical CD/DVD, or based on an ISO image. Virtual CD readers work differently depending on whether they are paravirtual or fully virtual.

#### 22.1.1 Virtual CD Readers on Paravirtual Machines

A paravirtual machine can have up to 100 block devices composed of virtual CD readers and virtual disks. On paravirtual machines, virtual CD readers present the CD as a virtual disk with read-only access. Virtual CD readers cannot be used to write data to a CD.

After you have finished accessing a CD on a paravirtual machine, it is recommended that you remove the virtual CD reader from the virtual machine.

Paravirtualized guests can use the device type `devtype=cdrom`. This partly emulates the behavior of a real CD reader, and allows CDs to be changed. It is even possible to use the eject command to open the tray of the CD reader.

#### 22.1.2 Virtual CD Readers on Fully Virtual Machines

A fully virtual machine can have up to four block devices composed of virtual CD readers and virtual disks. A virtual CD reader on a fully virtual machine interacts with an inserted CD in the way you would expect a physical CD reader to interact.

When a CD is inserted in the physical CD reader on the host computer, all virtual machines with virtual CD readers based on the physical CD reader, such as `/dev/cdrom/`, can read the inserted CD. Assuming the operating system has automount functionality, the CD should automatically appear in the file system. Virtual CD readers cannot be used to write data to a CD. They are configured as read-only devices.

## 22.1.3 Adding Virtual CD Readers

Virtual CD readers can be based on a CD inserted into the CD reader or on an ISO image file.

1. Make sure that the virtual machine is running and the operating system has finished booting.
2. Insert the desired CD into the physical CD reader or copy the desired ISO image to a location available to Dom0.
3. Select a new, unused block device in your VM Guest, such as `/dev/xvdb`.
4. Choose the CD reader or ISO image that you want to assign to the guest.
5. When using a real CD reader, use the following command to assign the CD reader to your VM Guest. In this example, the name of the guest is `alice`:

```
xl block-attach alice target=/dev/sr0,vdev=xvdb,access=ro
```

6. When assigning an image file, use the following command:

```
xl block-attach alice target=/path/to/file.iso,vdev=xvdb,access=ro
```

7. A new block device, such as `/dev/xvdb`, is added to the virtual machine.
8. If the virtual machine is running Linux, complete the following:

- a. Open a terminal in the virtual machine and enter `fdisk -l` to verify that the device was properly added. You can also enter `ls /sys/block` to see all disks available to the virtual machine.

The CD is recognized by the virtual machine as a virtual disk with a drive designation, for example:

```
/dev/xvdb
```

- b. Enter the command to mount the CD or ISO image using its drive designation. For example,

```
mount -o ro /dev/xvdb /mnt
```

mounts the CD to a mount point named `/mnt`.

The CD or ISO image file should be available to the virtual machine at the specified mount point.

9. If the virtual machine is running Windows, reboot the virtual machine.  
Verify that the virtual CD reader appears in its My Computer section.

### 22.1.4 Removing Virtual CD Readers

1. Make sure that the virtual machine is running and the operating system has finished booting.
2. If the virtual CD reader is mounted, unmount it from within the virtual machine.
3. Enter `xl block-list alice` on the host view of the guest block devices.
4. Enter `xl block-detach alice BLOCK_DEV_ID` to remove the virtual device from the guest. If that fails, try to add `-f` to force the removal.
5. Press the hardware eject button to eject the CD.

## 22.2 Remote Access Methods

Some configurations, such as those that include rack-mounted servers, require a computer to run without a video monitor, keyboard, or mouse. This type of configuration is often called headless and requires the use of remote administration technologies.

Typical configuration scenarios and technologies include:

### Graphical Desktop with X Window Server

If a graphical desktop, such as GNOME, is installed on the virtual machine host, you can use a remote viewer, such as a VNC viewer. On a remote computer, log in and manage the remote guest environment by using graphical tools, such as tigervnc or virt-viewer.

### Text Only

You can use the ssh command from a remote computer to log in to a virtual machine host and access its text-based console. You can then use the xl command to manage virtual machines, and the virt-install command to create new virtual machines.

## 22.3 VNC Viewer

VNC viewer is used to view the environment of the running guest system in a graphical way. You can use it from Dom0 (known as local access or on-box access), or from a remote computer.

You can use the IP address of a VM Host Server and a VNC viewer to view the display of this VM Guest. When a virtual machine is running, the VNC server on the host assigns the virtual machine a port number to be used for VNC viewer connections. The assigned port number is the lowest port number available when the virtual machine starts. The number is only available for the virtual machine while it is running. After shutting down, the port number might be assigned to other virtual machines.

For example, if ports 1 and 2 and 4 and 5 are assigned to the running virtual machines, the VNC viewer assigns the lowest available port number, 3. If port number 3 is still in use the next time the virtual machine starts, the VNC server assigns a different port number to the virtual machine.

To use the VNC viewer from a remote computer, the firewall must permit access to as many ports as VM Guest systems run from. This means from port 5900 and up. For example, to run 10 VM Guest systems, you need to open the TCP ports 5900:5910.

To access the virtual machine from the local console running a VNC viewer client, enter one of the following commands:

- `vncviewer ::590#`
- `vncviewer :#`

`#` is the VNC viewer port number assigned to the virtual machine.

When accessing the VM Guest from a machine other than Dom0, use the following syntax:

```
vncviewer 192.168.1.20::590#
```

In this case, the IP address of Dom0 is 192.168.1.20.

### 22.3.1 Assigning VNC Viewer Port Numbers to Virtual Machines

Although the default behavior of VNC viewer is to assign the first available port number, you should assign a specific VNC viewer port number to a specific virtual machine.

To assign a specific port number on a VM Guest, edit the `xl` setting of the virtual machine and change the `vnclisten` to the desired value. Note that for example for port number 5902, specify 2 only, as 5900 is added automatically:

```
vfb = [ 'vnc=1,vnclisten="localhost:2"' ]
```

For more information regarding editing the `xl` settings of a guest domain, see [Section 20.1, “XL —Xen Management Tool”](#).



## Tip

Assign higher port numbers to avoid conflict with port numbers assigned by the VNC viewer, which uses the lowest available port number.

### 22.3.2 Using SDL instead of a VNC Viewer

If you access a virtual machine's display from the virtual machine host console (known as local or on-box access), you should use SDL instead of VNC viewer. VNC viewer is faster for viewing desktops over a network, but SDL is faster for viewing desktops from the same computer.

To set the default to use SDL instead of VNC, change the virtual machine's configuration information to the following. For instructions, see [Section 20.1, “XL—Xen Management Tool”](#).

```
vfb = [ 'sdl=1' ]
```

Remember that, unlike a VNC viewer window, closing an SDL window terminates the virtual machine.

## 22.4 Virtual Keyboards

When a virtual machine is started, the host creates a virtual keyboard that matches the **keymap** entry according to the virtual machine's settings. If there is no **keymap** entry specified, the virtual machine's keyboard defaults to English (US).

To view a virtual machine's current **keymap** entry, enter the following command on the Dom0:

```
xl list -l VM_NAME | grep keymap
```

To configure a virtual keyboard for a guest, use the following snippet:

```
vfb = [ 'keymap="de"' ]
```

For a complete list of supported keyboard layouts, see the **Keymaps** section of the **xl.cfg** manual page **man 5 xl.cfg**.

## 22.5 Dedicating CPU Resources

In Xen it is possible to specify how many and which CPU cores the Dom0 or VM Guest should use to retain its performance. The performance of Dom0 is important for the overall system, as the disk and network drivers are running on it. Also I/O intensive guests' workloads may consume lots of Dom0s' CPU cycles. On the other hand, the performance of VM Guests is also important, to be able to accomplish the task they were set up for.

### 22.5.1 Dom0

Dedicating CPU resources to Dom0 results in a better overall performance of the virtualized environment because Dom0 has free CPU time to process I/O requests from VM Guests. Failing to dedicate exclusive CPU resources to Dom0 usually results in a poor performance and can cause the VM Guests to function incorrectly.

Dedicating CPU resources involves three basic steps: modifying Xen boot line, binding Dom0's VCPUs to a physical processor, and configuring CPU-related options on VM Guests:

1. First you need to append the `dom0_max_vcpus=X` to the Xen boot line. Do so by adding the following line to `/etc/default/grub`:

```
GRUB_CMDLINE_XEN="dom0_max_vcpus=X"
```

If `/etc/default/grub` already contains a line setting `GRUB_CMDLINE_XEN`, rather append `dom0_max_vcpus=X` to this line.

`X` needs to be replaced by the number of VCPUs dedicated to Dom0.

2. Update the GRUB 2 configuration file by running the following command:

```
grub2-mkconfig -o /boot/grub2/grub.cfg
```

3. Reboot for the change to take effect.

4. The next step is to bind (or “pin”) each Dom0's VCPU to a physical processor.

```
xl vcpu-pin Domain-0 0 0
xl vcpu-pin Domain-0 1 1
```

The first line binds Dom0's VCPU number 0 to the physical processor number 0, while the second line binds Dom0's VCPU number 1 to the physical processor number 1.



5. Lastly, you need to make sure no VM Guest uses the physical processors dedicated to VCPUs of Dom0. Assuming you are running an 8-CPU system, you need to add

```
cpus="2-8"
```

to the configuration file of the relevant VM Guest.

## 22.5.2 VM Guests

It is often necessary to dedicate specific CPU resources to a virtual machine. By default, a virtual machine uses any available CPU core. Its performance can be improved by assigning a reasonable number of physical processors to it as other VM Guests are not allowed to use them after that. Assuming a machine with 8 CPU cores while a virtual machine needs to use 2 of them, change its configuration file as follows:

```
vcpus=2
cpus="2,3"
```

The above example dedicates 2 processors to the VM Guest, and these being the 3rd and 4th one, (2 and 3 counted from zero). If you need to assign more physical processors, use the `cpus="2-8"` syntax.

If you need to change the CPU assignment for a guest named “alice” in a hotplug manner, do the following on the related Dom0:

```
xl vcpu-set alice 2
xl vcpu-pin alice 0 2
xl vcpu-pin alice 1 3
```

The example will dedicate 2 physical processors to the guest, and bind its VCPU 0 to physical processor 2 and VCPU 1 to physical processor 3. Now check the assignment:

```
xl vcpu-list alice
```

Name	ID	VCPUs	CPU	State	Time(s)	CPU Affinity
alice	4	0	2	-b-	1.9	2-3
alice	4	1	3	-b-	2.8	2-3

## 22.6 HVM Features

In Xen some features are only available for fully virtualized domains. They are not very often used, but still may be interesting in some environments.

## 22.6.1 Specify Boot Device on Boot

Just as with physical hardware, it is sometimes desirable to boot a VM Guest from a different device than its own boot device. For fully virtual machines, it is possible to select a boot device with the `boot` parameter in a domain xl configuration file:

```
boot = BOOT_DEVICE
```

`BOOT_DEVICE` can be one of `c` for hard disk, `d` for CD-ROM, or `n` for Network/PXE. You can specify multiple options, and they will be attempted in the given order. For example,

```
boot = dc
```

boots from CD-ROM, and falls back to the hard disk if CD-ROM is not bootable.

## 22.6.2 Changing CPUIDs for Guests

To be able to migrate a VM Guest from one VM Host Server to a different VM Host Server, the VM Guest system may only use CPU features that are available on both VM Host Server systems. If the actual CPUs are different on both hosts, it may be necessary to hide some features before the VM Guest is started. This maintains the possibility to migrate the VM Guest between both hosts. For fully virtualized guests, this can be achieved by configuring the `cpuid` that is available to the guest.

To gain an overview of the current CPU, have a look at `/proc/cpuinfo`. This contains all the important information that defines the current CPU.

To redefine a CPU, first have a look at the respective cpuid definitions of the CPU vendor. These are available from:

Intel

<http://www.intel.com/Assets/PDF/appnote/241618.pdf>

```
cpuid = "host,tm=0,sse3=0"
```

The syntax is a comma-separated list of key=value pairs, preceded by the word "host". A few keys take a numerical value, while all others take a single character which describes what to do with the feature bit. See **man 5 xl.cfg** for a complete list of cpuid keys. The respective bits may be changed by using the following values:

1

Force the corresponding bit to 1

0

Force the corresponding bit to 0

x

Use the values of the default policy

k

Use the values defined by the host

s

Like k, but preserve the value over migrations

Note that counting bits is done from right to left, starting with bit 0.

### 22.6.3 Increasing the Number of PCI-IRQs

In case you need to increase the default number of PCI-IRQs available to Dom0 and/or VM Guest, you can do so by modifying the Xen kernel command line. Use the command **extra\_guest\_irqs=** DOMU\_IRGS,DOM0\_IRGS. The optional first number DOMU\_IRGS is common for all VM Guests, while the optional second number DOM0\_IRGS (preceded by a comma) is for Dom0. Changing the setting for VM Guest has no impact on Dom0 and vice versa. For example to change Dom0 without changing VM Guest, use

```
extra_guest_irqs=,512
```

## 23 Administrative Tasks

### 23.1 The Boot Loader Program

The boot loader controls how the virtualization software boots and runs. You can modify the boot loader properties by using YaST, or by directly editing the boot loader configuration file. The YaST boot loader program is located at *YaST > System > Boot Loader*. Click the *Bootloader Options* tab and select the line containing the Xen kernel as the *Default Boot Section*.

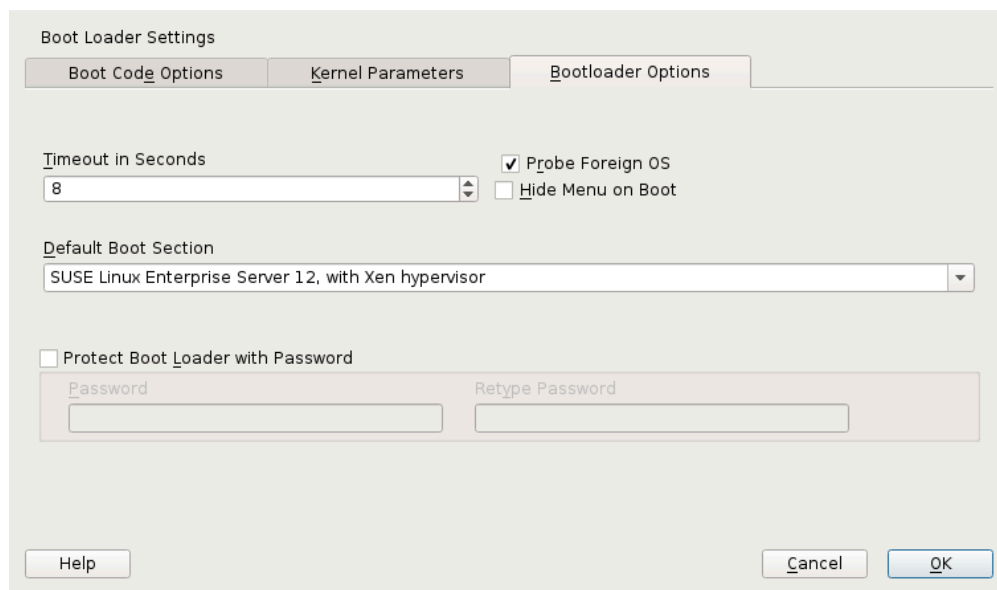


FIGURE 23.1: BOOT LOADER SETTINGS

Confirm with *OK*. Next time you boot the host, it will be ready to provide the Xen virtualization environment.

You can use the Boot Loader program to specify functionality, such as:

- Pass kernel command line parameters.
- Specify the kernel image and initial RAM disk.
- Select a specific hypervisor.
- Pass additional parameters to the hypervisor. See <http://xenbits.xen.org/docs/unstable/misc/xen-command-line.html> for their complete list.

You can customize your virtualization environment by editing the `/etc/default/grub` file. Add the following line to this file: `GRUB_CMDLINE_XEN="<boot_parameters>"`. Do not forget to run `grub2-mkconfig -o /boot/grub2/grub.cfg` after editing the file.

## 23.2 Sparse Image Files and Disk Space

If the host's physical disk reaches a state where it has no available space, a virtual machine using a virtual disk based on a sparse image file cannot write to its disk. Consequently, it reports I/O errors.

If this situation occurs, you should free up available space on the physical disk, remount the virtual machine's file system, and set the file system back to read-write.

To check the actual disk requirements of a sparse image file, use the command `du -h <image file>`.

To increase the available space of a sparse image file, first increase the file size and then the file system.



### Warning: Back Up Before Resizing

Touching the sizes of partitions or sparse files always bears the risk of data failure. Do not work without a backup.

The resizing of the image file can be done online, while the VM Guest is running. Increase the size of a sparse image file with:

```
dd if=/dev/zero of=<image file> count=0 bs=1M seek=<new size in MB>
```

For example, to increase the file `/var/lib/xen/images/sles/disk0` to a size of 16GB, use the command:

```
dd if=/dev/zero of=/var/lib/xen/images/sles/disk0 count=0 bs=1M seek=16000
```



## Note: Increasing Non-Sparse Images

It is also possible to increase the image files of devices that are not sparse files. However, you must know exactly where the previous image ends. Use the seek parameter to point to the end of the image file and use a command similar to the following:

```
dd if=/dev/zero of=/var/lib/xen/images/sles/disk0 seek=8000 bs=1M count=2000
```

Be sure to use the right seek, else data loss may happen.

If the VM Guest is running during the resize operation, also resize the loop device that provides the image file to the VM Guest. First detect the correct loop device with the command:

```
losetup -j /var/lib/xen/images/sles/disk0
```

Then resize the loop device, for example `/dev/loop0`, with the following command:

```
losetup -c /dev/loop0
```

Finally check the size of the block device inside the guest system with the command `fdisk -l /dev/xvdb`. The device name depends on the actually increased device.

The resizing of the file system inside the sparse file involves tools that are depending on the actual file system. This is described in detail in the *Book "Storage Administration Guide"*.

## 23.3 Migrating Xen VM Guest Systems

With Xen it is possible to migrate a VM Guest system from one VM Host Server to another with almost no service interruption. This could be used for example to move a busy VM Guest to a VM Host Server that has stronger hardware or is not yet loaded. Or, if a service of a VM Host Server is required, all VM Guest systems running on this machine can be migrated to other machines to avoid interruption of service. These are only two examples—many more reasons may apply to your personal situation.

Before starting, some preliminary considerations regarding the VM Host Server should be taken into account:

- All VM Host Server systems should use a similar CPU. The frequency is not so important, but they should be using the same CPU family. To get more information about the used CPU, see `cat /proc/cpuinfo`.
- All resources that are used by a specific guest system must be available on all involved VM Host Server systems—for example all used block devices must exist on both VM Host Server systems.
- If the hosts included in the migration process run in different subnets, make sure that either DHCP relay is available to the guests, or for guests with static network configuration, set up the network manually.
- Using special features like PCI Pass-Through may be problematic. Do not implement these when deploying for an environment that should migrate VM Guest systems between different VM Host Server systems.
- For fast migrations, a fast network is mandatory. If possible, use GB Ethernet and fast switches. Deploying VLAN might also help avoid collisions.

### 23.3.1 Preparing Block Devices for Migrations

The block devices needed by the VM Guest system must be available on all involved VM Host Server systems. This is done by implementing some kind of shared storage that serves as container for the root file system of the migrated VM Guest system. Common possibilities include:

- iSCSI can be set up to give access to the same block devices from different systems at the same time. For more information about iSCSI, see *Book “Storage Administration Guide”, Chapter 14 “Mass Storage over IP Networks: iSCSI”*.
- NFS is a widely used root file system that can easily be accessed from different locations. For more information, see *Book “Administration Guide”, Chapter 29 “Sharing File Systems with NFS”*.
- DRBD can be used if only two VM Host Server systems are involved. This gives some extra data security, because the used data is mirrored over the network. For more information, see the *SUSE Linux Enterprise High Availability 12 SP5* documentation at <http://www.suse.com/doc/>.

- SCSI can also be used if the available hardware permits shared access to the same disks.
- NPIV is a special mode to use Fibre channel disks. However, in this case all migration hosts must be attached to the same Fibre channel switch. For more information about NPIV, see [Section 21.1, “Mapping Physical Storage to Virtual Disks”](#). Commonly, this works if the Fibre channel environment supports 4 Gbit or faster connections.

### 23.3.2 Migrating VM Guest Systems

The actual migration of the VM Guest system is done with the command:

```
xl migrate <domain_name> <host>
```

The speed of the migration depends on how fast the memory print can be saved to disk, sent to the new VM Host Server and loaded there. This means that small VM Guest systems can be migrated faster than big systems with a lot of memory.

## 23.4 Monitoring Xen

For a regular operation of many virtual guests, having a possibility to check the sanity of all the different VM Guest systems is indispensable. Xen offers several tools besides the system tools to gather information about the system.



### Tip: Monitoring the VM Host Server

Basic monitoring of the VM Host Server (I/O and CPU) is available via the Virtual Machine Manager. Refer to [Section 10.8.1, “Monitoring with Virtual Machine Manager”](#) for details.

### 23.4.1 Monitor Xen with **xentop**

The preferred terminal application to gather information about Xen virtual environment is **xentop**. Unfortunately, this tool needs a rather broad terminal, else it inserts line breaks into the display.



**xentop** has several command keys that can give you more information about the system that is monitored. Some of the more important are:

D

Change the delay between the refreshes of the screen.

N

Also display network statistics. Note, that only standard configurations will be displayed. If you use a special configuration like a routed network, no network will be displayed.

B

Display the respective block devices and their cumulated usage count.

For more information about **xentop** see the manual page **man 1 xentop**.



### Tip: **virt-top**

libvirt offers the hypervisor-agnostic tool **virt-top**, which is recommended for monitoring VM Guests. See [Section 10.8.2, “Monitoring with virt-top”](#) for details.

## 23.4.2 Additional Tools

There are many system tools that also help monitoring or debugging a running SUSE Linux Enterprise system. Many of these are covered in *Book “System Analysis and Tuning Guide”, Chapter 2 “System Monitoring Utilities”*. Especially useful for monitoring a virtualization environment are the following tools:

**ip**

The command line utility **ip** may be used to monitor arbitrary network interfaces. This is especially useful if you have set up a network that is routed or applied a masqueraded network. To monitor a network interface with the name **alice.0**, run the following command:

```
watch ip -s link show alice.0
```

## brctl

In a standard setup, all the Xen VM Guest systems are attached to a virtual network bridge. **brctl** allows you to determine the connection between the bridge and the virtual network adapter in the VM Guest system. For example, the output of **brctl show** may look like the following:

bridge name	bridge id	STP enabled	interfaces
br0	8000.000476f060cc	no	eth0 vif1.0
br1	8000.00001cb5a9e7	no	vlan22

This shows that there are two virtual bridges defined on the system. One is connected to the physical Ethernet device eth0, the other one is connected to a VLAN interface vlan22. There is only one guest interface active in this setup, vif1.0. This means that the guest with ID 1 has an Ethernet interface eth0 assigned, that is connected to br0 in the VM Host Server.

## iptables-save

Especially when using masquerade networks, or if several Ethernet interfaces are set up together with a firewall setup, it may be helpful to check the current firewall rules.

The command **iptables** may be used to check all the different firewall settings. To list all the rules of a chain, or even of the complete setup, you may use the commands **iptables-save** or **iptables -S**.

## 23.5 Providing Host Information for VM Guest Systems

In a standard Xen environment, the VM Guest systems have only very limited information about the VM Host Server system they are running on. If a guest should know more about the VM Host Server it runs on, vhostmd can provide more information to selected guests. To set up your system to run vhostmd, proceed as follows:

1. Install the package vhostmd on the VM Host Server.
2. To add or remove metric sections from the configuration, edit the file /etc/vhostmd/vhostmd.conf. However, the default works well.
3. Check the validity of the vhostmd.conf configuration file with the command:

```
cd /etc/vhostmd
```

```
xmllint --postvalid --noout vhostmd.conf
```

4. Start the vhostmd daemon with the command **`sudo systemctl start vhostmd`**.

If vhostmd should be started automatically during start-up of the system, run the command:

```
sudo systemctl enable vhostmd
```

5. Attach the image file `/dev/shm/vhostmd0` to the VM Guest system named alice with the command:

```
xl block-attach opensuse /dev/shm/vhostmd0,,xvdb,ro
```

6. Log on the VM Guest system.
7. Install the client package `vm-dump-metrics`.
8. Run the command **`vm-dump-metrics`**. To save the result to a file, use the option `-d <filename>`.

The result of the `vm-dump-metrics` is an XML output. The respective metric entries follow the DTD `/etc/vhostmd/metric.dtd`.

For more information, see the manual pages **`man 8 vhostmd`** and `/usr/share/doc/vhostmd/README` on the VM Host Server system. On the guest, see the manual page **`man 1 vm-dump-metrics`**.

## 24 XenStore: Configuration Database Shared between Domains

This section introduces basic information about XenStore, its role in the Xen environment, the directory structure of files used by XenStore, and the description of XenStore's commands.

### 24.1 Introduction

XenStore is a database of configuration and status information shared between VM Guests and the management tools running in Dom0. VM Guests and the management tools read and write to XenStore to convey configuration information, status updates, and state changes. The XenStore database is managed by Dom0 and supports simple operations such as reading and writing a key. VM Guests and management tools can be notified of any changes in XenStore by watching entries of interest. Note that the `xenstored` daemon is managed by the `xencommons` service. XenStore is located on Dom0 in a single database file `/var/lib/xenstored/tdb` (`tdb` represents *tree database*).

### 24.2 File System Interface

XenStore database content is represented by a virtual file system similar to `/proc` (for more information on `/proc`, see Book “System Analysis and Tuning Guide”, Chapter 2 “System Monitoring Utilities”, Section 2.6 “The `/proc` File System”). The tree has three main paths: `/vm`, `/local/domain`, and `/tool`.

- `/vm` - stores information about the VM Guest configuration.
- `/local/domain` - stores information about VM Guest on the local node.
- `/tool` - stores general information about various tools.



#### Tip

Each VM Guest has two different ID numbers. The *universal unique identifier* (UUID) remains the same even if the VM Guest is migrated to another machine. The *domain identifier* (DOMID) is an identification number that represents a particular running instance. It typically changes when the VM Guest is migrated to another machine.

## 24.2.1 XenStore Commands

The file system structure of the XenStore database can be operated with the following commands:

### **xenstore-ls**

Displays the full dump of the XenStore database.

### **xenstore-read path\_to\_xenstore\_entry**

Displays the value of the specified XenStore entry.

### **xenstore-exists xenstore\_path**

Reports whether the specified XenStore path exists.

### **xenstore-list xenstore\_path**

Displays all the children entries of the specified XenStore path.

### **xenstore-write path\_to\_xenstore\_entry**

Updates the value of the specified XenStore entry.

### **xenstore-rm xenstore\_path**

Removes the specified XenStore entry or directory.

### **xenstore-chmod xenstore\_path mode**

Updates the read/write permission on the specified XenStore path.

### **xenstore-control**

Sends a command to the xenstored back-end, such as triggering an integrity check.

## 24.2.2 /vm

The /vm path is indexed by the UUID of each VM Guest, and stores configuration information such as the number of virtual CPUs and the amount of allocated memory. There is a /vm/<uuid> directory for each VM Guest. To list the directory content, use **xenstore-list**.

```
# xenstore-list /vm
00000000-0000-0000-0000-000000000000
9b30841b-43bc-2af9-2ed3-5a649f466d79-1
```

The first line of the output belongs to Dom0, and the second one to a running VM Guest. The following command lists all the entries related to the VM Guest:

```
# xenstore-list /vm/9b30841b-43bc-2af9-2ed3-5a649f466d79-1
```

```
image
rtc
device
pool_name
shadow_memory
uuid
on_reboot
start_time
on_poweroff
bootloader_args
on_crash
vcpus
vcpu_avail
bootloader
name
```

To read a value of an entry, for example the number of virtual CPUs dedicated to the VM Guest, use **xenstore-read**:

```
# xenstore-read /vm/9b30841b-43bc-2af9-2ed3-5a649f466d79-1/vcpus
1
```

A list of selected /vm/<uuid> entries follows:

#### uuid

UUID of the VM Guest. It does not change during the migration process.

#### on\_reboot

Specifies whether to destroy or restart the VM Guest in response to a reboot request.

#### on\_poweroff

Specifies whether to destroy or restart the VM Guest in response to a halt request.

#### on\_crash

Specifies whether to destroy or restart the VM Guest in response to a crash.

#### vcpus

Number of virtual CPUs allocated to the VM Guest.

#### vcpu\_avail

Bitmask of active virtual CPUs for the VM Guest. The bitmask has several bits equal to the value of vcpus, with a bit set for each online virtual CPU.

#### name

The name of the VM Guest.

Regular VM Guests (not Dom0) use the `/vm/<uuid>/image` path:

```
# xenstore-list /vm/9b30841b-43bc-2af9-2ed3-5a649f466d79-1/image
ostype
kernel
cmdline
ramdisk
dmargs
device-model
display
```

An explanation of the used entries follows:

#### ostype

The OS type of the VM Guest.

#### kernel

The path on Dom0 to the kernel for the VM Guest.

#### cmdline

The kernel command line for the VM Guest used when booting.

#### ramdisk

The path on Dom0 to the RAM disk for the VM Guest.

#### dmargs

Shows arguments passed to the QEMU process. If you look at the QEMU process with **ps**, you should see the same arguments as in `/vm/<uuid>/image/dmargs`.

### 24.2.3 `/local/domain/<domid>`

This path is indexed by the running domain (VM Guest) ID, and contains information about the running VM Guest. Remember that the domain ID changes during VM Guest migration. The following entries are available:

#### vm

The path of the `/vm` directory for this VM Guest.

#### on\_reboot, on\_poweroff, on\_crash, name

See identical options in [Section 24.2.2, “/vm”](#)

#### domid

Domain identifier for the VM Guest.

### cpu

The current CPU to which the VM Guest is pinned.

### cpu\_weight

The weight assigned to the VM Guest for scheduling purposes. Higher weights use the physical CPUs more often.

Apart from the individual entries described above, there are also several subdirectories under /local/domain/<domid>, containing specific entries. To see all entries available, refer to [XenStore Reference \(http://wiki.xen.org/wiki/XenStore\\_Reference\)](http://wiki.xen.org/wiki/XenStore_Reference).

### /local/domain/<domid>/memory

Contains memory information. /local/domain/<domid>/memory/target contains target memory size for the VM Guest (in kilobytes).

### /local/domain/<domid>/console

Contains information about a console used by the VM Guest.

### /local/domain/<domid>/backend

Contains information about all back-end devices used by the VM Guest. The path has subdirectories of its own.

### /local/domain/<domid>/device

Contains information about the front-end devices for the VM Guest.

### /local/domain/<domid>/device-misc

Contains miscellaneous information about devices.

### /local/domain/<domid>/store

Contains information about the VM Guest's store.



## 25 Xen as a High-Availability Virtualization Host

Setting up two Xen hosts as a failover system has several advantages compared to a setup where every server runs on dedicated hardware.

- Failure of a single server does not cause major interruption of the service.
- A single big machine is normally way cheaper than multiple smaller machines.
- Adding new servers as needed is a trivial task.
- The usage of the server is improved, which has positive effects on the power consumption of the system.

The setup of migration for Xen hosts is described in [Section 23.3, “Migrating Xen VM Guest Systems”](#). In the following, several typical scenarios are described.

### 25.1 Xen HA with Remote Storage

Xen can directly provide several remote block devices to the respective Xen guest systems. These include iSCSI, NPIV, and NBD. All of these may be used to do live migrations. When a storage system is already in place, first try to use the same device type you already used in the network. If the storage system cannot be used directly but provides a possibility to offer the needed space over NFS, it is also possible to create image files on NFS. If the NFS file system is available on all Xen host systems, this method also allows live migrations of Xen guests.

When setting up a new system, one of the main considerations is whether a dedicated storage area network should be implemented. The following possibilities are available:

TABLE 25.1: XEN REMOTE STORAGE

Method	Complexity	Comments
Ethernet	low	Note that all block device traffic goes over the same Ethernet interface as the network traffic. This may be limiting the performance of the guest.

Method	Complexity	Comments
Ethernet dedicated to storage.	medium	Running the storage traffic over a dedicated Ethernet interface may eliminate a bottleneck on the server side. However, planning your own network with your own IP address range and possibly a VLAN dedicated to storage requires numerous considerations.
NPIV	high	NPIV is a method to virtualize Fibre channel connections. This is available with adapters that support a data rate of at least 4 Gbit/s and allows the setup of complex storage systems.

Typically, a 1 Gbit/s Ethernet device can fully use a typical hard disk or storage system. When using very fast storage systems, such an Ethernet device will probably limit the speed of the system.

## 25.2 Xen HA with Local Storage

For space or budget reasons, it may be necessary to rely on storage that is local to the Xen host systems. To still maintain the possibility of live migrations, it is necessary to build block devices that are mirrored to both Xen hosts. The software that allows this is called Distributed Replicated Block Device (DRBD).

If a system that uses DRBD to mirror the block devices or files between two Xen hosts should be set up, both hosts should use the identical hardware. If one of the hosts has slower hard disks, both hosts will suffer from this limitation.

During the setup, each of the required block devices should use its own DRBD device. The setup of such a system is quite a complex task.

## 25.3 Xen HA and Private Bridges

When using several guest systems that need to communicate between each other, it is possible to do this over the regular interface. However, for security reasons it may be advisable to create a bridge that is only connected to guest systems.

In an HA environment that also should support live migrations, such a private bridge must be connected to the other Xen hosts. This is possible by using dedicated physical Ethernet devices and a dedicated network.

A different implementation method is using VLAN interfaces. In that case, all the traffic goes over the regular Ethernet interface. However, the VLAN interface does not get the regular traffic, because only the VLAN packets that are tagged for the correct VLAN are forwarded.

For more information about the setup of a VLAN interface see [Section 13.1.3, “Using VLAN Interfaces”](#).

## V Managing Virtual Machines with QEMU

- 26 QEMU Overview **232**
- 27 Setting Up a KVM VM Host Server **233**
- 28 Guest Installation **243**
- 29 Running Virtual Machines with qemu-system-ARCH **259**
- 30 Virtual Machine Administration Using QEMU Monitor **288**

## 26 QEMU Overview

QEMU is a fast, cross-platform open source machine emulator which can emulate a huge number of hardware architectures for you. QEMU lets you run a complete unmodified operating system (VM Guest) on top of your existing system (VM Host Server).

You can also use QEMU for debugging purposes—you can easily stop your running virtual machine, inspect its state and save and restore it later.

QEMU consists of the following parts:

- processor emulator (x86, IBM IBM Z, IBM POWER, Sparc)
- emulated devices (graphic card, network card, hard disks, mice)
- generic devices used to connect the emulated devices to the related host devices
- descriptions of the emulated machines (PC, Power Mac)
- debugger
- user interface used to interact with the emulator

QEMU is central to KVM and Xen Virtualization, where it provides the general machine emulation. Xen's usage of QEMU is somewhat hidden from the user, while KVM's usage exposes most QEMU features transparently. If the VM Guest hardware architecture is the same as the VM Host Server's architecture, QEMU can take advantage of the KVM acceleration (SUSE only supports QEMU with the KVM acceleration loaded).

Apart from providing a core virtualization infrastructure and processor-specific drivers, QEMU also provides an architecture-specific user space program for managing VM Guests. Depending on the architecture this program is one of:

- qemu-system-i386
- qemu-system-s390x
- qemu-system-x86\_64

In the following this command is called qemu-system-ARCH; in examples the qemu-system-x86\_64 command is used.

## 27 Setting Up a KVM VM Host Server

This section documents how to set up and use SUSE Linux Enterprise Server 12 SP5 as a QEMU-KVM based virtual machine host.



### Tip: Resources

In general, the virtual guest system needs the same hardware resources as if it were installed on a physical machine. The more guests you plan to run on the host system, the more hardware resources—CPU, disk, memory, and network—you need to add to the VM Host Server.

### 27.1 CPU Support for Virtualization

To run KVM, your CPU must support virtualization, and virtualization needs to be enabled in BIOS. The file `/proc/cpuinfo` includes information about your CPU features.

To find out whether your system supports virtualization, see [Section 7.3, “KVM Hardware Requirements”](#).

### 27.2 Required Software

The KVM host requires several packages to be installed. To install all necessary packages, do the following:

1. Verify that the `yast2-vm` package is installed. This package is YaST's configuration tool that simplifies the installation of virtualization hypervisors.
2. Run `YaST > Virtualization > Install Hypervisor and Tools`.

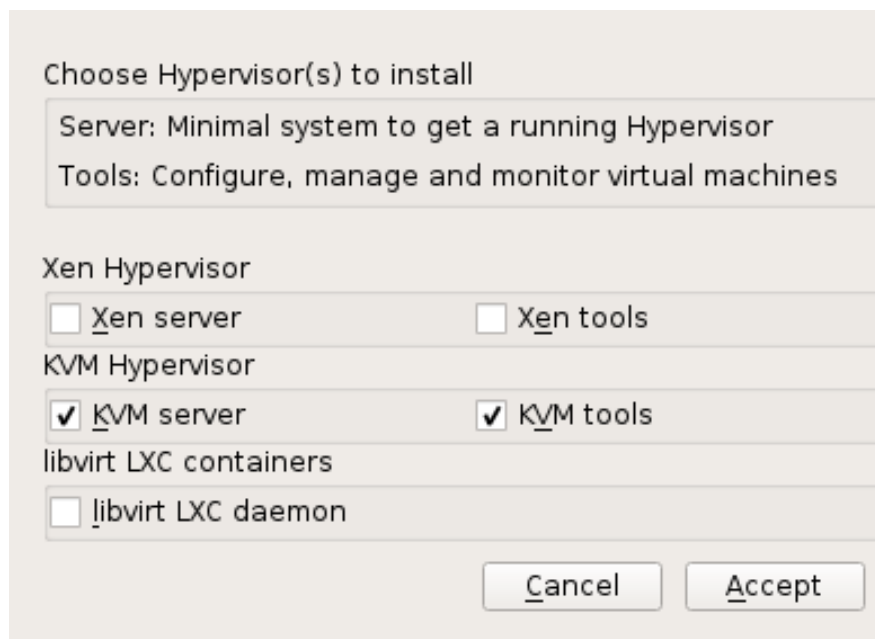


FIGURE 27.1: INSTALLING THE KVM HYPervisor AND TOOLS

3. Select *KVM server* and preferably also *KVM tools*, and confirm with *Accept*.
4. During the installation process, you can optionally let YaST create a *Network Bridge* for you automatically. If you do not plan to dedicate an additional physical network card to your virtual guests, network bridge is a standard way to connect the guest machines to the network.

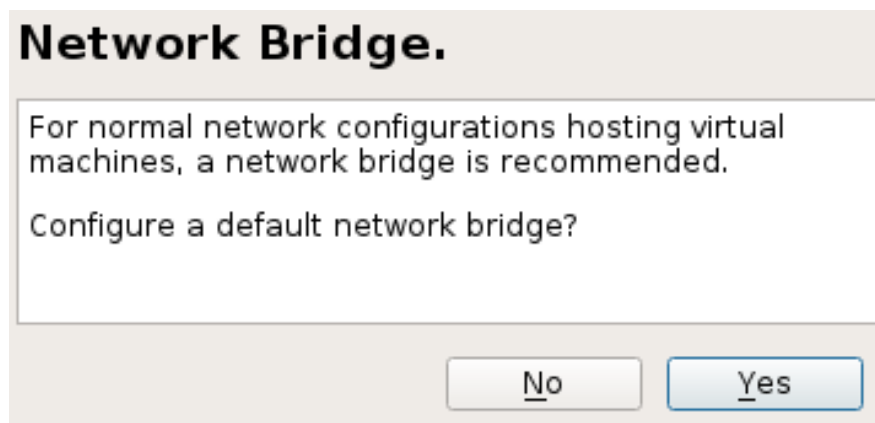


FIGURE 27.2: NETWORK BRIDGE

5. After all the required packages are installed (and new network setup activated), try to load the KVM kernel module relevant for your CPU type—`kvm-intel` or `kvm-amd`:

```
root # modprobe kvm-intel
```

Check if the module is loaded into memory:

```
tux > lsmod | grep kvm
kvm_intel          64835  6
kvm                411041  1 kvm_intel
```

Now the KVM host is ready to serve KVM VM Guests. For more information, see [Chapter 29, Running Virtual Machines with qemu-system-ARCH](#).

## 27.3 KVM Host-Specific Features

You can improve the performance of KVM-based VM Guests by letting them fully use specific features of the VM Host Server's hardware (*paravirtualization*). This section introduces techniques to make the guests access the physical host's hardware directly—without the emulation layer—to make the most use of it.



### Tip

Examples included in this section assume basic knowledge of the `qemu-system-ARCH` command line options. For more information, see [Chapter 29, Running Virtual Machines with qemu-system-ARCH](#).

### 27.3.1 Using the Host Storage with `virtio-scsi`

`virtio-scsi` is an advanced storage stack for KVM. It replaces the former `virtio-blk` stack for SCSI devices pass-through. It has several advantages over `virtio-blk`:

#### Improved scalability

KVM guests have a limited number of PCI controllers, which results in a limited number of possibly attached devices. `virtio-scsi` solves this limitation by grouping multiple storage devices on a single controller. Each device on a `virtio-scsi` controller is represented as a logical unit, or *LUN*.



## Standard command set

virtio-blk uses a small set of commands that need to be known to both the virtio-blk driver and the virtual machine monitor, and so introducing a new command requires updating both the driver and the monitor.

By comparison, virtio-scsi does not define commands, but rather a transport protocol for these commands following the industry-standard SCSI specification. This approach is shared with other technologies, such as Fibre Channel, ATAPI, and USB devices.

## Device naming

virtio-blk devices are presented inside the guest as /dev/vdX, which is different from device names in physical systems and may cause migration problems.

virtio-scsi keeps the device names identical to those on physical systems, making the virtual machines easily relocatable.

## SCSI device pass-through

For virtual disks backed by a whole LUN on the host, it is preferable for the guest to send SCSI commands directly to the LUN (pass-through). This is limited in virtio-blk, as guests need to use the virtio-blk protocol instead of SCSI command pass-through, and, moreover, it is not available for Windows guests. virtio-scsi natively removes these limitations.

### 27.3.1.1 virtio-scsi Usage

KVM supports the SCSI pass-through feature with the virtio-scsi-pci device:

```
qemu-system-x86_64 [...] \  
-device virtio-scsi-pci,id=scsi
```

### 27.3.2 Accelerated Networking with vhost-net

The vhost-net module is used to accelerate KVM's paravirtualized network drivers. It provides better latency and greater network throughput. Use the vhost-net driver by starting the guest with the following example command line:

```
qemu-system-x86_64 [...] \  
-netdev tap,id=guest0,vhost=on,script=no \  
-net nic,model=virtio,netdev=guest0,macaddr=00:16:35:AF:94:4B
```

Note that guest0 is an identification string of the vhost-driven device.

### 27.3.3 Scaling Network Performance with Multiqueue virtio-net

As the number of virtual CPUs increases in VM Guests, QEMU offers a way of improving the network performance using *multiqueue*. Multiqueue virtio-net scales the network performance by allowing VM Guest virtual CPUs to transfer packets in parallel. Multiqueue support is required on both the VM Host Server and VM Guest sides.



#### Tip: Performance Benefit

The multiqueue virtio-net solution is most beneficial in the following cases:

- Network traffic packets are large.
- VM Guest has many connections active at the same time, mainly between the guest systems, or between the guest and the host, or between the guest and an external system.
- The number of active queues is equal to the number of virtual CPUs in the VM Guest.



#### Note

While multiqueue virtio-net increases the total network throughput, it increases CPU consumption as it uses of the virtual CPU's power.

#### PROCEDURE 27.1: HOW TO ENABLE MULTIQUEUE VIRTIO-NET

The following procedure lists important steps to enable the multiqueue feature with **qemu-system-ARCH**. It assumes that a tap network device with multiqueue capability (supported since kernel version 3.8) is set up on the VM Host Server.

1. In **qemu-system-ARCH**, enable multiqueue for the tap device:

```
-netdev tap,vhost=on,queues=2*N
```

where N stands for the number of queue pairs.

2. In **qemu-system-ARCH**, enable multiqueue and specify MSI-X (Message Signaled Interrupt) vectors for the virtio-net-pci device:

```
-device virtio-net-pci,mq=on,vectors=2*N+2
```

where the formula for the number of MSI-X vectors results from: N vectors for TX (transmit) queues, N for RX (receive) queues, one for configuration purposes, and one for possible VQ (vector quantization) control.

3. In VM Guest, enable multiqueue on the relevant network interface (eth0 in this example):

```
ethtool -L eth0 combined 2*N
```

The resulting **qemu-system-ARCH** command line will look similar to the following example:

```
qemu-system-x86_64 [...] -netdev tap,id=guest0,queues=8,vhost=on \
-device virtio-net-pci,netdev=guest0,mq=on,vectors=10
```

Note that the id of the network device (guest0) needs to be identical for both options.

Inside the running VM Guest, specify the following command as root:

```
ethtool -L eth0 combined 8
```

Now the guest system networking uses the multiqueue support from the **qemu-system-ARCH** hypervisor.

## 27.3.4 VFIO: Secure Direct Access to Devices

Directly assigning a PCI device to a VM Guest (PCI pass-through) avoids performance issues caused by avoiding any emulation in performance-critical paths. VFIO replaces the traditional KVM PCI Pass-Through device assignment. A prerequisite for this feature is a VM Host Server configuration as described in *Important: Requirements for VFIO and SR-IOV*.

To be able to assign a PCI device via VFIO to a VM Guest, you need to find out which IOMMU Group it belongs to. The *IOMMU* (input/output memory management unit that connects a direct memory access-capable I/O bus to the main memory) API supports the notion of groups. A group is a set of devices that can be isolated from all other devices in the system. Groups are therefore the unit of ownership used by *VFIO*.

### PROCEDURE 27.2: ASSIGNING A PCI DEVICE TO A VM GUEST VIA VFIO

1. Identify the host PCI device to assign to the guest.

```
tux > sudo lspci -nn
[...]
```

```
00:10.0 Ethernet controller [0200]: Intel Corporation 82576 \
Virtual Function [8086:10ca] (rev 01)
[...]
```

Note down the device ID (00:10.0 in this case) and the vendor ID (8086:10ca).

2. Find the IOMMU group of this device:

```
tux > sudo readlink /sys/bus/pci/devices/0000\:00\:10.0/iommu_group
../../../../kernel/iommu_groups/20
```

The IOMMU group for this device is 20. Now you can check the devices belonging to the same IOMMU group:

```
ls -l /sys/bus/pci/devices/0000:01:10.0/iommu_group/devices/0000:01:10.0
[...] 0000:00:1e.0 -> ../../../../devices/pci0000:00/0000:00:1e.0
[...] 0000:01:10.0 -> ../../../../devices/pci0000:00/0000:00:1e.0/0000:01:10.0
[...] 0000:01:10.1 -> ../../../../devices/pci0000:00/0000:00:1e.0/0000:01:10.1
```

3. Unbind the device from the device driver:

```
sudo echo "0000:01:10.0" > /sys/bus/pci/devices/0000\:01\:10.0/driver/unbind
```

4. Bind the device to the vfio-pci driver using the vendor ID from step 1:

```
sudo echo "8086 153a" > /sys/bus/pci/drivers/vfio-pci/new_id
```

A new device /dev/vfio/IOMMU\_GROUP will be created as a result, /dev/vfio/20 in this case.

5. Change the ownership of the newly created device:

```
chown qemu.qemu /dev/vfio/DEVICE
```

6. Now run the VM Guest with the PCI device assigned.

```
qemu-system-ARCH [...] -device
vfio-pci,host=00:10.0,id=ID
```

## Important: No Hotplugging

As of SUSE Linux Enterprise Server 12 SP5 hotplugging of PCI devices passed to a VM Guest via VFIO is not supported.

You can find more detailed information on the [VFIO](#) driver in the `/usr/src/linux/Documentation/vfio.txt` file (package `kernel-source` needs to be installed).

### 27.3.5 VirtFS: Sharing Directories between Host and Guests

VM Guests usually run in a separate computing space—they are provided their own memory range, dedicated CPUs, and file system space. The ability to share parts of the VM Host Server's file system makes the virtualization environment more flexible by simplifying mutual data exchange. Network file systems, such as CIFS and NFS, have been the traditional way of sharing directories. But as they are not specifically designed for virtualization purposes, they suffer from major performance and feature issues.

KVM introduces a new optimized method called *VirtFS* (sometimes called “file system pass-through”). VirtFS uses a paravirtual file system driver, which avoids converting the guest application file system operations into block device operations, and then again into host file system operations.

You typically use VirtFS for the following situations:

- To access a shared directory from several guests, or to provide guest-to-guest file system access.
- To replace the virtual disk as the root file system to which the guest's RAM disk connects during the guest boot process.
- To provide storage services to different customers from a single host file system in a cloud environment.

#### 27.3.5.1 Implementation

In QEMU, the implementation of VirtFS is simplified by defining two types of devices:

- `virtio-9p-pci` device which transports protocol messages and data between the host and the guest.
- `fsdev` device which defines the export file system properties, such as file system type and security model.

#### EXAMPLE 27.1: EXPORTING HOST'S FILE SYSTEM WITH VIRTFS

```
qemu-system-x86_64 [...] \
```

```
-fsdev local,id=expl❶,path=/tmp/❷,security_model=mapped❸ \  
-device virtio-9p-pci,fsdev=expl❹,mount_tag=v_tmp❺
```

- ❶ Identification of the file system to be exported.
- ❷ File system path on the host to be exported.
- ❸ Security model to be used—`mapped` keeps the guest file system modes and permissions isolated from the host, while `none` invokes a “pass-through” security model in which permission changes on the guest's files are reflected on the host as well.
- ❹ The exported file system ID defined before with `-fsdev id=`.
- ❺ Mount tag used later on the guest to mount the exported file system.

Such an exported file system can be mounted on the guest as follows:

```
sudo mount -t 9p -o trans=virtio v_tmp /mnt
```

where `v_tmp` is the mount tag defined earlier with `-device mount_tag=` and `/mnt` is the mount point where you want to mount the exported file system.

### 27.3.6 KSM: Sharing Memory Pages between Guests

Kernel Same Page Merging (*KSM*) is a Linux kernel feature that merges identical memory pages from multiple running processes into one memory region. Because KVM guests run as processes under Linux, *KSM* provides the memory overcommit feature to hypervisors for more efficient use of memory. Therefore, if you need to run multiple virtual machines on a host with limited memory, *KSM* may be helpful to you.

*KSM* stores its status information in the files under the `/sys/kernel/mm/ksm` directory:

```
tux > ls -l /sys/kernel/mm/ksm  
full_scans  
merge_across_nodes  
pages_shared  
pages_sharing  
pages_to_scan  
pages_unshared  
pages_volatile  
run  
sleep_millisecs
```

For more information on the meaning of the `/sys/kernel/mm/ksm/*` files, see `/usr/src/linux/Documentation/vm/ksm.txt` (package `kernel-source`).

To use *KSM*, do the following.

1. Although SLES includes *KSM* support in the kernel, it is disabled by default. To enable it, run the following command:

```
root # echo 1 > /sys/kernel/mm/ksm/run
```

2. Now run several VM Guests under KVM and inspect the content of files pages\_sharing and pages\_shared, for example:

```
while [ 1 ]; do cat /sys/kernel/mm/ksm/pages_shared; sleep 1; done
13522
13523
13519
13518
13520
13520
13528
```

## 28 Guest Installation

The `libvirt`-based tools such as `virt-manager` and `virt-install` offer convenient interfaces to set up and manage virtual machines. They act as a kind of wrapper for the `qemu-system-ARCH` command. However, it is also possible to use `qemu-system-ARCH` directly without using `libvirt`-based tools.



### Warning: `qemu-system-ARCH` and `libvirt`

*Virtual Machines* created with `qemu-system-ARCH` are not "visible" for the `libvirt`-based tools.

### 28.1 Basic Installation with `qemu-system-ARCH`

In the following example, a virtual machine for a SUSE Linux Enterprise Server 11 installation is created. For detailed information on the commands, refer to the respective man pages.

If you do not already have an image of a system that you want to run in a virtualized environment, you need to create one from the installation media. In such case, you need to prepare a hard disk image, and obtain an image of the installation media or the media itself.

Create a hard disk with `qemu-img`.

```
qemu-img create ❶ -f raw❷ /images/sles/hda❸ 8G❹
```

- ❶ The subcommand `create` tells `qemu-img` to create a new image.
- ❷ Specify the disk's format with the `-f` parameter.
- ❸ The full path to the image file.
- ❹ The size of the image—8 GB in this case. The image is created as a *Sparse image file* file that grows when the disk is filled with data. The specified size defines the maximum size to which the image file can grow.

After at least one hard disk image is created, you can set up a virtual machine with `qemu-system-ARCH` that will boot into the installation system:

```
root # qemu-system-x86_64 -name "sles" ❶ -machine accel=kvm -M pc❷ -m 768❸ \  
-smp 2❹ -boot d❺ \  
-drive file=/images/sles/hda,if=virtio,index=0,media=disk,format=raw❻ \  
\
```



```
-drive file=/isos/SLES-11-SP3-DVD-x86_64-GM-DVD1.iso,index=1,media=cdrom ⑦ \  
-net nic,model=virtio,macaddr=52:54:00:05:11:11 ⑧ -net user \  
-vga cirrus ⑨ -balloon virtio ⑩
```

- ① Name of the virtual machine that will be displayed in the window caption and be used for the VNC server. This name must be unique.
- ② Specifies the machine type. Use **qemu-system-ARCH** `-M ?` to display a list of valid parameters. `pc` is the default *Standard PC*.
- ③ Maximum amount of memory for the virtual machine.
- ④ Defines an SMP system with two processors.
- ⑤ Specifies the boot order. Valid values are `a`, `b` (floppy 1 and 2), `c` (first hard disk), `d` (first CD-ROM), or `n` to `p` (Ether-boot from network adapter 1-3). Defaults to `c`.
- ⑥ Defines the first (`index=0`) hard disk. It will be accessed as a paravirtualized (`if=virtio`) drive in `raw` format.
- ⑦ The second (`index=1`) image drive will act as a CD-ROM.
- ⑧ Defines a paravirtualized (`model=virtio`) network adapter with the MAC address `52:54:00:05:11:11`. Be sure to specify a unique MAC address, otherwise a network conflict may occur.
- ⑨ Specifies the graphic card. If you specify `none`, the graphic card will be disabled.
- ⑩ Defines the paravirtualized balloon device that allows to dynamically change the amount of memory (up to the maximum value specified with the parameter `-m`).

After the installation of the guest operating system finishes, you can start the related virtual machine without the need to specify the CD-ROM device:

```
root # qemu-system-x86_64 -name "sles" -machine type=pc,accel=kvm -m 768 \  
-smp 2 -boot c \  
-drive file=/images/sles/hda,if=virtio,index=0,media=disk,format=raw \  
-net nic,model=virtio,macaddr=52:54:00:05:11:11 \  
-vga cirrus -balloon virtio
```

## 28.2 Managing Disk Images with **qemu-img**

In the previous section (see [Section 28.1, “Basic Installation with \*\*qemu-system-ARCH\*\*”](#)), we used the **qemu-img** command to create an image of a hard disk. You can, however, use **qemu-img** for general disk image manipulation. This section introduces **qemu-img** subcommands to help manage the disk images flexibly.

## 28.2.1 General Information on qemu-img Invocation

**qemu-img** uses subcommands (like **zypper** does) to do specific tasks. Each subcommand understands a different set of options. Some options are general and used by more of these subcommands, while some are unique to the related subcommand. See the **qemu-img** manual page (**man 1 qemu-img**) for a list of all supported options. **qemu-img** uses the following general syntax:

```
tux > qemu-img subcommand [options]
```

and supports the following subcommands:

### create

Creates a new disk image on the file system.

### check

Checks an existing disk image for errors.

### compare

Check if two images have the same content.

### map

Dumps the metadata of the image file name and its backing file chain.

### amend

Amends the image format specific options for the image file name.

### convert

Converts an existing disk image to a new one in a different format.

### info

Displays information about the relevant disk image.

### snapshot

Manages snapshots of existing disk images.

### commit

Applies changes made to an existing disk image.

### rebase

Creates a new base image based on an existing image.

### resize

Increases or decreases the size of an existing image.

## 28.2.2 Creating, Converting and Checking Disk Images

This section describes how to create disk images, check their condition, convert a disk image from one format to another, and get detailed information about a particular disk image.

### 28.2.2.1 `qemu-img create`

Use **`qemu-img create`** to create a new disk image for your VM Guest operating system. The command uses the following syntax:

```
tux > qemu-img create -f fmt❶ -o options❷ fname❸ size❹
```

- ❶ The format of the target image. Supported formats are `qed`, `qcow2`, and `raw`.
- ❷ Some image formats support additional options to be passed on the command line. You can specify them here with the `-o` option. The `raw` image format supports only the `size` option, so it is possible to insert `-o size=8G` instead of adding the size option at the end of the command.
- ❸ Path to the target disk image to be created.
- ❹ Size of the target disk image (if not already specified with the `-o size=<image_size>` option. Optional suffixes for the image size are `K` (kilobyte), `M` (megabyte), `G` (gigabyte), or `T` (terabyte).

To create a new disk image `sles.raw` in the directory `/images` growing up to a maximum size of 4 GB, run the following command:

```
tux > qemu-img create -f raw -o size=4G /images/sles.raw
Formatting '/images/sles.raw', fmt=raw size=4294967296

tux > ls -l /images/sles.raw
-rw-r--r-- 1 tux users 4294967296 Nov 15 15:56 /images/sles.raw

tux > qemu-img info /images/sles.raw
image: /images/sles11.raw
file format: raw
virtual size: 4.0G (4294967296 bytes)
disk size: 0
```

As you can see, the *virtual* size of the newly created image is 4 GB, but the actual reported disk size is 0 as no data has been written to the image yet.



## Tip: VM Guest Images on the Btrfs File System

If you need to create a disk image on the Btrfs file system, you can use `nocow=on` to reduce the performance overhead created by the copy-on-write feature of Btrfs:

```
tux > qemu-img create -o nocow=on test.img 8G
```

If you, however, want to use copy-on-write (for example for creating snapshots or sharing them across virtual machines), then leave the command line without the `nocow` option.

### 28.2.2.2 `qemu-img convert`

Use `qemu-img convert` to convert disk images to another format. To get a complete list of image formats supported by QEMU, run `qemu-img -h` and look at the last line of the output. The command uses the following syntax:

```
tux > qemu-img convert -c ❶ -f fmt ❷ -O out_fmt ❸ -o options ❹ fname ❺ out_fname ❻
```

- ❶ Applies compression on the target disk image. Only `qcow` and `qcow2` formats support compression.
- ❷ The format of the source disk image. It is usually autodetected and can therefore be omitted.
- ❸ The format of the target disk image.
- ❹ Specify additional options relevant for the target image format. Use `-o ?` to view the list of options supported by the target image format.
- ❺ Path to the source disk image to be converted.
- ❻ Path to the converted target disk image.

```
tux > qemu-img convert -O vmdk /images/sles.raw \
/images/sles.vmdk

tux > ls -l /images/
-rw-r--r-- 1 tux users 4294967296 16. lis 10.50 sles.raw
-rw-r--r-- 1 tux users 2574450688 16. lis 14.18 sles.vmdk
```

To see a list of options relevant for the selected target image format, run the following command (replace `vmdk` with your image format):

```
tux > qemu-img convert -O vmdk /images/sles.raw \
/images/sles.vmdk -o ?
Supported options:
```

size	Virtual disk size
backing_file	File name of a base image
compat6	VMDK version 6 image
subformat	VMDK flat extent format, can be one of {monolithicSparse \ (default)   monolithicFlat   twoGbMaxExtentSparse   twoGbMaxExtentFlat}
scsi	SCSI image

### 28.2.2.3 `qemu-img check`

Use **`qemu-img check`** to check the existing disk image for errors. Not all disk image formats support this feature. The command uses the following syntax:

```
tux > qemu-img check -f fmt❶ fname❷
```

- ❶ The format of the source disk image. It is usually autodetected and can therefore be omitted.
- ❷ Path to the source disk image to be checked.

If no error is found, the command returns no output. Otherwise, the type and number of errors found is shown.

```
tux > qemu-img check -f qcow2 /images/sles.qcow2
ERROR: invalid cluster offset=0x2af0000
[...]
ERROR: invalid cluster offset=0x34ab0000
378 errors were found on the image.
```

### 28.2.2.4 Increasing the Size of an Existing Disk Image

When creating a new image, you must specify its maximum size before the image is created (see [Section 28.2.2.1, “`qemu-img create`”](#)). After you have installed the VM Guest and have been using it for some time, the initial size of the image may no longer be sufficient. In that case, add more space to it.

To increase the size of an existing disk image by 2 gigabytes, use:

```
tux > qemu-img resize /images/sles.raw +2GB
```



#### Note

You can resize the disk image using the formats `raw`, `qcow2` and `qed`. To resize an image in another format, convert it to a supported format with **`qemu-img convert`** first.

The image now contains an empty space of 2 GB after the final partition. You can resize the existing partitions or add new ones.

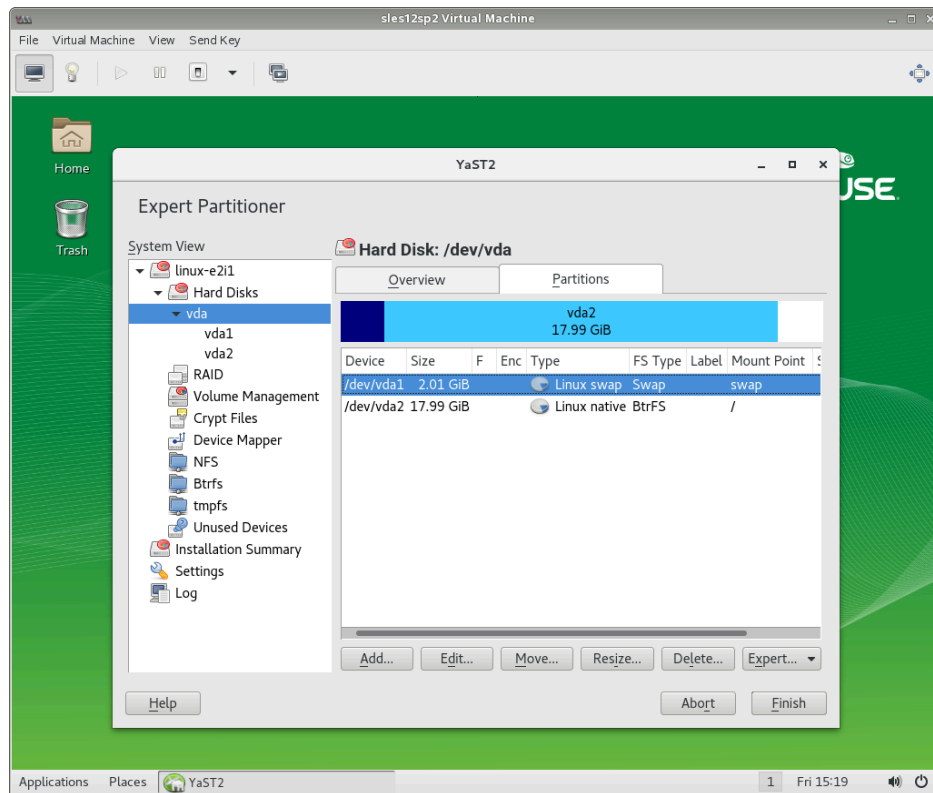


FIGURE 28.1: NEW 2 GB PARTITION IN GUEST YAST PARTITIONER

#### 28.2.2.5 Advanced Options for the qcow2 File Format

*qcow2* is the main disk image format used by QEMU. Its size grows on demand, and the disk space is only allocated when it is actually needed by the virtual machine.

A *qcow2* formatted file is organized in units of constant size. These units are called *clusters*. Viewed from the guest side, the virtual disk is also divided into clusters of the same size. QEMU defaults to 64 kB clusters, but you can specify a different value when creating a new image:

```
tux > qemu-img create -f qcow2 -o cluster_size=128K virt_disk.qcow2 4G
```

A *qcow2* image contains a set of tables organized in two levels that are called the L1 and L2 tables. There is just one L1 table per disk image, while there can be many L2 tables depending on how big the image is.

To read or write data to the virtual disk, QEMU needs to read its corresponding L2 table to find out the relevant data location. Because reading the table for each I/O operation consumes system resources, QEMU keeps a cache of L2 tables in memory to speed up disk access.

#### 28.2.2.5.1 Choosing the Right Cache Size

The cache size relates to the amount of allocated space. L2 cache can map the following amount of virtual disk:

```
disk_size = l2_cache_size * cluster_size / 8
```

With the default 64 kB of cluster size, that is

```
disk_size = l2_cache_size * 8192
```

Therefore, to have a cache that maps n gigabytes of disk space with the default cluster size, you need

```
l2_cache_size = disk_size_GB * 131072
```

QEMU uses 1 MB (1048576 bytes) of L2 cache by default. Following the above formulas, 1 MB of L2 cache covers 8 GB (1048576 / 131072) of virtual disk. This means that the performance is fine with the default L2 cache size if your virtual disk size is up to 8 GB. For larger disks, you can speed up the disk access by increasing the L2 cache size.

#### 28.2.2.5.2 Configuring the Cache Size

You can use the `-drive` option on the QEMU command line to specify the cache sizes. Alternatively when communicating via QMP, use the `blockdev-add` command. For more information on QMP, see [Section 30.11, “QMP - QEMU Machine Protocol”](#).

The following options configure the cache size for the virtual guest:

##### `l2-cache-size`

The maximum size of the L2 table cache.

##### `refcount-cache-size`

The maximum size of the *refcount* block cache. For more information on *refcount*, see <https://raw.githubusercontent.com/qemu/qemu/master/docs/qcow2-cache.txt> [↗](#).

## cache-size

The maximum size of both caches combined.

When specifying values for the options above, be aware of the following:

- The size of both the L2 and refcount block caches needs to be a multiple of the cluster size.
- If you only set one of the options, QEMU will automatically adjust the other options so that the L2 cache is 4 times bigger than the refcount cache.

The refcount cache is used much less often than the L2 cache, therefore you can keep it relatively small:

```
root # qemu-system-ARCH [...] \  
-drive file=disk_image.qcow2,l2-cache-size=4194304,refcount-cache-size=262144
```

### 28.2.2.5.3 Reducing the Memory Usage

The larger the cache, the more memory it consumes. There is a separate L2 cache for each qcow2 file. When using a lot of big disk images, you will probably need a considerably large amount of memory. Memory consumption is even worse if you add backing files ([Section 28.2.4, “Manipulate Disk Images Effectively”](#)) and snapshots (see [Section 28.2.3, “Managing Snapshots of Virtual Machines with qemu-img”](#)) to the guest's setup chain.

That is why QEMU introduced the `cache-clean-interval` setting. It defines an interval in seconds after which all cache entries that have not been accessed are removed from memory.

The following example removes all unused cache entries every 10 minutes:

```
root # qemu-system-ARCH [...] -drive file=hd.qcow2,cache-clean-interval=600
```

If this option is not set, the default value is 0 and it disables this feature.

## 28.2.3 Managing Snapshots of Virtual Machines with qemu-img

*Virtual Machine* snapshots are snapshots of the complete environment in which a VM Guest is running. The snapshot includes the state of the processor (CPU), memory (RAM), devices, and all writable disks.

Snapshots are helpful when you need to save your virtual machine in a particular state. For example, after you configured network services on a virtualized server and want to quickly start the virtual machine in the same state you last saved it. Or you can create a snapshot after



the virtual machine has been powered off to create a backup state before you try something experimental and possibly make VM Guest unstable. This section introduces the latter case, while the former is described in [Chapter 30, Virtual Machine Administration Using QEMU Monitor](#).

To use snapshots, your VM Guest must contain at least one writable hard disk image in `qcow2` format. This device is usually the first virtual hard disk.

*Virtual Machine* snapshots are created with the `savevm` command in the interactive QEMU monitor. To make identifying a particular snapshot easier, you can assign it a *tag*. For more information on QEMU monitor, see [Chapter 30, Virtual Machine Administration Using QEMU Monitor](#).

Once your `qcow2` disk image contains saved snapshots, you can inspect them with the `qemu-img snapshot` command.



### Warning: Shut Down the VM Guest

Do not create or delete virtual machine snapshots with the `qemu-img snapshot` command while the virtual machine is running. Otherwise, you may damage the disk image with the state of the virtual machine saved.

#### 28.2.3.1 Listing Existing Snapshots

Use `qemu-img snapshot -l DISK_IMAGE` to view a list of all existing snapshots saved in the `disk_image` image. You can get the list even while the VM Guest is running.

```
tux > qemu-img snapshot -l /images/sles.qcow2
Snapshot list:
ID ①      TAG ②          VM SIZE ③      DATE ④          VM CLOCK ⑤
1      booting      4.4M 2013-11-22 10:51:10    00:00:20.476
2      booted       184M 2013-11-22 10:53:03    00:02:05.394
3      logged_in    273M 2013-11-22 11:00:25    00:04:34.843
4      ff_and_term_running 372M 2013-11-22 11:12:27    00:08:44.965
```

- ① Unique identification number of the snapshot. Usually auto-incremented.
- ② Unique description string of the snapshot. It is meant as a human-readable version of the ID.
- ③ The disk space occupied by the snapshot. Note that the more memory is consumed by running applications, the bigger the snapshot is.
- ④ Time and date the snapshot was created.
- ⑤ The current state of the virtual machine's clock.

### 28.2.3.2 Creating Snapshots of a Powered-Off Virtual Machine

Use **qemu-img snapshot -c** *SNAPSHOT\_TITLE* *DISK\_IMAGE* to create a snapshot of the current state of a virtual machine that was previously powered off.

```
tux > qemu-img snapshot -c backup_snapshot /images/sles.qcow2
```

```
tux > qemu-img snapshot -l /images/sles.qcow2
```

Snapshot list:

ID	TAG	VM SIZE	DATE	VM CLOCK
1	booting	4.4M	2013-11-22 10:51:10	00:00:20.476
2	booted	184M	2013-11-22 10:53:03	00:02:05.394
3	logged_in	273M	2013-11-22 11:00:25	00:04:34.843
4	ff_and_term_running	372M	2013-11-22 11:12:27	00:08:44.965
5	backup_snapshot	0	2013-11-22 14:14:00	00:00:00.000

If something breaks in your VM Guest and you need to restore the state of the saved snapshot (ID 5 in our example), power off your VM Guest and execute the following command:

```
tux > qemu-img snapshot -a 5 /images/sles.qcow2
```

The next time you run the virtual machine with **qemu-system-ARCH**, it will be in the state of snapshot number 5.



#### Note

The **qemu-img snapshot -c** command is not related to the **savevm** command of QEMU monitor (see [Chapter 30, Virtual Machine Administration Using QEMU Monitor](#)). For example, you cannot apply a snapshot with **qemu-img snapshot -a** on a snapshot created with **savevm** in QEMU's monitor.

### 28.2.3.3 Deleting Snapshots

Use **qemu-img snapshot -d** *SNAPSHOT\_ID* *DISK\_IMAGE* to delete old or unneeded snapshots of a virtual machine. This saves some disk space inside the *qcow2* disk image as the space occupied by the snapshot data is restored:

```
tux > qemu-img snapshot -d 2 /images/sles.qcow2
```

## 28.2.4 Manipulate Disk Images Effectively

Imagine the following real-life situation: you are a server administrator who runs and manages several virtualized operating systems. One group of these systems is based on one specific distribution, while another group (or groups) is based on different versions of the distribution or even on a different (and maybe non-Unix) platform. To make the case even more complex, individual virtual guest systems based on the same distribution usually differ according to the department and deployment. A file server typically uses a different setup and services than a Web server does, while both may still be based on SUSE® Linux Enterprise Server.

With QEMU it is possible to create “base” disk images. You can use them as template virtual machines. These base images will save you plenty of time because you will never need to install the same operating system more than once.

### 28.2.4.1 Base and Derived Images

First, build a disk image as usual and install the target system on it. For more information, see [Section 28.1, “Basic Installation with qemu-system-ARCH”](#) and [Section 28.2.2, “Creating, Converting and Checking Disk Images”](#). Then build a new image while using the first one as a base image. The base image is also called a *backing* file. After your new *derived* image is built, never boot the base image again, but boot the derived image instead. Several derived images may depend on one base image at the same time. Therefore, changing the base image can damage the dependencies. While using your derived image, QEMU writes changes to it and uses the base image only for reading.

It is a good practice to create a base image from a freshly installed (and, if needed, registered) operating system with no patches applied and no additional applications installed or removed. Later on, you can create another base image with the latest patches applied and based on the original base image.

### 28.2.4.2 Creating Derived Images



#### Note

While you can use the `raw` format for base images, you cannot use it for derived images because the `raw` format does not support the `backing_file` option. Use for example the `qcow2` format for the derived images.

For example, `/images/sles_base.raw` is the base image holding a freshly installed system.

```
tux > qemu-img info /images/sles_base.raw
image: /images/sles_base.raw
file format: raw
virtual size: 4.0G (4294967296 bytes)
disk size: 2.4G
```

The image's reserved size is 4 GB, the actual size is 2.4 GB, and its format is `raw`. Create an image derived from the `/images/sles_base.raw` base image with:

```
tux > qemu-img create -f qcow2 /images/sles_derived.qcow2 \
-o backing_file=/images/sles_base.raw
Formatting '/images/sles_derived.qcow2', fmt=qcow2 size=4294967296 \
backing_file='/images/sles_base.raw' encryption=off cluster_size=0
```

Look at the derived image details:

```
tux > qemu-img info /images/sles_derived.qcow2
image: /images/sles_derived.qcow2
file format: qcow2
virtual size: 4.0G (4294967296 bytes)
disk size: 140K
cluster_size: 65536
backing file: /images/sles_base.raw \
(actual path: /images/sles_base.raw)
```

Although the reserved size of the derived image is the same as the size of the base image (4 GB), the actual size is 140 KB only. The reason is that only changes made to the system inside the derived image are saved. Run the derived virtual machine, register it, if needed, and apply the latest patches. Do any other changes in the system such as removing unneeded or installing new software packages. Then shut the VM Guest down and examine its details once more:

```
tux > qemu-img info /images/sles_derived.qcow2
image: /images/sles_derived.qcow2
file format: qcow2
virtual size: 4.0G (4294967296 bytes)
disk size: 1.1G
cluster_size: 65536
backing file: /images/sles_base.raw \
(actual path: /images/sles_base.raw)
```

The `disk size` value has grown to 1.1 GB, which is the disk space occupied by the changes on the file system compared to the base image.

### 28.2.4.3 Rebasing Derived Images

After you have modified the derived image (applied patches, installed specific applications, changed environment settings, etc.), it reaches the desired state. At that point, you can merge the original base image and the derived image to create a new base image.

Your original base image (`/images/sles_base.raw`) holds a freshly installed system. It can be a template for new modified base images, while the new one can contain the same system as the first one plus all security and update patches applied, for example. After you have created this new base image, you can use it as a template for more specialized derived images as well. The new base image becomes independent of the original one. The process of creating base images from derived ones is called *rebasing*:

```
tux > qemu-img convert /images/sles_derived.qcow2 \  
-O raw /images/sles_base2.raw
```

This command created the new base image `/images/sles_base2.raw` using the `raw` format.

```
tux > qemu-img info /images/sles_base2.raw  
image: /images/sles11_base2.raw  
file format: raw  
virtual size: 4.0G (4294967296 bytes)  
disk size: 2.8G
```

The new image is 0.4 gigabytes bigger than the original base image. It uses no backing file, and you can easily create new derived images based upon it. This lets you create a sophisticated hierarchy of virtual disk images for your organization, saving a lot of time and work.

### 28.2.4.4 Mounting an Image on a VM Host Server

It can be useful to mount a virtual disk image under the host system. It is strongly recommended to read [Chapter 17, libguestfs](#) and use dedicated tools to access a virtual machine image. However, if you need to do this manually, follow this guide.

Linux systems can mount an internal partition of a `raw` disk image using a loopback device. The first example procedure is more complex but more illustrative, while the second one is straightforward:

#### PROCEDURE 28.1: MOUNTING DISK IMAGE BY CALCULATING PARTITION OFFSET

1. Set a *loop* device on the disk image whose partition you want to mount.

```
tux > losetup /dev/loop0 /images/sles_base.raw
```

2. Find the *sector size* and the starting *sector number* of the partition you want to mount.

```
tux > fdisk -lu /dev/loop0
```

```
Disk /dev/loop0: 4294 MB, 4294967296 bytes
255 heads, 63 sectors/track, 522 cylinders, total 8388608 sectors
Units = sectors of 1 * 512 = 512 ❶ bytes
Disk identifier: 0x000ceca8
```

Device	Boot	Start	End	Blocks	Id	System
/dev/loop0p1		63	1542239	771088+	82	Linux swap
/dev/loop0p2	*	1542240 ❷	8385929	3421845	83	Linux

- ❶ The disk sector size.
- ❷ The starting sector of the partition.

3. Calculate the partition start offset:

```
sector_size * sector_start = 512 * 1542240 = 789626880
```

4. Delete the loop and mount the partition inside the disk image with the calculated offset on a prepared directory.

```
tux > losetup -d /dev/loop0
tux > mount -o loop,offset=789626880 \
/images/sles_base.raw /mnt/sles/
tux > ls -l /mnt/sles/
total 112
drwxr-xr-x  2 root root  4096 Nov 16 10:02 bin
drwxr-xr-x  3 root root  4096 Nov 16 10:27 boot
drwxr-xr-x  5 root root  4096 Nov 16 09:11 dev
[...]
drwxrwxrwt 14 root root  4096 Nov 24 09:50 tmp
drwxr-xr-x 12 root root  4096 Nov 16 09:16 usr
drwxr-xr-x 15 root root  4096 Nov 16 09:22 var
```

5. Copy one or more files onto the mounted partition and unmount it when finished.

```
tux > cp /etc/X11/xorg.conf /mnt/sles/root/tmp
tux > ls -l /mnt/sles/root/tmp
tux > umount /mnt/sles/
```



## Warning: Do not Write to Images Currently in Use

Never mount a partition of an image of a running virtual machine in a read-write mode. This could corrupt the partition and break the whole VM Guest.

## 29 Running Virtual Machines with qemu-system-ARCH

Once you have a virtual disk image ready (for more information on disk images, see [Section 28.2, “Managing Disk Images with qemu-img”](#)), it is time to start the related virtual machine. [Section 28.1, “Basic Installation with qemu-system-ARCH”](#) introduced simple commands to install and run a VM Guest. This chapter focuses on a more detailed explanation of **qemu-system-ARCH** usage, and shows solutions for more specific tasks. For a complete list of **qemu-system-ARCH**'s options, see its manual page (`man 1 qemu`).

### 29.1 Basic qemu-system-ARCH Invocation

The **qemu-system-ARCH** command uses the following syntax:

```
qemu-system-ARCH options ❶ disk_img ❷
```

- ❶ **qemu-system-ARCH** understands many options. Most of them define parameters of the emulated hardware, while others affect more general emulator behavior. If you do not supply any options, default values are used, and you need to supply the path to a disk image to be run.
- ❷ Path to the disk image holding the guest system you want to virtualize. **qemu-system-ARCH** supports many image formats. Use `qemu-img --help` to list them. If you do not supply the path to a disk image as a separate argument, you need to use the `-drive file=` option.

### 29.2 General qemu-system-ARCH Options

This section introduces general **qemu-system-ARCH** options and options related to the basic emulated hardware, such as the virtual machine's processor, memory, model type, or time processing methods.

`-name NAME_OF_GUEST`

Specifies the name of the running guest system. The name is displayed in the window caption and used for the VNC server.



### -boot *OPTIONS*

Specifies the order in which the defined drives will be booted. Drives are represented by letters, where a and b stand for the floppy drives 1 and 2, c stands for the first hard disk, d stands for the first CD-ROM drive, and n to p stand for Ether-boot network adapters. For example, `qemu-system-ARCH [...] -boot order=ndc` first tries to boot from network, then from the first CD-ROM drive, and finally from the first hard disk.

### -pidfile *FILENAME*

Stores the QEMU's process identification number (PID) in a file. This is useful if you run QEMU from a script.

### -nodefaults

By default QEMU creates basic virtual devices even if you do not specify them on the command line. This option turns this feature off, and you must specify every single device manually, including graphical and network cards, parallel or serial ports, or virtual consoles. Even QEMU monitor is not attached by default.

### -daemonize

“Daemonizes” the QEMU process after it is started. QEMU will detach from the standard input and standard output after it is ready to receive connections on any of its devices.



## Note: SeaBIOS BIOS Implementation

SeaBIOS is the default BIOS used. You can boot USB devices, any drive (CD-ROM, Floppy, or a hard disk). It has USB mouse and keyboard support and supports multiple VGA cards. For more information about SeaBIOS, refer to the [SeaBIOS Website \(https://www.seabios.org/SeaBIOS\)](https://www.seabios.org/SeaBIOS).

## 29.2.1 Basic Virtual Hardware

### 29.2.1.1 Machine Type

You can specify the type of the emulated machine. Run `qemu-system-ARCH -M help` to view a list of supported machine types.



## Note: ISA-PC

The machine type *isapc*: *ISA-only-PC* is unsupported.

### 29.2.1.2 CPU Model

To specify the type of the processor (CPU) model, run `qemu-system-ARCH -cpu MODEL`. Use `qemu-system-ARCH -cpu help` to view a list of supported CPU models.

CPU flags information can be found at [CPUID Wikipedia \(http://en.wikipedia.org/wiki/CPUID\)](http://en.wikipedia.org/wiki/CPUID).

### 29.2.1.3 Other Basics Options

The following is a list of most commonly used options while launching *qemu* from command line. To see all options available refer to *qemu-doc* man page.

#### `-m MEGABYTES`

Specifies how many megabytes are used for the virtual RAM size.

#### `-balloon virtio`

Specifies a paravirtualized device to dynamically change the amount of virtual RAM memory assigned to VM Guest. The top limit is the amount of memory specified with `-m`.

#### `-smp NUMBER_OF_CPUS`

Specifies how many CPUs will be emulated. QEMU supports up to 255 CPUs on the PC platform (up to 64 with KVM acceleration used). This option also takes other CPU-related parameters, such as number of *sockets*, number of *cores* per socket, or number of *threads* per core.

The following is an example of a working `qemu-system-ARCH` command line:

```
tux > qemu-system-x86_64 -name "SLES 12 SP2" -M pc-i440fx-2.7 -m 512 \
-machine accel=kvm -cpu kvm64 -smp 2 -drive /images/sles.raw
```

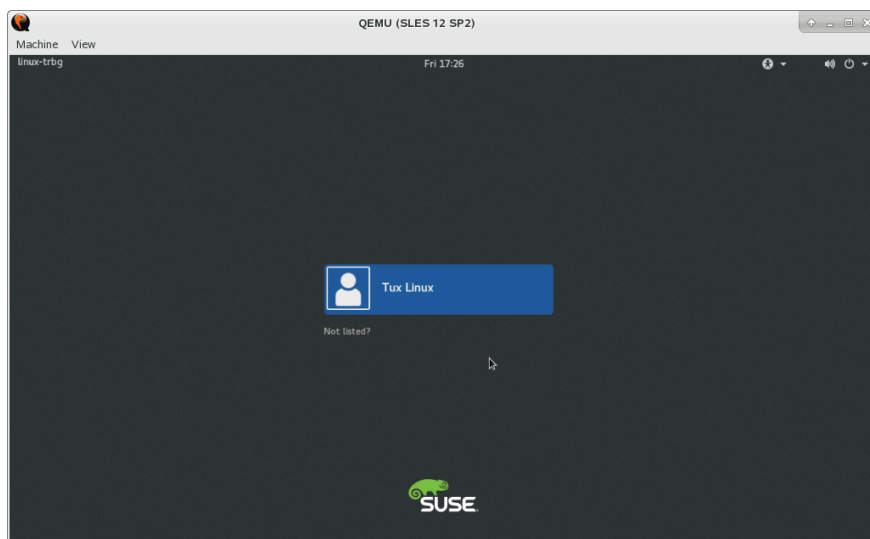


FIGURE 29.1: QEMU WINDOW WITH SLES 11 SP3 AS VM GUEST

#### -no-acpi

Disables *ACPI* support.

#### -S

QEMU starts with CPU stopped. To start CPU, enter c in QEMU monitor. For more information, see *Chapter 30, Virtual Machine Administration Using QEMU Monitor*.

## 29.2.2 Storing and Reading Configuration of Virtual Devices

#### -readconfig CFG\_FILE

Instead of entering the devices configuration options on the command line each time you want to run VM Guest, **qemu-system-ARCH** can read it from a file that was either previously saved with -writeconfig or edited manually.

#### -writeconfig CFG\_FILE

Dumps the current virtual machine's devices configuration to a text file. It can be consequently re-used with the -readconfig option.

```
tux > qemu-system-x86_64 -name "SLES 12 SP2" -machine accel=kvm -M pc-i440fx-2.7 -m
512 -cpu kvm64 \
-smp 2 /images/sles.raw -writeconfig /images/sles.cfg
(exited)
tux > cat /images/sles.cfg
# qemu config file
```

```
[drive]
  index = "0"
  media = "disk"
  file = "/images/sles_base.raw"
```

This way you can effectively manage the configuration of your virtual machines' devices in a well-arranged way.

### 29.2.3 Guest Real-Time Clock

#### -rtc OPTIONS

Specifies the way the RTC is handled inside a VM Guest. By default, the clock of the guest is derived from that of the host system. Therefore, it is recommended that the host system clock is synchronized with an accurate external clock (for example, via NTP service).

If you need to isolate the VM Guest clock from the host one, specify clock=vm instead of the default clock=host.

You can also specify the initial time of the VM Guest's clock with the base option:

```
qemu-system-x86_64 [...] -rtc clock=vm,base=2010-12-03T01:02:00
```

Instead of a time stamp, you can specify utc or localtime. The former instructs VM Guest to start at the current UTC value (Coordinated Universal Time, see <http://en.wikipedia.org/wiki/UTC>), while the latter applies the local time setting.

## 29.3 Using Devices in QEMU

QEMU virtual machines emulate all devices needed to run a VM Guest. QEMU supports, for example, several types of network cards, block devices (hard and removable drives), USB devices, character devices (serial and parallel ports), or multimedia devices (graphic and sound cards). This section introduces options to configure various types of supported devices.



#### Tip

If your device, such as -drive, needs a special driver and driver properties to be set, specify them with the -device option, and identify with drive= suboption. For example:

```
qemu-system-x86_64 [...] -drive if=none,id=drive0,format=raw \
```

```
-device virtio-blk-pci,drive=drive0,scsi=off ...
```

To get help on available drivers and their properties, use `-device ?` and `-device DRIVER, ?`.

### 29.3.1 Block Devices

Block devices are vital for virtual machines. In general, these are fixed or removable storage media usually called *drives*. One of the connected hard disks typically holds the guest operating system to be virtualized.

*Virtual Machine* drives are defined with `-drive`. This option has many sub-options, some of which are described in this section. For the complete list, see the manual page ([man 1 qemu](#)).

#### SUB-OPTIONS FOR THE `-drive` OPTION

file=*image\_fname*

Specifies the path to the disk image that will be used with this drive. If not specified, an empty (removable) drive is assumed.

if=*drive\_interface*

Specifies the type of interface to which the drive is connected. Currently only floppy, scsi, ide, or virtio are supported by SUSE. virtio defines a paravirtualized disk driver. Default is ide.

index=*index\_of\_connector*

Specifies the index number of a connector on the disk interface (see the if option) where the drive is connected. If not specified, the index is automatically incremented.

media=*type*

Specifies the type of media. Can be disk for hard disks, or cdrom for removable CD-ROM drives.

format=*img\_fmt*

Specifies the format of the connected disk image. If not specified, the format is autodetected. Currently, SUSE supports qcow2, qed and raw formats.

## cache=method

Specifies the caching method for the drive. Possible values are `unsafe`, `writethrough`, `writeback`, `directsync`, or `none`. To improve performance when using the `qcow2` image format, select `writeback`. `none` disables the host page cache and, therefore, is the safest option. Default for image files is `writeback`. For more information, see [Chapter 15, Disk Cache Modes](#).



### Tip

To simplify defining block devices, QEMU understands several shortcuts which you may find handy when entering the `qemu-system-ARCH` command line.

You can use

```
qemu-system-x86_64 -cdrom /images/cdrom.iso
```

instead of

```
qemu-system-x86_64 -drive file=/images/cdrom.iso,index=2,media=cdrom
```

and

```
qemu-system-x86_64 -hda /images/image1.raw -hdb /images/image2.raw -hdc \
/images/image3.raw -hdd /images/image4.raw
```

instead of

```
qemu-system-x86_64 -drive file=/images/image1.raw,index=0,media=disk \
-drive file=/images/image2.raw,index=1,media=disk \
-drive file=/images/image3.raw,index=2,media=disk \
-drive file=/images/image4.raw,index=3,media=disk
```



### Tip: Using Host Drives Instead of Images

As an alternative to using disk images (see [Section 28.2, “Managing Disk Images with `qemu-img`”](#)) you can also use existing VM Host Server disks, connect them as drives, and access them from VM Guest. Use the host disk device directly instead of disk image file names.

To access the host CD-ROM drive, use

```
qemu-system-x86_64 [...] -drive file=/dev/cdrom,media=cdrom
```

To access the host hard disk, use

```
qemu-system-x86_64 [...] -drive file=/dev/hdb,media=disk
```

A host drive used by a VM Guest must not be accessed concurrently by the VM Host Server or another VM Guest.

### 29.3.1.1 Freeing Unused Guest Disk Space

A *sparse image file* is a type of disk image file that grows in size as the user adds data to it, taking up only as much disk space as is stored in it. For example, if you copy 1 GB of data inside the sparse disk image, its size grows by 1 GB. If you then delete for example 500 MB of the data, the image size does not by default decrease as expected.

That is why the `discard=on` option is introduced on the KVM command line. It tells the hypervisor to automatically free the “holes” after deleting data from the sparse guest image. Note that this option is valid only for the `if=scsi` drive interface:

```
qemu-system-x86_64 [...] -drive file=/path/to/file.img,if=scsi,discard=on
```



#### Important: Support Status

`if=scsi` is not supported. This interface does not map to *virtio-scsi*, but rather to the *lsi SCSI adapter*.

### 29.3.1.2 IOThreads

IOThreads are dedicated event loop threads for virtio devices to perform I/O requests in order to improve scalability, especially on an SMP VM Host Server with SMP VM Guests using many disk devices. Instead of using QEMU's main event loop for I/O processing, IOThreads allow spreading I/O work across multiple CPUs and can improve latency when properly configured.

IOThreads are enabled by defining IOThread objects. virtio devices can then use the objects for their I/O event loops. Many virtio devices can use a single IOThread object, or virtio devices and IOThread objects can be configured in a 1:1 mapping. The following example creates a single IOThread with ID `iothread0` which is then used as the event loop for two virtio-blk devices.

```
tux > qemu-system-x86_64 [...] -object iothread,id=iothread0\
```

```
-drive if=none,id=drive0,cache=none,aio=native,\
format=raw,file=filename -device virtio-blk-pci,drive=drive0,scsi=off,\
iothread=iothread0 -drive if=none,id=drive1,cache=none,aio=native,\
format=raw,file=filename -device virtio-blk-pci,drive=drive1,scsi=off,\
iothread=iothread0 [...]
```

The following qemu command line example illustrates a 1:1 virtio device to IOThread mapping:

```
tux > qemu-system-x86_64 [...] -object iothread,id=iothread0\
-object iothread,id=iothread1 -drive if=none,id=drive0,cache=none,aio=native,\
format=raw,file=filename -device virtio-blk-pci,drive=drive0,scsi=off,\
iothread=iothread0 -drive if=none,id=drive1,cache=none,aio=native,\
format=raw,file=filename -device virtio-blk-pci,drive=drive1,scsi=off,\
iothread=iothread1 [...]
```

### 29.3.1.3 Bio-Based I/O Path for virtio-blk

For better performance of I/O-intensive applications, a new I/O path was introduced for the virtio-blk interface in kernel version 3.7. This bio-based block device driver skips the I/O scheduler, and thus shortens the I/O path in guest and has lower latency. It is especially useful for high-speed storage devices, such as SSD disks.

The driver is disabled by default. To use it, do the following:

1. Append `virtio_blk.use_bio=1` to the kernel command line on the guest. You can do so via *YaST* > *System* > *Boot Loader*.  
You can do it also by editing `/etc/default/grub`, searching for the line that contains `GRUB_CMDLINE_LINUX_DEFAULT=`, and adding the kernel parameter at the end. Then run **`grub2-mkconfig >/boot/grub2/grub.cfg`** to update the grub2 boot menu.
2. Reboot the guest with the new kernel command line active.



#### Tip: Bio-Based Driver on Slow Devices

The bio-based virtio-blk driver does not help on slow devices such as spin hard disks. The reason is that the benefit of scheduling is larger than what the shortened bio path offers. Do not use the bio-based driver on slow devices.



### 29.3.1.4 Accessing iSCSI Resources Directly

QEMU now integrates with `libiscsi`. This allows QEMU to access iSCSI resources directly and use them as virtual machine block devices. This feature does not require any host iSCSI initiator configuration, as is needed for a libvirt iSCSI target based storage pool setup. Instead it directly connects guest storage interfaces to an iSCSI target LUN by means of the user space library `libiscsi`. iSCSI-based disk devices can also be specified in the libvirt XML configuration.



#### Note: RAW Image Format

This feature is only available using the RAW image format, as the iSCSI protocol has some technical limitations.

The following is the QEMU command line interface for iSCSI connectivity.



#### Note: virt-manager Limitation

The use of `libiscsi` based storage provisioning is not yet exposed by the `virt-manager` interface, but instead it would be configured by directly editing the guest xml. This new way of accessing iSCSI based storage is to be done at the command line.

```
qemu-system-x86_64 -machine accel=kvm \  
-drive file=iscsi://192.168.100.1:3260/iqn.2016-08.com.example:314605ab-a88e-49af-  
b4eb-664808a3443b/0,\  
format=raw,if=none,id=mydrive,cache=none \  
-device ide-hd,bus=ide.0,unit=0,drive=mydrive ...
```

Here is an example snippet of guest domain xml which uses the protocol based iSCSI:

```
<devices>  
...  
<disk type='network' device='disk'>  
  <driver name='qemu' type='raw'/>  
  <source protocol='iscsi' name='iqn.2013-07.com.example:iscsi-nopool/2'>  
    <host name='example.com' port='3260'/>  
  </source>  
  <auth username='myuser'>  
    <secret type='iscsi' usage='libvirtiscsi'/>  
  </auth>  
  <target dev='vda' bus='virtio'/>  
</disk>  
</devices>
```

Contrast that with an example which uses the host based iSCSI initiator which virt-manager sets up:

```
<devices>
...
  <disk type='block' device='disk'>
    <driver name='qemu' type='raw' cache='none' io='native' />
    <source dev='/dev/disk/by-path/scsi-0:0:0:0' />
    <target dev='hda' bus='ide' />
    <address type='drive' controller='0' bus='0' target='0' unit='0' />
  </disk>
  <controller type='ide' index='0'>
    <address type='pci' domain='0x0000' bus='0x00' slot='0x01'
      function='0x1' />
  </controller>
</devices>
```

### 29.3.1.5 Using RADOS Block Devices with QEMU

RADOS Block Devices (RBD) store data in a Ceph cluster. They allow snapshotting, replication, and data consistency. You can use an RBD from your KVM-managed VM Guests similarly to how you use other block devices.

Refer to [SUSE Enterprise Storage documentation \(https://documentation.suse.com/ses/html/ses-all/cha-ceph-kvm.html\)](https://documentation.suse.com/ses/html/ses-all/cha-ceph-kvm.html) for more details.

## 29.3.2 Graphic Devices and Display Options

This section describes QEMU options affecting the type of the emulated video card and the way VM Guest graphical output is displayed.

### 29.3.2.1 Defining Video Cards

QEMU uses `-vga` to define a video card used to display VM Guest graphical output. The `-vga` option understands the following values:

#### none

Disables video cards on VM Guest (no video card is emulated). You can still access the running VM Guest via the serial console.

### std

Emulates a standard VESA 2.0 VBE video card. Use it if you intend to use high display resolution on VM Guest.

### cirrus

Emulates Cirrus Logic GD5446 video card. Good choice if you insist on high compatibility of the emulated video hardware. Most operating systems (even Windows 95) recognize this type of card.



### Tip

For best video performance with the cirrus type, use 16-bit color depth both on VM Guest and VM Host Server.

## 29.3.2.2 Display Options

The following options affect the way VM Guest graphical output is displayed.

### -display gtk

Display video output in a GTK window. This interface provides UI elements to configure and control the VM during runtime.

### -display sdl

Display video output via SDL, usually in a separate graphics window. For more information, see the SDL documentation.

### -spice option[,option[,...]]

Enables the spice remote desktop protocol.

### -display vnc

Refer to [Section 29.5, “Viewing a VM Guest with VNC”](#) for more information.

### -nographic

Disables QEMU's graphical output. The emulated serial port is redirected to the console. After starting the virtual machine with -nographic, press **Ctrl** **A** **H** in the virtual console to view the list of other useful shortcuts, for example, to toggle between the console and the QEMU monitor.

```
tux > qemu-system-x86_64 -hda /images/sles_base.raw -nographic
```

```
C-a h    print this help
C-a x    exit emulator
C-a s    save disk data back to file (if -snapshot)
C-a t    toggle console timestamps
C-a b    send break (magic sysrq)
C-a c    switch between console and monitor
C-a C-a  sends C-a
          (pressed C-a c)

QEMU 2.3.1 monitor - type 'help' for more information
(qemu)
```

#### -no-frame

Disables decorations for the QEMU window. Convenient for dedicated desktop work space.

#### -full-screen

Starts QEMU graphical output in full screen mode.

#### -no-quit

Disables the close button of the QEMU window and prevents it from being closed by force.

#### -alt-grab, -ctrl-grab

By default, the QEMU window releases the “captured” mouse after pressing **Ctrl – Alt** . You can change the key combination to either **Ctrl – Alt – Shift** (-alt-grab), or the right **Ctrl** key (-ctrl-grab).

### 29.3.3 USB Devices

There are two ways to create USB devices usable by the VM Guest in KVM: you can either emulate new USB devices inside a VM Guest, or assign an existing host USB device to a VM Guest. To use USB devices in QEMU you first need to enable the generic USB driver with the -usb option. Then you can specify individual devices with the -usbdevice option.

#### 29.3.3.1 Emulating USB Devices in VM Guest

SUSE currently supports the following types of USB devices: disk, host, serial, braille, net, mouse, and tablet.

## TYPES OF USB DEVICES FOR THE `-usbdevice` OPTION

### disk

Emulates a mass storage device based on file. The optional `format` option is used rather than detecting the format.

```
qemu-system-x86_64 [...] -usbdevice  
    disk:format=raw:/virt/usb_disk.raw
```

### host

Pass through the host device (identified by `bus.addr`).

### serial

Serial converter to a host character device.

### braille

Emulates a braille device using BrlAPI to display the braille output.

### net

Emulates a network adapter that supports CDC Ethernet and RNDIS protocols.

### mouse

Emulates a virtual USB mouse. This option overrides the default PS/2 mouse emulation. The following example shows the hardware status of a mouse on VM Guest started with `qemu-system-ARCH [...] -usbdevice mouse`:

```
tux > sudo hwinfo --mouse  
20: USB 00.0: 10503 USB Mouse  
[Created at usb.122]  
UDI: /org/freedesktop/Hal/devices/usb_device_627_1_1_if0  
[...]  
Hardware Class: mouse  
Model: "Adomax QEMU USB Mouse"  
Hotplug: USB  
Vendor: usb 0x0627 "Adomax Technology Co., Ltd"  
Device: usb 0x0001 "QEMU USB Mouse"  
[...]
```

### tablet

Emulates a pointer device that uses absolute coordinates (such as touchscreen). This option overrides the default PS/2 mouse emulation. The tablet device is useful if you are viewing VM Guest via the VNC protocol. See [Section 29.5, “Viewing a VM Guest with VNC”](#) for more information.

## 29.3.4 Character Devices

Use `-chardev` to create a new character device. The option uses the following general syntax:

```
qemu-system-x86_64 [...] -chardev BACKEND_TYPE,id=ID_STRING
```

where `BACKEND_TYPE` can be one of `null`, `socket`, `udp`, `msmouse`, `vc`, `file`, `pipe`, `console`, `serial`, `pty`, `stdio`, `braille`, `tty`, or `parport`. All character devices must have a unique identification string up to 127 characters long. It is used to identify the device in other related directives. For the complete description of all back-end's sub-options, see the manual page (`man 1 qemu`). A brief description of the available `back-ends` follows:

### `null`

Creates an empty device that outputs no data and drops any data it receives.

### `stdio`

Connects to QEMU's process standard input and standard output.

### `socket`

Creates a two-way stream socket. If `PATH` is specified, a Unix socket is created:

```
qemu-system-x86_64 [...] -chardev \  
socket,id=unix_socket1,path=/tmp/unix_socket1,server
```

The `SERVER` suboption specifies that the socket is a listening socket.

If `PORT` is specified, a TCP socket is created:

```
qemu-system-x86_64 [...] -chardev \  
socket,id=tcp_socket1,host=localhost,port=7777,server,nowait
```

The command creates a local listening (`server`) TCP socket on port 7777. QEMU will not block waiting for a client to connect to the listening port (`nowait`).

### `udp`

Sends all network traffic from VM Guest to a remote host over the UDP protocol.

```
qemu-system-x86_64 [...] \  
-chardev udp,id=udp_fwd,host=mercury.example.com,port=7777
```

The command binds port 7777 on the remote host `mercury.example.com` and sends VM Guest network traffic there.

## vc

Creates a new QEMU text console. You can optionally specify the dimensions of the virtual console:

```
qemu-system-x86_64 [...] -chardev vc,id=vc1,width=640,height=480 \  
-mon chardev=vc1
```

The command creates a new virtual console called vc1 of the specified size, and connects the QEMU monitor to it.

## file

Logs all traffic from VM Guest to a file on VM Host Server. The path is required and will be created if it does not exist.

```
qemu-system-x86_64 [...] \  
-chardev file,id=qemu_log1,path=/var/log/qemu/guest1.log
```

By default QEMU creates a set of character devices for serial and parallel ports, and a special console for QEMU monitor. However, you can create your own character devices and use them for the mentioned purposes. The following options will help you:

### -serial CHAR\_DEV

Redirects the VM Guest's virtual serial port to a character device CHAR\_DEV on VM Host Server. By default, it is a virtual console (vc) in graphical mode, and stdio in non-graphical mode. The -serial understands many sub-options. See the manual page man 1 qemu for a complete list of them.

You can emulate up to 4 serial ports. Use -serial none to disable all serial ports.

### -parallel DEVICE

Redirects the VM Guest's parallel port to a DEVICE. This option supports the same devices as -serial.



## Tip

With SUSE Linux Enterprise Server as a VM Host Server, you can directly use the hardware parallel port devices /dev/parportN where N is the number of the port.

You can emulate up to 3 parallel ports. Use -parallel none to disable all parallel ports.

-monitor CHAR\_DEV

Redirects the QEMU monitor to a character device CHAR\_DEV on VM Host Server. This option supports the same devices as -serial. By default, it is a virtual console (vc) in a graphical mode, and stdio in non-graphical mode.

For a complete list of available character devices back-ends, see the man page (man 1 qemu).

## 29.4 Networking in QEMU

Use the -netdev option in combination with -device to define a specific type of networking and a network interface card for your VM Guest. The syntax for the -netdev option is

```
-netdev type[,prop[=value][,...]]
```

Currently, SUSE supports the following network types: user, bridge, and tap. For a complete list of -netdev sub-options, see the manual page (man 1 qemu).

### SUPPORTED -netdev SUB-OPTIONS

#### bridge

Uses a specified network helper to configure the TAP interface and attach it to a specified bridge. For more information, see [Section 29.4.3, “Bridged Networking”](#).

#### user

Specifies user-mode networking. For more information, see [Section 29.4.2, “User-Mode Networking”](#).

#### tap

Specifies bridged or routed networking. For more information, see [Section 29.4.3, “Bridged Networking”](#).

### 29.4.1 Defining a Network Interface Card

Use -netdev together with the related -device option to add a new emulated network card:

```
qemu-system-x86_64 [...] \  
-netdev tap❶,id=hostnet0 \  
-device virtio-net-pci❷,netdev=hostnet0,vlan=1❸,\  
macaddr=00:16:35:AF:94:4B❹,name=ncard1
```

- ❶ Specifies the network device type.



- ② Specifies the model of the network card. Use `qemu-system-ARCH -device help` and search for the `Network devices:` section to get the list of all network card models supported by QEMU on your platform.

Currently, SUSE supports the models `rtl8139`, `e1000` and its variants `e1000-82540em`, `e1000-82544gc` and `e1000-82545em`, and `virtio-net-pci`. To view a list of options for a specific driver, add `help` as a driver option:

```
qemu-system-x86_64 -device e1000,help
e1000.mac=macaddr
e1000.vlan=vlan
e1000.netdev=netdev
e1000.bootindex=int32
e1000.autonegotiation=on/off
e1000.mitigation=on/off
e1000.addr=pci-devfn
e1000.romfile=str
e1000.rombar=uint32
e1000.multifunction=on/off
e1000.command_serr_enable=on/off
```

- ③ Connects the network interface to VLAN number 1. You can specify your own number—it is mainly useful for identification purpose. If you omit this suboption, QEMU uses the default 0.
- ④ Specifies the Media Access Control (MAC) address for the network card. It is a unique identifier and you are advised to always specify it. If not, QEMU supplies its own default MAC address and creates a possible MAC address conflict within the related VLAN.

## 29.4.2 User-Mode Networking

The `-netdev user` option instructs QEMU to use user-mode networking. This is the default if no networking mode is selected. Therefore, these command lines are equivalent:

```
qemu-system-x86_64 -hda /images/sles_base.raw
```

```
qemu-system-x86_64 -hda /images/sles_base.raw -netdev user,id=hostnet0
```

This mode is useful if you want to allow the VM Guest to access the external network resources, such as the Internet. By default, no incoming traffic is permitted and therefore, the VM Guest is not visible to other machines on the network. No administrator privileges are required in this networking mode. The user-mode is also useful for doing a network boot on your VM Guest from a local directory on VM Host Server.

The VM Guest allocates an IP address from a virtual DHCP server. VM Host Server (the DHCP server) is reachable at 10.0.2.2, while the IP address range for allocation starts from 10.0.2.15. You can use **ssh** to connect to VM Host Server at 10.0.2.2, and **scp** to copy files back and forth.

### 29.4.2.1 Command Line Examples

This section shows several examples on how to set up user-mode networking with QEMU.

#### EXAMPLE 29.1: RESTRICTED USER-MODE NETWORKING

```
qemu-system-x86_64 [...] \  
-netdev user❶,id=hostnet0 \  
-device virtio-net-pci,netdev=hostnet0,vlan=1❷,name=user_net1❸,restrict=yes❹
```

- ❶ Specifies user-mode networking.
- ❷ Connects to VLAN number 1. If omitted, defaults to 0.
- ❸ Specifies a human-readable name of the network stack. Useful when identifying it in the QEMU monitor.
- ❹ Isolates VM Guest. It then cannot communicate with VM Host Server and no network packets will be routed to the external network.

#### EXAMPLE 29.2: USER-MODE NETWORKING WITH CUSTOM IP RANGE

```
qemu-system-x86_64 [...] \  
-netdev user,id=hostnet0 \  
-device virtio-net-pci,netdev=hostnet0,net=10.2.0.0/8❶,host=10.2.0.6❷,\  
dhcpstart=10.2.0.20❸,hostname=tux_kvm_guest❹
```

- ❶ Specifies the IP address of the network that VM Guest sees and optionally the netmask. Default is 10.0.2.0/8.
- ❷ Specifies the VM Host Server IP address that VM Guest sees. Default is 10.0.2.2.
- ❸ Specifies the first of the 16 IP addresses that the built-in DHCP server can assign to VM Guest. Default is 10.0.2.15.
- ❹ Specifies the host name that the built-in DHCP server will assign to VM Guest.

#### EXAMPLE 29.3: USER-MODE NETWORKING WITH NETWORK-BOOT AND TFTP

```
qemu-system-x86_64 [...] \  
-netdev user,id=hostnet0 \  
-device virtio-net-pci,netdev=hostnet0,tftp=/images/tftp_dir❶,\
```

```
bootfile=/images/boot/pxelinux.0 ②
```

- ① Activates a built-in TFTP (a file transfer protocol with the functionality of a very basic FTP) server. The files in the specified directory will be visible to a VM Guest as the root of a TFTP server.
- ② Broadcasts the specified file as a BOOTP (a network protocol that offers an IP address and a network location of a boot image, often used in diskless workstations) file. When used together with `tftp`, the VM Guest can boot from network from the local directory on the host.

#### EXAMPLE 29.4: USER-MODE NETWORKING WITH HOST PORT FORWARDING

```
qemu-system-x86_64 [...] \  
-netdev user,id=hostnet0 \  
-device virtio-net-pci,netdev=hostnet0,hostfwd=tcp::2222-:22
```

Forwards incoming TCP connections to the port 2222 on the host to the port 22 (`SSH`) on VM Guest. If `sshd` is running on VM Guest, enter

```
ssh qemu_host -p 2222
```

where `qemu_host` is the host name or IP address of the host system, to get a `SSH` prompt from VM Guest.

### 29.4.3 Bridged Networking

With the `-netdev tap` option, QEMU creates a network bridge by connecting the host TAP network device to a specified VLAN of VM Guest. Its network interface is then visible to the rest of the network. This method does not work by default and needs to be explicitly specified.

First, create a network bridge and add a VM Host Server physical network interface (usually `eth0`) to it:

1. Start *YaST Control Center* and select *System > Network Settings*.
2. Click *Add* and select *Bridge* from the *Device Type* drop-down box in the *Hardware Dialog* window. Click *Next*.
3. Choose whether you need a dynamically or statically assigned IP address, and fill the related network settings if applicable.
4. In the *Bridged Devices* pane, select the Ethernet device to add to the bridge.

**Network Card Setup**

**General** | **Address**

Device Type: Bridge | Configuration Name: br0

☒ Dynamic Address DHCP | DHCP both version 4 and 6

☐ Statically assigned IP Address

IP Address:  | Subnet Mask:  | Hostname:

Bridged Devices

☒ eth0 - N10/ICH 7 Family LAN Controller (configuration)

Help Cancel Back Next

FIGURE 29.2: CONFIGURING NETWORK BRIDGE WITH YAST

Click *Next*. When asked about adapting an already configured device, click *Continue*.

- Click *OK* to apply the changes. Check if the bridge is created:

```
tux > brctl show
bridge name bridge id          STP enabled  interfaces
br0          8000.001676d670e4  no          eth0
```

### 29.4.3.1 Connecting to a Bridge Manually

Use the following example script to connect VM Guest to the newly created bridge interface `br0`. Several commands in the script are run via the **sudo** mechanism because they require root privileges.



#### Note: Required Packages

Make sure the `tunctl` and `bridge-utils` packages are installed on the VM Host Server. If not, install them with **`zypper in tunctl bridge-utils`**.

```
#!/bin/bash
bridge=br0 ❶
tap=$(sudo tuncctl -u $(whoami) -b) ❷
sudo ip link set $tap up ❸
sleep 1s ❹
sudo brctl addif $bridge $tap ❺
qemu-system-x86_64 -machine accel=kvm -m 512 -hda /images/sles_base.raw \
-netdev tap,id=hostnet0 \
-device virtio-net-pci,netdev=hostnet0,vlan=0,macaddr=00:16:35:AF:94:4B,\
ifname=$tap ❻,script=no ❼,downscript=no
sudo brctl delif $bridge $tap ❽
sudo ip link set $tap down ❾
sudo tuncctl -d $tap ❿
```

- ❶ Name of the bridge device.
- ❷ Prepare a new TAP device and assign it to the user who runs the script. TAP devices are virtual network devices often used for virtualization and emulation setups.
- ❸ Bring up the newly created TAP network interface.
- ❹ Make a 1-second pause to make sure the new TAP network interface is really up.
- ❺ Add the new TAP device to the network bridge br0.
- ❻ The ifname= suboption specifies the name of the TAP network interface used for bridging.
- ❼ Before **qemu-system-ARCH** connects to a network bridge, it checks the script and downscript values. If it finds the specified scripts on the VM Host Server file system, it runs the script before it connects to the network bridge and downscript after it exits the network environment. You can use these scripts to first set up and bring up the bridged network devices, and then to destroy it. By default, /etc/qemu-ifup and /etc/qemu-if-down are examined. If script=no and downscript=no are specified, the script execution is disabled and you need to take care of it manually.
- ❽ Deletes the TAP interface from a network bridge br0.
- ❾ Sets the state of the TAP device to down.
- ❿ Destroys the TAP device.

### 29.4.3.2 Connecting to a Bridge with qemu-bridge-helper

Another way to connect VM Guest to a network through a network bridge is by means of the qemu-bridge-helper helper program. It configures the TAP interface for you, and attaches it to the specified bridge. The default helper executable is /usr/lib/qemu-bridge-helper. The

helper executable is `setuid root`, which is only executable by the members of the virtualization group (`kvm`). Therefore the `qemu-system-ARCH` command itself does not need to be run under `root` privileges.

The helper is automatically called when you specify a network bridge:

```
qemu-system-x86_64 [...] \  
-netdev bridge,id=hostnet0,vlan=0,br=br0 \  
-device virtio-net-pci,netdev=hostnet0
```

You can specify your own custom helper script that will take care of the TAP device (de)configuration, with the `helper=/path/to/your/helper` option:

```
qemu-system-x86_64 [...] \  
-netdev bridge,id=hostnet0,vlan=0,br=br0,helper=/path/to/bridge-helper \  
-device virtio-net-pci,netdev=hostnet0
```



### Tip

To define access privileges to `qemu-bridge-helper`, inspect the `/etc/qemu/bridge.conf` file. For example the following directive

```
allow br0
```

allows the `qemu-system-ARCH` command to connect its VM Guest to the network bridge `br0`.

## 29.5 Viewing a VM Guest with VNC

By default QEMU uses a GTK (a cross-platform toolkit library) window to display the graphical output of a VM Guest. With the `-vnc` option specified, you can make QEMU listen on a specified VNC display and redirect its graphical output to the VNC session.



### Tip

When working with QEMU's virtual machine via VNC session, it is useful to work with the `-usbdevice tablet` option.

Moreover, if you need to use another keyboard layout than the default `en-us`, specify it with the `-k` option.

The first suboption of `-vnc` must be a *display* value. The `-vnc` option understands the following display specifications:

host:display

Only connections from host on the display number display will be accepted. The TCP port on which the VNC session is then running is normally a 5900 + display number. If you do not specify host, connections will be accepted from any host.

unix:path

The VNC server listens for connections on Unix domain sockets. The path option specifies the location of the related Unix socket.

none

The VNC server functionality is initialized, but the server itself is not started. You can start the VNC server later with the QEMU monitor. For more information, see [Chapter 30, Virtual Machine Administration Using QEMU Monitor](#).

Following the display value there may be one or more option flags separated by commas. Valid options are:

reverse

Connect to a listening VNC client via a *reverse* connection.

websocket

Opens an additional TCP listening port dedicated to VNC Websocket connections. By definition the Websocket port is 5700 + display.

password

Require that password-based authentication is used for client connections.

tls

Require that clients use TLS when communicating with the VNC server.

x509=/path/to/certificate/dir

Valid if TLS is specified. Require that x509 credentials are used for negotiating the TLS session.

x509verify=/path/to/certificate/dir

Valid if TLS is specified. Require that x509 credentials are used for negotiating the TLS session.

#### sasl

Require that the client uses SASL to authenticate with the VNC server.

#### acl

Turn on access control lists for checking of the x509 client certificate and SASL party.

#### lossy

Enable lossy compression methods (gradient, JPEG, ...).

#### non-adaptive

Disable adaptive encodings. Adaptive encodings are enabled by default.

#### share=[allow-exclusive|force-shared|ignore]

Set display sharing policy.



### Note

For more details about the display options, see the *qemu-doc* man page.

An example VNC usage:

```
tux > qemu-system-x86_64 [...] -vnc :5
(on the client:)
wilber > :~>vinagre venus:5905 &
```



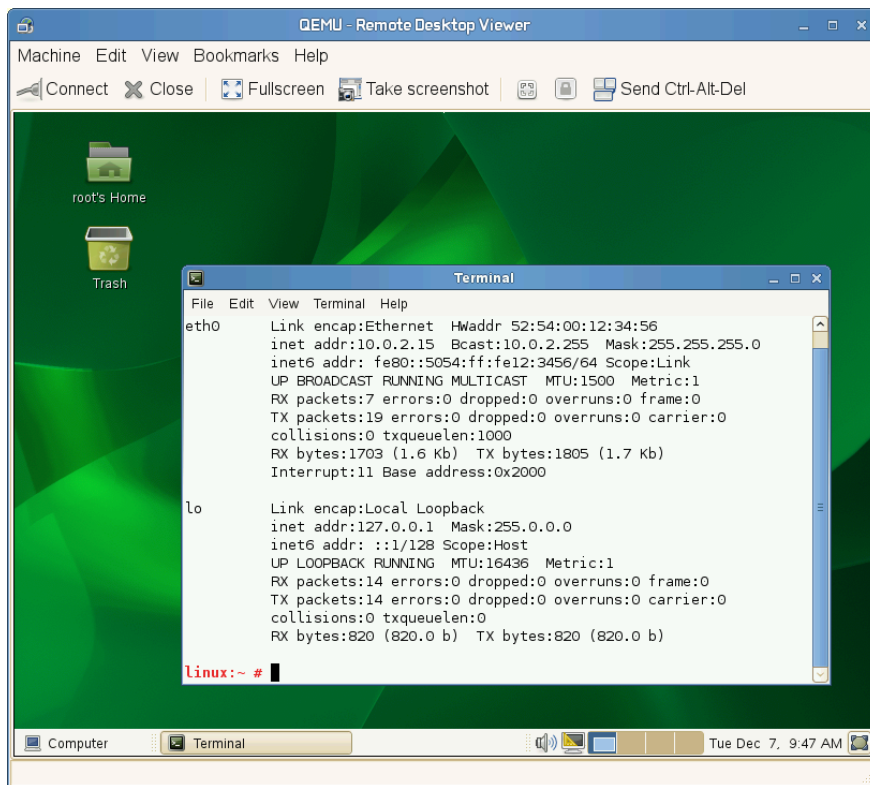


FIGURE 29.3: QEMU VNC SESSION

## 29.5.1 Secure VNC Connections

The default VNC server setup does not use any form of authentication. In the previous example, any user can connect and view the QEMU VNC session from any host on the network.

There are several levels of security that you can apply to your VNC client/server connection. You can either protect your connection with a password, use x509 certificates, use SASL authentication, or even combine some authentication methods in one QEMU command.

See [Section B.2, “Generating x509 Client/Server Certificates”](#) for more information about the x509 certificates generation. For more information about configuring x509 certificates on a VM Host Server and the client, see [Section 11.3.2, “Remote TLS/SSL Connection with x509 Certificate \(qemu+tls or xen+tls\)”](#) and [Section 11.3.2.3, “Configuring the Client and Testing the Setup”](#).

The Vinagre VNC viewer supports advanced authentication mechanisms. Therefore, it will be used to view the graphical output of VM Guest in the following examples. For this example, let us assume that the server x509 certificates `ca-cert.pem`, `server-cert.pem`, and `server-key.pem` are located in the `/etc/pki/qemu` directory on the host, while the client's certificates are distributed in the following locations on the client:

```
/etc/pki/CA/cacert.pem
/etc/pki/libvirt-vnc/clientcert.pem
/etc/pki/libvirt-vnc/private/clientkey.pem
```

#### EXAMPLE 29.5: PASSWORD AUTHENTICATION

```
qemu-system-x86_64 [...] -vnc :5,password -monitor stdio
```

Starts the VM Guest graphical output on VNC display number 5 (usually port 5905). The `password` suboption initializes a simple password-based authentication method. There is no password set by default and you need to set one with the `change vnc password` command in QEMU monitor:

```
QEMU 2.3.1 monitor - type 'help' for more information
(qemu) change vnc password
Password: ****
```

You need the `-monitor stdio` option here, because you would not be able to manage the QEMU monitor without redirecting its input/output.

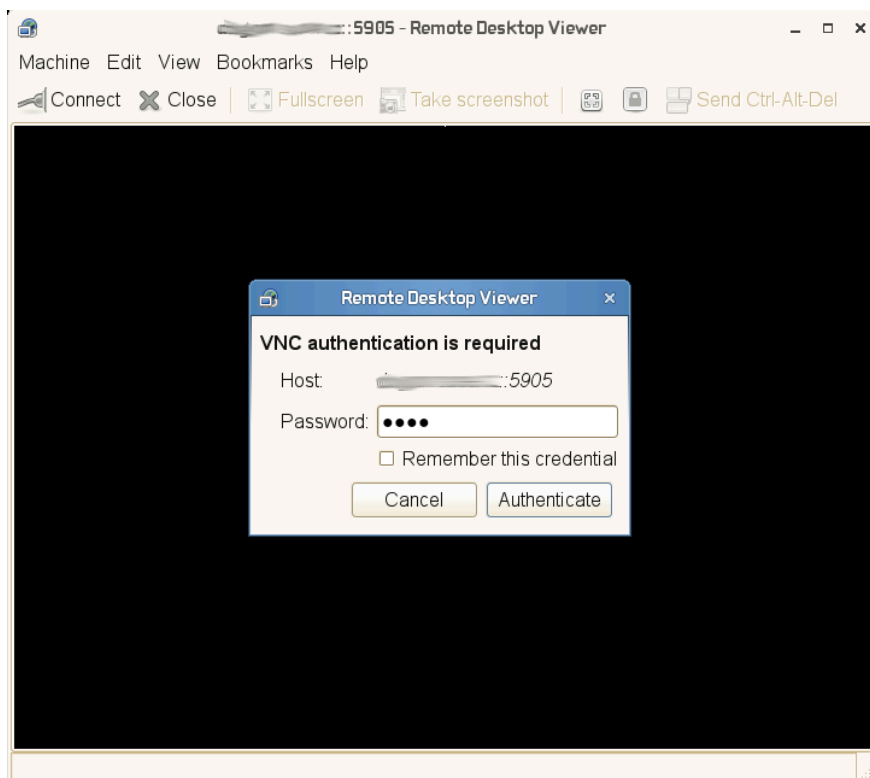


FIGURE 29.4: AUTHENTICATION DIALOG IN VINAGRE

#### EXAMPLE 29.6: X509 CERTIFICATE AUTHENTICATION

The QEMU VNC server can use TLS encryption for the session and x509 certificates for authentication. The server asks the client for a certificate and validates it against the CA certificate. Use this authentication type if your company provides an internal certificate authority.

```
qemu-system-x86_64 [...] -vnc :5,tls,x509verify=/etc/pki/qemu
```

#### EXAMPLE 29.7: X509 CERTIFICATE AND PASSWORD AUTHENTICATION

You can combine the password authentication with TLS encryption and x509 certificate authentication to create a two-layer authentication model for clients. Remember to set the password in the QEMU monitor after you run the following command:

```
qemu-system-x86_64 [...] -vnc :5,password,tls,x509verify=/etc/pki/qemu \
-monitor stdio
```

#### EXAMPLE 29.8: SASL AUTHENTICATION

Simple Authentication and Security Layer (SASL) is a framework for authentication and data security in Internet protocols. It integrates several authentication mechanisms, like PAM, Kerberos, LDAP and more. SASL keeps its own user database, so the connecting user accounts do not need to exist on VM Host Server.

For security reasons, you are advised to combine SASL authentication with TLS encryption and x509 certificates:

```
qemu-system-x86_64 [...] -vnc :5,tls,x509,sasl -monitor stdio
```

## 30 Virtual Machine Administration Using QEMU Monitor

When a virtual machine is invoked by the `qemu-system-ARCH` command, for example `qemu-system-x86_64`, a monitor console is provided for performing interaction with the user. Using the commands available in the monitor console, it is possible to inspect the running operating system, change removable media, take screenshots or audio grabs and control other aspects of the virtual machine.



### Note

The following sections list selected useful QEMU monitor commands and their purpose. To get the full list, enter `help` in the QEMU monitor command line.

### 30.1 Accessing Monitor Console



#### Tip: No Monitor Console for libvirt

You can access the monitor console only if you started the virtual machine directly with the `qemu-system-ARCH` command and are viewing its graphical output in a native QEMU window.

If you started the virtual machine with `libvirt` (for example using `virt-manager`) and are viewing its output via VNC or Spice sessions, you cannot access the monitor console directly. You can, however, send the monitor command to the virtual machine via `virsh`:

```
root # virsh qemu-monitor-command COMMAND
```

The way you access the monitor console depends on which display device you use to view the output of a virtual machine. Find more details about displays in [Section 29.3.2.2, “Display Options”](#). For example, to view the monitor while the `-display gtk` option is in use, press `Ctrl-Alt-2`. Similarly, when the `-nographic` option is in use, you can switch to the monitor console by pressing `Ctrl-a c`.

To get help while using the console, use `help` or `?`. To get help for a specific command, use `help COMMAND`.

## 30.2 Getting Information about the Guest System

To get information about the guest system, use **info**. If used without any option, the list of possible options is printed. Options determine which part of the system will be analyzed:

### **info version**

Shows the version of QEMU.

### **info commands**

Lists available QMP commands.

### **info network**

Shows the network state.

### **info chardev**

Shows the character devices.

### **info block**

Information about block devices, such as hard disks, floppy drives, or CD-ROMs.

### **info blockstats**

Read and write statistics on block devices.

### **info registers**

Shows the CPU registers.

### **info cpus**

Shows information about available CPUs.

### **info history**

Shows the command line history.

### **info irq**

Shows the interrupt statistics.

### **info pic**

Shows the i8259 (PIC) state.

### **info pci**

Shows the PCI information.

### **info tlb**

Shows virtual to physical memory mappings.

#### **info mem**

Shows the active virtual memory mappings.

#### **info jit**

Shows dynamic compiler information.

#### **info kvm**

Shows the KVM information.

#### **info numa**

Shows the NUMA information.

#### **info usb**

Shows the guest USB devices.

#### **info usbhost**

Shows the host USB devices.

#### **info profile**

Shows the profiling information.

#### **info capture**

Shows the capture (audio grab) information.

#### **info snapshots**

Shows the currently saved virtual machine snapshots.

#### **info status**

Shows the current virtual machine status.

#### **info pcmcia**

Shows the guest PCMCIA status.

#### **info mice**

Shows which guest mice are receiving events.

#### **info vnc**

Shows the VNC server status.

#### **info name**

Shows the current virtual machine name.

#### **info uuid**

Shows the current virtual machine UUID.

#### **info usernet**

Shows the user network stack connection states.

#### **info migrate**

Shows the migration status.

#### **info balloon**

Shows the balloon device information.

#### **info qtree**

Shows the device tree.

#### **info qdm**

Shows the qdev device model list.

#### **info roms**

Shows the ROMs.

#### **info migrate\_cache\_size**

Shows the current migration xbzrle (“Xor Based Zero Run Length Encoding”) cache size.

#### **info migrate\_capabilities**

Shows the status of the various migration capabilities, such as xbzrle compression.

#### **info mtree**

Shows the VM Guest memory hierarchy.

#### **info trace-events**

Shows available trace-events and their status.

## 30.3 Changing VNC Password

To change the VNC password, use the **change vnc password** command and enter the new password:

```
(qemu) change vnc password
Password: *****
(qemu)
```



## 30.4 Managing Devices

To add a new disk while the guest is running (hotplug), use the **drive\_add** and **device\_add** commands. First define a new drive to be added as a device to bus 0:

```
(qemu) drive_add 0 if=none,file=/tmp/test.img,format=raw,if=disk1
OK
```

You can confirm your new device by querying the block subsystem:

```
(qemu) info block
[...]
disk1: removable=1 locked=0 tray-open=0 file=/tmp/test.img ro=0 drv=raw \
encrypted=0 bps=0 bps_rd=0 bps_wr=0 iops=0 iops_rd=0 iops_wr=0
```

After the new drive is defined, it needs to be connected to a device so that the guest can see it. The typical device would be a **virtio-blk-pci** or **scsi-disk**. To get the full list of available driver values, run:

```
(qemu) device_add ?
name "VGA", bus PCI
name "usb-storage", bus usb-bus
[...]
name "virtio-blk-pci", bus virtio-bus
```

Now add the device

```
(qemu) device_add virtio-blk-pci,drive=disk1,id=myvirtio1
```

and confirm with

```
(qemu) info pci
[...]
Bus 0, device 4, function 0:
  SCSI controller: PCI device 1af4:1001
  IRQ 0.
  BAR0: I/O at 0xffffffffffffffff [0x003e].
  BAR1: 32 bit memory at 0xffffffffffffffff [0x0000ffe].
  id "myvirtio1"
```



### Tip

Devices added with the **device\_add** command can be removed from the guest with **device\_del**. Enter **help device\_del** on the QEMU monitor command line for more information.

To release the device or file connected to the removable media device, use the **eject** *DEVICE* command. Use the optional **-f** to force ejection.

To change removable media (like CD-ROMs), use the **change** *DEVICE* command. The name of the removable media can be determined using the **info block** command:

```
(qemu) info block
ide1-cd0: type=cdrom removable=1 locked=0 file=/dev/sr0 ro=1 drv=host_device
(qemu) change ide1-cd0 /path/to/image
```

## 30.5 Controlling Keyboard and Mouse

It is possible to use the monitor console to emulate keyboard and mouse input if necessary. For example, if your graphical user interface intercepts some key combinations at low level (such as **Ctrl – Alt – F1** in X Window), you can still enter them using the **sendkey** *KEYS*:

```
sendkey ctrl-alt-f1
```

To list the key names used in the *KEYS* option, enter **sendkey** and press **→|**.

To control the mouse, the following commands can be used:

### **mouse\_move** *DX dy [DZ]*

Move the active mouse pointer to the specified coordinates dx, dy with the optional scroll axis dz.

### **mouse\_button** *VAL*

Change the state of the mouse buttons (1 = left, 2 = middle, 4 = right).

### **mouse\_set** *INDEX*

Set which mouse device receives events. Device index numbers can be obtained with the **info mice** command.

## 30.6 Changing Available Memory

If the virtual machine was started with the **-balloon virtio** option (the paravirtualized balloon device is therefore enabled), you can change the available memory dynamically. For more information about enabling the balloon device, see [Section 28.1, “Basic Installation with qemu-system-ARCH”](#).

To get information about the balloon device in the monitor console and to determine whether the device is enabled, use the **info balloon** command:

```
(qemu) info balloon
```

If the balloon device is enabled, use the **balloon MEMORY\_IN\_MB** command to set the requested amount of memory:

```
(qemu) balloon 400
```

## 30.7 Dumping Virtual Machine Memory

To save the content of the virtual machine memory to a disk or console output, use the following commands:

### **memsave** *ADDR SIZE FILENAME*

Saves virtual memory dump starting at *ADDR* of size *SIZE* to file *FILENAME*

### **pmemsave** *ADDR SIZE FILENAME*

Saves physical memory dump starting at *ADDR* of size *SIZE* to file *FILENAME* -

### **x / FMT ADDR**

Makes a virtual memory dump starting at address *ADDR* and formatted according to the *FMT* string. The *FMT* string consists of three parameters *COUNTFORMATSIZE*:

The *COUNT* parameter is the number of items to be dumped.

The *FORMAT* can be *x* (hex), *d* (signed decimal), *u* (unsigned decimal), *o* (octal), *c* (char) or *i* (assembly instruction).

The *SIZE* parameter can be *b* (8 bits), *h* (16 bits), *w* (32 bits) or *g* (64 bits). On x86, *h* or *w* can be specified with the *i* format to respectively select 16 or 32-bit code instruction size.

### **xp / FMT ADDR**

Makes a physical memory dump starting at address *ADDR* and formatted according to the *FMT* string. The *FMT* string consists of three parameters *COUNTFORMATSIZE*:

The *COUNT* parameter is the number of the items to be dumped.

The *FORMAT* can be *x* (hex), *d* (signed decimal), *u* (unsigned decimal), *o* (octal), *c* (char) or *i* (asm instruction).

The SIZE parameter can be b (8 bits), h (16 bits), w (32 bits) or g (64 bits). On x86, h or w can be specified with the i format to respectively select 16 or 32-bit code instruction size.

## 30.8 Managing Virtual Machine Snapshots

Managing snapshots in QEMU monitor is not officially supported by SUSE yet. The information found in this section may be helpful in specific cases.

*Virtual Machine* snapshots are snapshots of the complete virtual machine including the state of CPU, RAM, and the content of all writable disks. To use virtual machine snapshots, you must have at least one non-removable and writable block device using the qcow2 disk image format. Snapshots are helpful when you need to save your virtual machine in a particular state. For example, after you have configured network services on a virtualized server and want to quickly start the virtual machine in the same state that was saved last. You can also create a snapshot after the virtual machine has been powered off to create a backup state before you try something experimental and possibly make VM Guest unstable. This section introduces the former case, while the latter is described in *Section 28.2.3, “Managing Snapshots of Virtual Machines with qemu-img”*.

The following commands are available for managing snapshots in QEMU monitor:

### savevm NAME

Creates a new virtual machine snapshot under the tag NAME or replaces an existing snapshot.

### loadvm NAME

Loads a virtual machine snapshot tagged NAME.

### delvm

Deletes a virtual machine snapshot.

### info snapshots

Prints information about available snapshots.

```
(qemu) info snapshots
Snapshot list:
ID ①      TAG ②      VM SIZE ③    DATE ④      VM CLOCK ⑤
1       booting    4.4M 2013-11-22 10:51:10 00:00:20.476
2       booted     184M 2013-11-22 10:53:03 00:02:05.394
3       logged_in  273M 2013-11-22 11:00:25 00:04:34.843
```

4	ff_and_term_running	372M	2013-11-22 11:12:27	00:08:44.965
---	---------------------	------	---------------------	--------------

- ❶ Unique identification number of the snapshot. Usually auto-incremented.
- ❷ Unique description string of the snapshot. It is meant as a human readable version of the ID.
- ❸ The disk space occupied by the snapshot. Note that the more memory is consumed by running applications, the bigger the snapshot is.
- ❹ Time and date the snapshot was created.
- ❺ The current state of the virtual machine's clock.

## 30.9 Suspending and Resuming Virtual Machine Execution

The following commands are available for suspending and resuming virtual machines:

### stop

Suspends the execution of the virtual machine.

### cont

Resumes the execution of the virtual machine.

### system\_reset

Resets the virtual machine. The effect is similar to the reset button on a physical machine. This may leave the file system in an unclean state.

### system\_powerdown

Sends an *ACPI* shutdown request to the machine. The effect is similar to the power button on a physical machine.

### q or quit

Terminates QEMU immediately.

## 30.10 Live Migration

The live migration process allows to transmit any virtual machine from one host system to another host system without any interruption in availability. It is possible to change hosts permanently or only during maintenance.

The requirements for live migration:

- All requirements from [Section 10.7.1, “Migration Requirements”](#) are applicable.
- Live migration is only possible between VM Host Servers with the same CPU features.
- [AHCI](#) interface, [VirtFS](#) feature, and the `-mem-path` command line option are not compatible with migration.
- The guest on the source and destination hosts must be started in the same way.
- `-snapshot` qemu command line option should not be used for migration (and this `qemu` command line option is not supported).



### Important: Support Status

The `postcopy` mode is not yet supported in SUSE Linux Enterprise Server. It is released as a technology preview only. For more information about `postcopy`, see <http://wiki.qemu.org/Features/PostCopyLiveMigration>.

More recommendations can be found at the following Web site: <http://www.linux-kvm.org/page/Migration>

The live migration process has the following steps:

1. The virtual machine instance is running on the source host.
2. The virtual machine is started on the destination host in the frozen listening mode. The parameters used are the same as on the source host plus the `-incoming tcp:IP:PORT` parameter, where `IP` specifies the IP address and `PORT` specifies the port for listening to the incoming migration. If 0 is set as IP address, the virtual machine listens on all interfaces.
3. On the source host, switch to the monitor console and use the `migrate -d tcp: DESTINATION_IP:PORT` command to initiate the migration.
4. To determine the state of the migration, use the `info migrate` command in the monitor console on the source host.
5. To cancel the migration, use the `migrate_cancel` command in the monitor console on the source host.

6. To set the maximum tolerable downtime for migration in seconds, use the `migrate_set_downtime NUMBER_OF_SECONDS` command.
7. To set the maximum speed for migration in bytes per second, use the `migrate_set_speed BYTES_PER_SECOND` command.

## 30.11 QMP - QEMU Machine Protocol

QMP is a JSON-based protocol that allows applications—such as `libvirt`—to communicate with a running QEMU instance. There are several ways you can access the QEMU monitor using QMP commands.

### 30.11.1 Access QMP via Standard Input/Output

The most flexible way to use QMP is by specifying the `-mon` option. The following example creates a QMP instance using standard input/output. Note that in the following examples, `->` marks lines with commands sent from client to the running QEMU instance, while `<-` marks lines with the output returned from QEMU.

```
# qemu-system-x86_64 [...] \  
-chardev stdio,id=mon0 \  
-mon chardev=mon0,mode=control,pretty=on  
  
<- {  
  "QMP": {  
    "version": {  
      "qemu": {  
        "micro": 0,  
        "minor": 0,  
        "major": 2  
      },  
      "package": ""  
    },  
    "capabilities": [  
    ]  
  }  
}
```

When a new QMP connection is established, QMP sends its greeting message and enters capabilities negotiation mode. In this mode, only the `qmp_capabilities` command works. To exit capabilities negotiation mode and enter command mode, the `qmp_capabilities` command must be issued first:

```
-> { "execute": "qmp_capabilities" }
<- {
  "return": {
  }
}
```

Note that `"return": {}` is a QMP's success response.

QMP's commands can have arguments. For example to eject a CD-ROM drive, enter the following:

```
->{ "execute": "eject", "arguments": { "device": "ide1-cd0" } }
<- {
  "timestamp": {
    "seconds": 1410353381,
    "microseconds": 763480
  },
  "event": "DEVICE_TRAY_MOVED",
  "data": {
    "device": "ide1-cd0",
    "tray-open": true
  }
}
{
  "return": {
  }
}
```

### 30.11.2 Access QMP via Telnet

Instead of the standard input/output, you can connect the QMP interface to a network socket and communicate with it via a specified port:

```
# qemu-system-x86_64 [...] \
-chardev socket,id=mon0,host=localhost,port=4444,server,nowait \
-mon chardev=mon0,mode=control,pretty=on
```

And then run telnet to connect to port 4444:

```
# telnet localhost 4444
```



```
Trying ::1...
Connected to localhost.
Escape character is '^]'.
<- {
  "QMP": {
    "version": {
      "qemu": {
        "micro": 0,
        "minor": 0,
        "major": 2
      },
      "package": ""
    },
    "capabilities": [
    ]
  }
}
```

You can create several monitor interfaces at the same time. The following example creates one HMP instance—human monitor which understands 'normal' QEMU monitor's commands—on the standard input/output, and one QMP instance on localhost port 4444:

```
# qemu-system-x86_64 [...] \
-chardev stdio,id=mon0 -mon chardev=mon0,mode=readline \
-chardev socket,id=mon1,host=localhost,port=4444,server,nowait \
-mon chardev=mon1,mode=control,pretty=on
```

### 30.11.3 Access QMP via Unix Socket

Invoke QEMU using the `-qmp` option, and create a unix socket:

```
# qemu-system-x86_64 [...] \
-qmp unix:/tmp/qmp-sock,server --monitor stdio

QEMU waiting for connection on: unix:./qmp-sock,server
```

To communicate with the QEMU instance via the `/tmp/qmp-sock` socket, use `nc` (see [man 1 nc](#) for more information) from another terminal on the same host:

```
# nc -U /tmp/qmp-sock
<- {"QMP": {"version": {"qemu": {"micro": 0, "minor": 0, "major": 2} [...]}}
```

## 30.11.4 Access QMP via libvirt's **virsh** Command

If you run your virtual machines under **libvirt** (see *Part II, “Managing Virtual Machines with libvirt”*), you can communicate with its running guests by running the **virsh qemu-monitor-command**:

```
# virsh qemu-monitor-command vm_guest1 \  
--pretty '{"execute":"query-kvm"}'  
<- {  
  "return": {  
    "enabled": true,  
    "present": true  
  },  
  "id": "libvirt-8"  
}
```

In the above example, we ran the simple command **query-kvm** which checks if the host is capable of running KVM and if KVM is enabled.



### Tip: Generating Human-Readable Output

To use the standard human-readable output format of QEMU instead of the JSON format, use the **--hmp** option:

```
# virsh qemu-monitor-command vm_guest1 --hmp "query-kvm"
```

## VI Managing Virtual Machines with LXC

31 Linux Containers **303**

32 Migration from LXC to `libvirt-lxc` **310**

## 31 Linux Containers

### 31.1 Setting Up LXC Distribution Containers

A container is a kind of “virtual machine” that can be started, stopped, frozen, or cloned (to name but a few tasks). To set up an LXC container, you first need to create a root file system containing the guest distribution:

#### PROCEDURE 31.1: CREATING A ROOT FILE SYSTEM

There is currently no GUI to create a root file system. You will thus need to open a terminal and use **virt-create-rootfs** as root to populate the new root file system. In the following steps, the new root file system will be created in /path/to/rootfs.



#### Important: Registration Code Needed

**virt-create-rootfs** needs a registration code to set up a SUSE Linux Enterprise Server root file system.

1. Run the **virt-create-rootfs** command:

```
virt-create-rootfs --root /PATH/TO/ROOTFS --distro SLES-12.0 -c REGISTRATION_CODE
```

2. Change the root path to the root file system with the **chroot** command:

```
chroot /path/to/rootfs
```

3. Change the password for user root with **passwd**.

4. Create an operator user without root privileges:

```
useradd -m operator
```

5. Change the operator's password:

```
passwd operator
```

6. Leave the chroot environment with **exit**.

#### PROCEDURE 31.2: DEFINING THE CONTAINER

1. Start Virtual Machine Manager.

2. (Optional) If not already present, add a local LXC connection by clicking *File > Add Connection*.  
Select *LXC (Linux Containers)* as the hypervisor and click *Connect*.
3. Select the *localhost (LXC)* connection and click *File New Virtual Machine* menu.
4. Activate *Operating system container* and click *Forward*.
5. Type the path to the root file system from *Procedure 31.1, "Creating a Root File System"* and click the *Forward* button.
6. Choose the maximum amount of memory and CPUs to allocate to the container. Then click the *Forward* button.
7. Type in a name for the container. This name will be used for all **virsh** commands on the container.  
Click *Advanced options*. Select the network to connect the container to and click the *Finish* button: the container will then be created and started. A console will also be automatically opened.

#### PROCEDURE 31.3: CONFIGURING IP ADDRESSES FOR NETWORK INTERFACES

Network devices and hostdev devices with network capabilities can be provided with one or more IP addresses to set on the network device in the guest. However, some hypervisors or network device types will simply ignore them or only use the first one.

1. Edit the container XML configuration using **virsh**:

```
virsh -c lxc:/// edit MYCONTAINER
```

2. The following example shows how to set one or multiple IP addresses:

```
[...]
<devices>
  <interface type='network'>
    <source network='default' />
    <target dev='vnet0' />
    <ip address='192.168.122.5' prefix='24' />
    <ip address='192.168.122.5' prefix='24' peer①='10.0.0.10' />
    <route family②='ipv4' address③='192.168.122.0' prefix④='24'
      gateway⑤='192.168.122.1' />
    <route family②='ipv4' address③='192.168.122.8' gateway⑤='192.168.122.1' />
  </interface>
[...]
```

```

<hostdev mode='capabilities' type='net'>
  <source>
    <interface>eth0</interface>
  </source>
  <ip address='192.168.122.6' prefix='24' />
  <route family='ipv4' address='192.168.122.0' prefix='24' gateway='192.168.122.1' />
  <route family='ipv4' address='192.168.122.8' gateway='192.168.122.1' />
</hostdev>
</devices>
[...]
```

- ❶ Optional attribute. Holds the IP address of the other end of a point-to-point network device.
  - ❷ Can be set to either ipv4 or ipv6.
  - ❸ Contains the IP address.
  - ❹ Optional parameter (will be automatically set if not specified). Defines the number of 1 bits in the netmask. For IPv4, the default prefix is determined according to the network “class” (A, B, or C). For IPv6, the default prefix is 64.
  - ❺ If you do not specify a default gateway in the XML file, none will be set.
3. You can also add route elements to define IP routes to add in the guest. This is used by the LXC driver.

```

[...]
```

```

<devices>
  <interface type❶='ethernet'>
    <source/>❷
    <ip address❸='192.168.123.1' prefix='24' />
    <ip address❹='10.0.0.10' prefix='24' peer='192.168.122.5' />
    <route❺ family='ipv4' address='192.168.42.0' prefix='24'
      gateway='192.168.123.4' />
    <source/>
    [...]
  </interface>
  [...]
</devices>
[...]
```

- ❶ Network devices of type ethernet can optionally be provided with one or multiple IP addresses (❸, ❹) and with one or multiple routes (❺) to set on the host side of the network device.

These are configured as subelements of the `source` element (2) of the interface. They have the same attributes as the similarly named elements used to configure the guest side of the interface (see the step above).

- 3 First IP address for the network device of type `ethernet`.
- 4 Second IP address for the network device of type `ethernet`.
- 5 Route to set on the host side of the network device.

Find further details about the attributes of this element at <https://libvirt.org/formatnetwork.html#elementsStaticroute>.

4. Save the changes and exit the editor.



### Note: Container Network

To configure the container network, edit the `/etc/sysconfig/network/ifcfg-*` files.

## 31.2 Setting Up LXC Application Containers

Libvirt also allows to run single applications instead of full blown Linux distributions in containers. In this example, `bash` will be started in its own container.

### PROCEDURE 31.4: DEFINING AN APPLICATION CONTAINER USING YAST

1. Start Virtual Machine Manager.
2. (Optional) If not already present, add a local LXC connection by clicking *File > Add Connection*.  
Select *LXC (Linux Containers)* as the hypervisor and click *Connect*.
3. Select the *localhost (LXC)* connection and click *File New Virtual Machine* menu.
4. Activate *Application container* and click *Forward*.  
Set the path to the application to be launched. As an example, the field is filled with `/bin/sh`, which is fine to create a first container. Click *Forward*.
5. Choose the maximum amount of memory and CPUs to allocate to the container. Click *Forward*.
6. Type in a name for the container. This name will be used for all `virsh` commands on the container.

Click *Advanced options*. Select the network to connect the container to and click *Finish*. The container will be created and started. A console will be opened automatically. Note that the container will be destroyed after the application has finished running.

## 31.3 Securing a Container Using AppArmor

By default, containers are not secured using AppArmor or SELinux. There is no graphical user interface to change the security model for a libvirt domain, but virsh will help.

1. Edit the container XML configuration using virsh:

```
virsh -c lxc:/// edit MYCONTAINER
```

2. Add the following to the XML configuration, save it and exit the editor.

```
<domain>
...
  <seclabel type="dynamic" model="apparmor"/>
...
</domain>
```

3. With this configuration, an AppArmor profile for the container will be created in the `/etc/apparmor.d/libvirt` directory. The default profile only allows the minimum applications to run in the container. This can be changed by modifying the `libvirt-CONTAINER-uuid` file: this file is not overwritten by libvirt.

## 31.4 Differences Between the libvirt LXC Driver and LXC

SUSE Linux Enterprise Server 11 SP3 was shipping LXC, while SUSE Linux Enterprise Server 12 comes with the libvirt LXC driver, sometimes named `libvirt-lxc` to avoid confusion. The containers are not managed or configured in the same way in these tools. Here is a non-exhaustive list of differences.



The main difference is that domain configuration in libvirt is an XML file, while LXC configuration is a properties file. Most of the LXC properties can be mapped to the domain XML. The properties that cannot be migrated are:

- *lxc.network.script.up*: this script can be implemented using the /etc/libvirt/hooks/network libvirt hook, though the script will need to be adapted.
- *lxc.network.ipv\**: libvirt cannot set the container network configuration from the domain configuration.
- *lxc.network.name*: libvirt cannot set the container network card name.
- *lxc.devtttydir*: libvirt does not allow changing the location of the console devices.
- *lxc.console*: there is currently no way to log the output of the console into a file on the host for libvirt LXC containers.
- *lxc.pivotdir*: libvirt does not allow to fine-tune the directory used for the pivot\_root. /olroot is used.
- *lxc.rootfs.mount*: libvirt does not allow to fine-tune this.

LXC VLAN networks automatically create the VLAN interface on the host and then move it into the guest namespace. libvirt-lxc configuration can mention a VLAN tag ID only for Open vSwitch tap devices or PCI pass-through of SR-IOV VF. The conversion tool actually needs the user to manually create the VLAN interface on the host side.

LXC rootfs can also be an image file, but LXC brute-forces the mount to try to detect the proper file system format. libvirt-lxc can mount image files of several formats, but the 'auto' value for the format parameter is explicitly not supported. This means that the generated configuration will need to be tweaked by the user to get a proper match in that case.

LXC can support any cgroup configuration, even future ones, while libvirt domain configuration, needs to map each of them.

LXC can mount block devices in the rootfs, but it cannot mount raw partition files: the file needs to be manually attached to a loop device. On the other hand libvirt-lxc can mount block devices, but also partition files of any format.

## 31.5 Sharing Namespaces Across Containers

Like Docker Open Source Engine, libvirt allows you to inherit the namespace from containers or processes to share the network namespace. The following example shows how to share required namespaces.

```
<domain type='lxc' xmlns:lxc='http://libvirt.org/schemas/domain/lxc/1.0'>
  [...]
  <lxc:namespace>
    <lxc:sharenet type='netns' value='red' />
    <lxc:shareuts type='name' value='CONTAINER_1' />
    <lxc:shareipc type='pid' value='12345' />
  </lxc:namespace>
</domain>
```

The `netns` option is specific to `sharenet`. Use it to use an existing network namespace (instead of creating a new network namespace for the container). In this case, the `privnet` option will be ignored.

## 31.6 For More Information

### LXC Container Driver

<https://libvirt.org/drvlxc.html> 

## 32 Migration from LXC to `libvirt-lxc`

Since SUSE Linux Enterprise Server 12, LXC is integrated into `libvirt` library. This decision has several advantages over using LXC as a separate solution—such as a unified approach with other virtualization solutions or independence on the kernel used. This chapter describes steps needed to migrate an existing LXC environment for use with the `libvirt` library.

### 32.1 Host Migration

The migration itself has two phases. You first need to migrate the host, then the LXC containers. After that, you can run the original containers as VM Guests in the `libvirt` environment.

#### PROCEDURE 32.1: HOST MIGRATION

1. Upgrade the host to SUSE Linux Enterprise Server 12 using the official DVD media.
2. After the upgrade, install the `libvirt-daemon-lxc` and `libvirt-daemon-config-network` packages.
3. Create a `libvirt` XML configuration `lxc_container.xml` from the existing container `lxc_container`:

```
# virt-lxc-convert /etc/lxc/lxc_container/config > lxc_container.xml
```

4. Check if the network configuration on the host is the same as in the container configuration file, and fix it if needed.
5. Check the `lxc_container.xml` file for any weird or missing configuration. Note that some LXC configuration options cannot be mapped to `libvirt` configuration. Although the conversion should usually be fine, check [Section 31.4, “Differences Between the libvirt LXC Driver and LXC”](#) for more details.
6. Define the container in `libvirt` based on the created XML definition:

```
# virsh -c lxc:/// define lxc_container.xml
```

### 32.2 Container Migration

After the host is migrated, the LXC container in `libvirt` will not boot. It needs to be migrated to SUSE Linux Enterprise Server 12 as well to get everything working.

1. The `baseproduct` file is missing (and `zypper` keeps complaining about it). Create the relevant symbolic link:

```
# R00TFS=/var/lib/lxc/lxc_container/rootfs
# ln -s $R00TFS/etc/products.d/SUSE_SLES.prod $R00TFS/etc/products.d/baseproduct
```

2. Add the DVD repository. Note that you need to replace the DVD device with the one attached to your container:

```
# zypper --root $R00TFS ar \
cd:///?devices=/dev/dvd SLES12-12
```

3. Disable or remove previous repositories:

```
# zypper --root $R00TFS lr
| Alias | Name | Enabled | Refresh |
+-----+-----+-----+-----+
1 | SLES12-12 | SLES12-12 | Yes | No |
2 | SUSE-[...]-Server-11-SP3 38 | SUSE-[...]-Server-11-SP3 138 | Yes | No |

# zypper --root $R00TFS rr 2
```

4. Upgrade the container:

```
# zypper --root $R00TFS dup
```

5. Install the *Minimal* pattern to make sure everything required is installed:

```
# zypper --root $R00TFS in -t pattern Minimal
```

## 32.3 Starting the Container

After the host and container migration is complete, the container can be started:

```
# virsh -c lxc:/// start lxc_container
```

If you need to get a console to view the logging messages produced by the container, run:

```
# virsh -c lxc:/// console lxc_container
```

# Glossary

## General

### Create Virtual Machine Wizard

A software program available in YaST and Virtual Machine Manager that provides a graphical interface to guide you through the steps to create virtual machines. It can also be run in text mode by entering `virt-install` at a command prompt in the host environment.

### Dom0

The term is used in Xen environments, and refers to a virtual machine. The host operating system is actually a virtual machine running in a privileged domain and can be called Dom0. All other virtual machines on the host run in unprivileged domains and can be called domain U's.

### hardware-assisted

Intel\* and AMD\* provide virtualization hardware-assisted technology. This reduces the frequency of VM IN/OUT (fewer VM traps), because software is a major source of overhead, and increases the efficiency (the execution is done by the hardware). Moreover, this reduces the memory footprint, provides better resource control, and allows secure assignment of specific I/O devices.

### Host Environment

The desktop or command line environment that allows interaction with the host computer's environment. It provides a command line environment and can also include a graphical desktop, such as GNOME or IceWM. The host environment runs as a special type of virtual machine that has privileges to control and manage other virtual machines. Other commonly used terms include *Dom0*, privileged domain, and host operating system.

### Hypervisor

The software that coordinates the low-level interaction between virtual machines and the underlying physical computer hardware.

### KVM

See *Chapter 3, Introduction to KVM Virtualization*

## Paravirtualized Frame Buffer

The video output device that drives a video display from a memory buffer containing a complete frame of data for virtual machine displays running in paravirtual mode.

## VHS

Virtualization Host Server

The physical computer running a SUSE virtualization platform software. The virtualization environment consists of the hypervisor, the host environment, virtual machines, and associated tools, commands, and configuration files. Other commonly used terms include host, Host Computer, Host Machine (HM), Virtual Server (VS), Virtual Machine Host (VMH), and VM Host Server (VHS).

## VirtFS

VirtFS is a new paravirtualized file system interface designed for improving pass-through technologies in the KVM environment. It is based on the VirtIO framework.

## Virtual Machine

A virtualized PC environment (VM) capable of hosting a guest operating system and associated applications. Could be also called a VM Guest.

## Virtual Machine Manager

A software program that provides a graphical user interface for creating and managing virtual machines.

## Virtualized

A guest operating system or application running on a virtual machine.

## Xen

See [Chapter 2, Introduction to Xen Virtualization](#)

## xl

A set of commands for Xen that lets administrators manage virtual machines from a command prompt on the host computer. It replaced the deprecated `xm` tool stack.

# CPU

## CPU capping

Virtual CPU capping allows you to set vCPU capacity to 1–100 percent of the physical CPU capacity.

## CPU hotplugging

CPU hotplugging is used to describe the functions of replacing/adding/removing a CPU without shutting down the system.

## CPU over-commitment

Virtual CPU over-commitment is the ability to assign more virtual CPUs to VMs than the actual number of physical CPUs present in the physical system. This procedure does not increase the overall performance of the system, but might be useful for testing purposes.

## CPU pinning

Processor affinity, or CPU pinning enables the binding and unbinding of a process or a thread to a central processing unit (CPU) or a range of CPUs.

# Network

## Bridged Networking

A type of network connection that lets a virtual machine be identified on an external network as a unique identity that is separate from and unrelated to its host computer.

## Empty Bridge

A type of network bridge that has no physical network device or virtual network device provided by the host. This lets virtual machines communicate with other virtual machines on the same host but not with the host or on an external network.

## External Network

The network outside a host's internal network environment.

## Internal Network

A type of network configuration that restricts virtual machines to their host environment.

### **Local Bridge**

A type of network bridge that has a virtual network device but no physical network device provided by the host. This lets virtual machines communicate with the host and other virtual machines on the host. Virtual machines can communicate on an external network through the host.

### **Network Address Translation (NAT)**

A type of network connection that lets a virtual machine use the IP address and MAC address of the host.

### **No Host Bridge**

A type of network bridge that has a physical network device but no virtual network device provided by the host. This lets virtual machines communicate on an external network but not with the host. This lets you separate virtual machine network communications from the host environment.

### **Traditional Bridge**

A type of network bridge that has both a physical network device and a virtual network device provided by the host.

## **Storage**

### **AHCI**

The Advanced Host Controller Interface (AHCI) is a technical standard defined by Intel\* that specifies the operation of Serial ATA (SATA) host bus adapters in a non-implementation-specific manner.

### **Block Device**

Data storage devices, such as CD-ROM drives or disk drives, that move data in the form of blocks. Partitions and volumes are also considered block devices.

### **File-Backed Virtual Disk**

A virtual disk based on a file, also called a disk image file.

### **Raw Disk**

A method of accessing data on a disk at the individual byte level instead of through its file system.



### Sparse image file

A disk image file that does not reserve its entire amount of disk space but expands as data is written to it.

### xvda

The drive designation given to the first virtual disk on a paravirtual machine.

## Linux Containers

### cgroups

Kernel Control Groups (commonly called “cgroups”) are a kernel feature that allows aggregating or partitioning tasks (processes) and all their children into hierarchical organized groups to isolate resources.

See also *Book “System Analysis and Tuning Guide”, Chapter 9 “Kernel Control Groups”*.

### chroot

A *change root* (chroot, or change root jail) is a section in the file system that is isolated from the rest of the file system. For this purpose, the **chroot** or **pivot\_root** command is used to change the root of the file system. A program that is executed in such a “chroot jail” cannot access files outside the designated directory tree.

### container

Can be seen as a kind of “virtual machine” on the host server that can run any Linux system, for example openSUSE, SUSE Linux Enterprise Desktop, or SUSE Linux Enterprise Server. The main difference with a normal virtual machine is that the container shares its kernel with the host it runs on.

### Kernel namespaces

A kernel feature to isolate some resources like network, users, and others for a group of processes.

# Acronyms

## ACPI

Advanced Configuration and Power Interface (ACPI) specification provides an open standard for device configuration and power management by the operating system.

## AER

Advanced Error Reporting

AER is a capability provided by the PCI Express specification which allows for reporting of PCI errors and recovery from some of them.

## APIC

Advanced Programmable Interrupt Controller (APIC) is a family of interrupt controllers.

## BDF

Bus:Device:Function

Notation used to succinctly describe PCI and PCIe devices.

## CG

Control Groups

Feature to limit, account and isolate resource usage (CPU, memory, disk I/O, etc.).

## EDF

Earliest Deadline First

This scheduler provides weighted CPU sharing in an intuitive way and uses real-time algorithms to ensure time guarantees.

## EPT

Extended Page Tables

Performance in a virtualized environment is close to that in a native environment. Virtualization does create some overheads, however. These come from the virtualization of the CPU, the *MMU*, and the I/O devices. In some recent x86 processors AMD and Intel have begun to provide hardware extensions to help bridge this performance gap. In 2006, both vendors introduced their first generation hardware support for x86 virtualization with AMD-Virtualization (AMD-V) and Intel® VT-x technologies. Recently Intel introduced its second generation of hardware support that incorporates MMU-virtualization, called Extended Page

Tables (EPT). EPT-enabled systems can improve performance compared to using shadow paging for *MMU* virtualization. EPT increases memory access latencies for a few workloads. This cost can be reduced by effectively using large pages in the guest and the hypervisor.

## FLASK

Flux Advanced Security Kernel

Xen implements a type of mandatory access control via a security architecture called FLASK using a module of the same name.

## HAP

High Assurance Platform

HAP combines hardware and software technologies to improve workstation and network security.

## HVM

Hardware Virtual Machine (commonly called like this by Xen).

## IOMMU

Input/Output Memory Management Unit

IOMMU (AMD\* technology) is a memory management unit (*MMU*) that connects a direct memory access-capable (DMA-capable) I/O bus to the main memory.

## KSM

Kernel Same Page Merging

KSM allows for automatic sharing of identical memory pages between guests to save host memory. KVM is optimized to use KSM if enabled on the VM Host Server.

## MMU

Memory Management Unit

is a computer hardware component responsible for handling accesses to memory requested by the CPU. Its functions include translation of virtual addresses to physical addresses (that is, virtual memory management), memory protection, cache control, bus arbitration and in simpler computer architectures (especially 8-bit systems) bank switching.

## PAE

Physical Address Extension

32-bit x86 operating systems use Physical Address Extension (PAE) mode to enable addressing of more than 4 GB of physical memory. In PAE mode, page table entries (PTEs) are 64 bits in size.

## PCID

Process-context identifiers

These are a facility by which a logical processor may cache information for multiple linear-address spaces so that the processor may retain cached information when software switches to a different linear address space. INVPCID instruction is used for fine-grained *TLB* flush, which is benefit for kernel.

## PCIe

Peripheral Component Interconnect Express

PCIe was designed to replace older PCI, PCI-X and AGP bus standards. PCIe has numerous improvements including a higher maximum system bus throughput, a lower I/O pin count and smaller physical footprint. Moreover it also has a more detailed error detection and reporting mechanism (*AER*), and a native hotplug functionality. It is also backward compatible with PCI.

## PSE and PSE36

Page Size Extended

PSE refers to a feature of x86 processors that allows for pages larger than the traditional 4 KiB size. PSE-36 capability offers 4 more bits, in addition to the normal 10 bits, which are used inside a page directory entry pointing to a large page. This allows a large page to be located in 36-bit address space.

## PT

Page Table

A page table is the data structure used by a virtual memory system in a computer operating system to store the mapping between virtual addresses and physical addresses. Virtual addresses are those unique to the accessing process. Physical addresses are those unique to the hardware (RAM).

## QXL

QXL is a cirrus VGA framebuffer (8M) driver for virtualized environment.

## RVI or NPT

Rapid Virtualization Indexing, Nested Page Tables

An AMD second generation hardware-assisted virtualization technology for the processor memory management unit (*MMU*).

## **SATA**

Serial ATA

SATA is a computer bus interface that connects host bus adapters to mass storage devices such as hard disks and optical drives.

## **Seccomp2-based sandboxing**

Sandboxed environment where only predetermined system calls are permitted for added protection against malicious behavior.

## **SMEP**

Supervisor Mode Execution Protection

This prevents the execution of user-mode pages by the Xen hypervisor, making many application-to-hypervisor exploits much harder.

## **SPICE**

Simple Protocol for Independent Computing Environments

## **SXP**

An SXP file is a Xen Configuration File.

## **TCG**

Tiny Code Generator

Instructions are emulated rather than executed by the CPU.

## **THP**

Transparent Huge Pages

This allows CPUs to address memory using pages larger than the default 4 KB. This helps reduce memory consumption and CPU cache usage. KVM is optimized to use THP (via mad-*vice* and opportunistic methods) if enabled on the VM Host Server.

## **TLB**

Translation Lookaside Buffer

TLB is a cache that memory management hardware uses to improve virtual address translation speed. All current desktop, notebook, and server processors use a TLB to map virtual and physical address spaces, and it is nearly always present in any hardware that uses virtual memory.

## VCPU

A scheduling entity, containing each state for virtualized CPU.

## VDI

Virtual Desktop Infrastructure

## VFIO

Since kernel v3.6; a new method of accessing PCI devices from user space called VFIO.

## VHS

Virtualization Host Server

## VM root

*VMM* will run in *VMX* root operation and guest software will run in *VMX* non-root operation. Transitions between *VMX* root operation and *VMX* non-root operation are called *VMX* transitions.

## VMCS

Virtual Machine Control Structure

VMX non-root operation and VMX transitions are controlled by a data structure called a virtual-machine control structure (VMCS). Access to the VMCS is managed through a component of processor state called the VMCS pointer (one per logical processor). The value of the VMCS pointer is the 64-bit address of the VMCS. The VMCS pointer is read and written using the instructions VMPTRST and VMPTRLD. The *VMM* configures a VMCS using the VMREAD, VMWRITE, and VMCLEAR instructions. A *VMM* could use a different VMCS for each virtual machine that it supports. For a virtual machine with multiple logical processors (virtual processors), the *VMM* could use a different VMCS for each virtual processor.

## VMDq

Virtual Machine Device Queue

Multi-queue network adapters exist which support multiple VMs at the hardware level, having separate packet queues associated to the different hosted VMs (by means of the IP addresses of the VMs).

## VMM

Virtual Machine Monitor (Hypervisor)

When the processor encounters an instruction or event of interest to the Hypervisor (*VMM*), it exits from guest mode back to the VMM. The VMM emulates the instruction or other event, at a fraction of native speed, and then returns to guest mode. The transitions from guest mode to the VMM and back again are high-latency operations, during which guest execution is completely stalled.

## VMX

Virtual Machine eXtensions

## VPID

New support for software control of *TLB* (VPID improves *TLB* performance with small *VMM* development effort).

## VT-d

Virtualization Technology for Directed I/O

Like *IOMMU* for Intel\* (<https://software.intel.com/en-us/articles/intel-virtualization-technology-for-directed-io-vt-d-enhancing-intel-platforms-for-efficient-virtualization-of-io-devices>)<sup>7</sup>.


## vTPM


Component to establish end-to-end integrity for guests via Trusted Computing.

## A Virtual Machine Drivers

Virtualization allows the consolidation of workloads on newer, more powerful, energy-efficient hardware. Paravirtualized operating systems such as SUSE® Linux Enterprise Server and other Linux distributions are aware of the underlying virtualization platform, and can therefore interact efficiently with it. Unmodified operating systems such as Microsoft Windows\* are unaware of the virtualization platform and expect to interact directly with the hardware. Because this is not possible when consolidating servers, the hardware must be emulated for the operating system. Emulation can be slow, but it is especially troubling for high-throughput disk and network subsystems. Most performance loss occurs in this area.

The SUSE Linux Enterprise Virtual Machine Driver Pack (VMDP) contains 32-bit and 64-bit paravirtualized network, bus and block drivers for several Microsoft Windows operating systems. These drivers bring many of the performance advantages of paravirtualized operating systems to unmodified operating systems: Only the paravirtualized device driver (not the rest of the operating system) is aware of the virtualization platform. For example, a paravirtualized disk device driver appears as a normal, physical disk to the operating system. However, the device driver interacts directly with the virtualization platform (with no emulation). This helps to efficiently deliver disk access, allowing the disk and network subsystems to operate at near native speeds in a virtualized environment, without requiring changes to existing operating systems.

The SUSE® Linux Enterprise Virtual Machine Driver Pack is available as an add-on product for SUSE Linux Enterprise Server. For detailed information refer to <https://www.suse.com/products/vmdriverpack/> .

Refer to the Official VMDP Installation Guide at <https://documentation.suse.com/sle-vmdp/>  for more information.



## B Appendix

### B.1 Installing Paravirtualized Drivers

#### B.1.1 Installing virtio Drivers for Microsoft Windows\*

SUSE has developed virtio-based drivers for Windows, which are available in the Virtual Machine Driver Pack (VMDP). See <https://www.suse.com/products/vmdriverpack/> for more information on the VMDP. Installation instructions are now available in a dedicated official documentation.

### B.2 Generating x509 Client/Server Certificates

To be able to create x509 client and server certificates you need to issue them by a Certificate Authority (CA). It is recommended to set up an independent CA that only issues certificates for `libvirt`.

1. Set up a CA as described in Book *"Security and Hardening Guide"*, Chapter 18 *"Managing X.509 Certification"*, Section 18.2.1 *"Creating a Root CA"*.
2. Create a server and a client certificate as described in Book *"Security and Hardening Guide"*, Chapter 18 *"Managing X.509 Certification"*, Section 18.2.4 *"Creating or Revoking User Certificates"*. The Common Name (CN) for the server certificate must be the fully qualified host name, while the Common Name for the client certificate can be freely chosen. For all other fields stick with the defaults suggested by YaST.

Export the client and server certificates to a temporary location (for example, `/tmp/x509/`) by performing the following steps:

- a. Select the certificate on the *certificates* tab.
- b. Choose *Export > Export to File > Certificate and the Key Unencrypted in PEM Format*, provide the *Certificate Password* and the full path and the file name under *File Name*, for example, `/tmp/x509/server.pem` or `/tmp/x509/client.pem`.

- c. Open a terminal and change to the directory where you have saved the certificate and issue the following commands to split it into certificate and key (this example splits the server key):

```
csplit -z -f s_server.pem '/-----BEGIN/' '{1}'  
mv s_00 servercert.pem  
mv s_01 serverkey.pem
```

- d. Repeat the procedure for each client and server certificate you want to export.

3. Finally export the CA certificate by performing the following steps:

- a. Switch to the *Description* tab.
- b. Choose *Advanced* › *Export to File* › *Only the Certificate in PEM Format* and enter the full path and the file name under *File Name*, for example, /tmp/x509/cacert.pem.

## C XM, XL Tool Stacks and Libvirt framework

### C.1 Xen Tool Stacks

Since the early Xen 2.x releases, **xend** has been the de facto tool stack for managing Xen installations. In Xen 4.1, a new tool stack called libxenlight (also known as libxl) was introduced with technology preview status. libxl is a small, low-level library written in C. It has been designed to provide a simple API for all client tool stacks (**XAPI** (<http://wiki.xen.org/wiki/XAPI>), **libvirt**, **xl**). In Xen 4.2, libxl was promoted to officially supported status and **xend** was marked deprecated. **xend** has been included in the Xen 4.3 and 4.4 series to give users ample time to convert their tooling to libxl. It has been removed from the upstream Xen project and will no longer be provided starting with the Xen 4.5 series and SUSE Linux Enterprise Server 12 SP1.

Although SLES 11 SP3 contains Xen 4.2, SUSE retained the **xend** tool stack since making such an invasive change in a service pack would be too disruptive for SUSE Linux Enterprise customers. However, SLES 12 provides a suitable opportunity to move to the new libxl tool stack and remove the deprecated, unmaintained **xend** stack. Starting with SUSE Linux Enterprise Server 12 SP1, **xend** is no longer supported.

One of the major differences between **xend** and libxl is that the former is stateful, while the latter is stateless. With **xend**, all client applications such as **xm** and **libvirt** see the same system state. **xend** is responsible for maintaining state for the entire Xen host. In libxl, client applications such as **xl** or **libvirt** must maintain state. Thus domains created with **xl** or not visible or known to other libxl applications such as **libvirt**. Generally, it is discouraged to mix and match libxl applications and is preferred that a single libxl application be used to manage a Xen host. In SUSE Linux Enterprise Server, we recommend to use **libvirt** to manage Xen hosts. This allows management of the Xen system through **libvirt** applications such as **virt-manager**, **virt-install**, **virt-viewer**, **libguestfs**, etc. If **xl** is used to manage the Xen host, any virtual machines under its management will not be accessible to **libvirt**. Hence, they are not accessible to any of the **libvirt** applications.

#### C.1.1 Upgrading from xend/xm to xl/libxl

The **xl** application, along with its configuration format (see **man xl.cfg**), was designed to be backward-compatible with the **xm** application and its configuration format (see **man xm.cfg**). Existing **xm** configuration should be usable with **xl**. Since libxl is stateless, and **xl** does not

support the notion of managed domains, SUSE recommends using `libvirt` to manage SLES 12 Xen hosts. SUSE has provided a tool called `xen2libvirt`, which provides a simple mechanism to import domains previously managed by `xend` into `libvirt`. See [Section C.2, “Import Xen Domain Configuration into libvirt”](#) for more information on `xen2libvirt`.

## C.1.2 XL design

The basic structure of every `xl` command is:

```
xl subcommand OPTIONS DOMAIN
```

`DOMAIN` is the numeric domain id, or the domain name (which will be internally translated to domain id), and `OPTIONS` are subcommand specific options.

Although `xl/libxl` was designed to be backward-compatible with `xm/xend`, there are a few differences that should be noted:

- Managed or persistent domains. `libvirt` now provides this functionality.
- `xl/libxl` does not support Python code in the domain configuration files.
- `xl/libxl` does not support creating domains from SXP format configuration files (`xm create -F`).
- `xl/libxl` does not support sharing storage across DomU's via `w!` in domain configuration files.

`xl/libxl` is relatively new and under heavy development, hence a few features are still missing with regard to the `xm/xend` tool stack:

- SCSI LUN/Host pass-through (PVSCSI)
- USB pass-through (PVUSB)
- Direct Kernel Boot for fully virtualized Linux guests for Xen

## C.1.3 Checklist before Upgrade

Before upgrading a SLES 11 SP3 Xen host to SLES 12:

- You must remove any Python code from your `xm` domain configuration files.
- It is recommended to capture the libvirt domain XML from all existing virtual machines using `virsh dumpxml DOMAIN_NAME DOMAIN_NAME.xml`.
- It is recommended to do a backup of `/etc/xen/xend-config.sxp` and `/boot/grub/menu.lst` files to keep references of previous parameters used for Xen.



### Note

Currently, live migrating virtual machines running on a SLES 11 SP3 Xen host to a SLES 12 Xen host is not supported. The `xend` and `libxl` tool stacks are not runtime-compatible. Virtual machine downtime will be required to move the virtual machines from SLES 11 SP3 to a SLES 12 host.

## C.2 Import Xen Domain Configuration into libvirt

`xen2libvirt` is a command line tool to import legacy Xen domain configuration into the `libvirt` virtualization library (see The Virtualization book for more information on `libvirt`). `xen2libvirt` provides an easy way to import domains managed by the deprecated `xm`/`xend` tool stack into the new `libvirt`/`libxl` tool stack. Several domains can be imported at once using its `--recursive` mode

`xen2libvirt` is included in the `xen-tools` package. If needed, install it with

```
zypper install xen-tools
```

`xen2libvirt` general syntax is

```
xen2libvirt <options> /path/to/domain/config
```

where `options` can be:

`-h, --help`

Prints short information about `xen2libvirt` usage.

-c, --convert-only

Converts the domain configuration to the libvirt XML format, but does not do the import to libvirt.

-r, --recursive

Converts and/or imports all domains configuration recursively, starting at the specified path.

-f, --format

Specifies the format of the source domain configuration. Can be either xm, or sexpr (S-expression format).

-v, --verbose

Prints more detailed information about the import process.

#### EXAMPLE C.1: CONVERTING XEN DOMAIN CONFIGURATION TO libvirt

Suppose you have a Xen domain managed with xm with the following configuration saved in /etc/xen/sle12.xm:

```
kernel = "/boot/vmlinuz-2.6-xenU"
memory = 128
name = "SLE12"
root = "/dev/hda1 ro"
disk = [ "file:/var/xen/sle12.img,hda1,w" ]
```

Convert it to libvirt XML without importing it, and look at its content:

```
# xen2libvirt -f xm -c /etc/xen/sle12.xm > /etc/libvirt/qemu/sles12.xml
# cat /etc/libvirt/qemu/sles12.xml
<domain type='xen'>
  <name>SLE12</name>
  <uuid>43e1863c-8116-469c-a253-83d8be09a1d</uuid>
  <memory unit='KiB'>131072</memory>
  <currentMemory unit='KiB'>131072</currentMemory>
  <vcpu placement='static'>1</vcpu>
  <os>
    <type arch='x86_64' machine='xenpv'>linux</type>
    <kernel>/boot/vmlinuz-2.6-xenU</kernel>
  </os>
  <clock offset='utc' adjustment='reset'/>
  <on_poweroff>destroy</on_poweroff>
  <on_reboot>restart</on_reboot>
  <on_crash>restart</on_crash>
  <devices>
    <disk type='file' device='disk'>
```

```
<driver name='file' />
<source file='/var/xen/sles12.img' />
<target dev='hda1' bus='xen' />
</disk>
<console type='pty'>
<target type='xen' port='0' />
</console>
</devices>
</domain>
```

To import the domain into `libvirt`, you can either run the same `xen2libvirt` command without the `-c` option, or use the exported file `/etc/libvirt/qemu/sles12.xml` and define a new Xen domain using `virsh`:

```
# sudo virsh define /etc/libvirt/qemu/sles12.xml
```

## C.3 Differences Between the `xm` and `xl` Applications

The purpose of this chapter is to list all differences between `xm` and `xl` applications. Generally, `xl` is designed to be compatible with `xm`. Replacing `xm` with `xl` in custom scripts or tools is usually sufficient.

You can also use the `libvirt` framework using the `virsh` command. In this documentation only the first `OPTION` for `virsh` will be shown. To get more help on this option do a:

```
virsh help OPTION
```

### C.3.1 Notation Conventions

To easily understand the difference between `xl` and `xm` commands, the following notation is used in this section:

TABLE C.1: NOTATION CONVENTIONS

Notation	Meaning
(-) minus	Option exists in <code>xm</code> , but <code>xl</code> does not include it.
(+) plus	Option exists in <code>xl</code> , but <code>xm</code> does not include it.

## C.3.2 New Global Options

TABLE C.2: NEW GLOBAL OPTIONS

Options	Task
(+) <u>-v</u>	Verbose, increase the verbosity of the output
(+) <u>-N</u>	Dry run, do not actually execute the command
(+) <u>-f</u>	Force execution. <u>xl</u> will refuse to run some commands if it detects that <u>xend</u> is also running, this option will force the execution of those commands, even though it is unsafe

## C.3.3 Unchanged Options

List of common options of xl and xm, and their libvirt equivalents.

TABLE C.3: COMMON OPTIONS

Options	Task	<u>libvirt</u> equivalent
destroy <u>DOMAIN</u>	Immediately terminate the domain.	<u>virsh</u> <u>destroy</u>
domid <u>DOMAIN_NAME</u>	Convert a domain name to a <u>DOMAIN_ID</u> .	<u>virsh</u> <u>domid</u>
domname <u>DOMAIN_ID</u>	Convert a <u>DOMAIN_ID</u> to a <u>DOMAIN_NAME</u> .	<u>virsh</u> <u>domname</u>
help	Display the short help message (that is, common commands).	<u>virsh</u> <u>help</u>
pause <u>DOMAIN_ID</u>	Pause a domain. When in a paused state, the domain will still consume allocated re-	<u>virsh</u> <u>suspend</u>



Options	Task	libvirt equivalent
	sources such as memory, but will not be eligible for scheduling by the Xen hypervisor.	
unpause <u>DOMAIN_ID</u>	Move a domain out of the paused state. This will allow a previously paused domain to be eligible for scheduling by the Xen hypervisor.	<b>virsh</b> <u>resume</u>
rename <u>DOMAIN_ID</u> <u>NEW_DOMAIN_NAME</u>	Change the domain name of <u>DOMAIN_ID</u> to <u>NEW_DOMAIN_NAME</u> .	<ol style="list-style-type: none"> <li>1. <pre>virsh   dumpxml DOMAINNAME &gt;   DOMXML</pre></li> <li>2. modify the domain's name in <u>DOMXML</u></li> <li>3. <pre>virsh   undefine DOMAINNAME</pre></li> <li>4. <pre>virsh   define DOMAINNAME</pre></li> </ol>
sysrq <u>DOMAIN</u> <letter>	Send a Magic System Request to the domain, each type of request is represented by a different letter. It can be used to send SysRq requests to Linux guests, see <a href="https://www.kernel.org/doc/html/latest/admin-guide/sysrq.html">https://www.kernel.org/doc/html/latest/admin-guide/sysrq.html</a> for more information. It requires PV drivers to be installed in your guest OS.	<b>virsh</b> <u>send-keys</u> can send Magic Sys Req only for KVM

Options	Task	libvirt equivalent
<code>vncviewer</code> <u>OPTIONS</u> <u>DOMAIN</u>	Attach to domain's VNC server, forking a vncviewer process.	<u>virt-view</u> <u>DOMAIN_ID</u> <u>virsh</u> <u>VNCDISPLAY</u>
<code>vcpu-set</code> <u>DOMAIN_ID</u> <vCPUs>	Enable the vcpu-count virtual CPUs for the domain in question. Like <u>mem-set</u> , this command can only allocate up to the maximum virtual CPU count configured at boot for the domain.	<u>virsh</u> <u>setvcpus</u>
<code>vcpu-list</code> <u>DOMAIN_ID</u>	List VCPU information for a specific domain. If no domain is specified, VCPU information for all domains will be provided.	<u>virsh</u> <u>vcpuinfo</u>
<code>vcpu-pin</code> <u>DOMAIN_ID</u> <VCPU all> <CPUs all>	Pin the VCPU to only run on the specific CPUs. The keyword all can be used to apply the CPU list to all VCPUs in the domain.	<u>virsh</u> <u>vcupin</u>
<code>dmesg [-c]</code>	Read the Xen message buffer, similar to dmesg on a Linux system. The buffer contains informational, warning, and error messages created during Xen's boot process.	
<code>top</code>	Execute the <u>xentop</u> command, which provides real time monitoring of domains. <u>xentop</u> is a curses interface.	<u>virsh</u> <u>nodecpustats</u> <u>virsh</u> <u>nodememstats</u>

Options	Task	<u>libvirt</u> equivalent
uptime [-s] <u>DOMAIN</u>	Print the current uptime of the domains running. With the <b>xl</b> command, the <u>DOMAIN</u> argument is mandatory.	
debug-keys <u>KEYS</u>	Send debug keys to Xen. It is the same as pressing the Xen <i>conswitch</i> (Ctrl-A by default) three times and then pressing "keys".	
cpupool-migrate <u>DOMAIN</u> <u>CPU_POOL</u>	Move a domain specified by <u>DOMAIN_ID</u> or <u>DOMAIN</u> into a <u>CPU_POOL</u> .	
cpupool-destroy <u>CPU_POOL</u>	Deactivate a CPU pool. This is possible only if no domain is active in the CPU pool.	
block-detach <u>DOMAIN_ID</u> <u>DevId</u>	Detach a domain's virtual block device. <i>devId</i> may be the symbolic name or the numeric device id given to the device by Dom0. You will need to run <b>xl block-list</b> to determine that number.	<b><u>virsh</u></b> <u>detach-disk</u>
network-attach <u>DOMAIN_ID</u> <u>NETWORK_DEVICE</u>	Create a new network device in the domain specified by <u>DOMAIN_ID</u> . <i>network-device</i> describes the device to attach, using the same format as the vif string in the domain configuration file	<b><u>virsh</u></b> <u>attach-interface</u> <b><u>virsh</u></b> <u>attach-device</u>

Options	Task	libvirt equivalent
pci-attach <u>DOMAIN</u> <BDF> [Virtual Slot]	Hotplug a new pass-through PCI device to the specified domain. <i>BDF</i> is the PCI Bus/Device/Function of the physical device to be passed through.	<u>virsh</u> <u>attach-device</u>
pci-list <u>DOMAIN_ID</u>	List pass-through PCI devices for a domain	
getenforce	Determine if the <i>FLASK</i> security module is loaded and enforcing its policy.	
setenforce <1 0 Enforcing Permissive>	Enable or disable enforcing of the <i>FLASK</i> access controls. The default is permissive and can be changed using the flask_enforcing option on the hypervisor's command line.	

## C.3.4 Removed Options

List of xm options which are no more available with the XL tool stack and a replacement solution if available.

### C.3.4.1 Domain Management

The list of Domain management removed command and their replacement.

TABLE C.4: DOMAIN MANAGEMENT REMOVED OPTIONS

Domain Management Removed Options		
Options	Task	Equivalent
(-) <u>log</u>	Print the Xend log.	This log file can be found in <u>/var/log/xend.log</u>
(-) <u>delete</u>	Remove a domain from Xend domain management. The <u>list</u> option shows the domain names	<u>virsh</u> <u>undefine</u>
(-) <u>new</u>	Adds a domain to Xend domain management	<u>virsh</u> <u>define</u>
(-) <u>start</u>	Start a Xend managed domain that was added using the <u>xm new</u> command	<u>virsh</u> <u>start</u>
(-) <u>dryrun</u>	Dry run - prints the resulting configuration in <i>SXP</i> but does not create the domain	<u>xl</u> <u>-N</u>
(-) <u>reset</u>	Reset a domain	<u>virsh</u> <u>reset</u>
(-) <u>domstate</u>	Show domain state	<u>virsh</u> <u>domstate</u>
(-) <u>serve</u>	Proxy Xend XMLRPC over stdio	
(-) <u>resume</u> <i>DOMAIN</i> <i>OPTIONS</i>	Moves a domain out of the suspended state and back into memory	<u>virsh</u> <u>resume</u>
(-) <u>suspend</u> <i>DOMAIN</i>	Suspend a domain to a state file so that it can be later resumed using the <u>resume</u> subcommand. Similar to	<u>virsh</u> <u>managesave</u> <u>virsh</u> <u>suspend</u>

Domain Management Removed Options		
Options	Task	Equivalent
	the <u>save</u> subcommand although the state file may not be specified	

### C.3.4.2 USB Devices

USB options are not available with xl/libxl tool stack. virsh has the attach-device and detach-device options but it does not work yet with USB.

TABLE C.5: USB DEVICES MANAGEMENT REMOVED OPTIONS

USB Devices Management Removed Options	
Options	Task
(-) <u>usb-add</u>	Add a new USB physical bus to a domain
(-) <u>usb-del</u>	Delete a USB physical bus from a domain
(-) <u>usb-attach</u>	Attach a new USB physical bus to domain's virtual port
(-) <u>usb-detach</u>	Detach a USB physical bus from domain's virtual port
(-) <u>usb-list</u>	List domain's attachment state of all virtual port
(-) <u>usb-list-assignable-devices</u>	List all the assignable USB devices
(-) <u>usb-hc-create</u>	Create a domain's new virtual USB host controller
(-) <u>usb-hc-destroy</u>	Destroy a domain's virtual USB host controller

### C.3.4.3 CPU Management

CPU management options has changed. New options are available, see: [Section C.3.5.10, “xl cpupool -\\*”](#)

TABLE C.6: CPU MANAGEMENT REMOVED OPTIONS

CPU Management Removed Options	
Options	Task
(-) <u>cpupool-new</u>	Adds a CPU pool to Xend CPU pool management
(-) <u>cpupool-start</u>	Starts a Xend CPU pool
(-) <u>cpupool-delete</u>	Removes a CPU pool from Xend management

### C.3.4.4 Other Options

TABLE C.7: OTHER OPTIONS

Other Removed Options	
Options	Task
(-) <u>shell</u>	Launch an interactive shell
(-) <u>change-vnc-passwd</u>	Change VNC password
(-) <u>vtpm-list</u>	List virtual TPM devices
(-) <u>block-configure</u>	Change block device configuration

## C.3.5 Changed Options

### C.3.5.1 create

**xl create** CONFIG\_FILE OPTIONS VARS



## Note: libvirt Equivalent:

virsh create

TABLE C.8: **xl** create CHANGED OPTIONS

<u>create</u> <b>Changed Options</b>	
<i>Options</i>	<i>Task</i>
(*) -f= <u>FILE</u> , --defconfig= <u>FILE</u>	Use the given configuration file

TABLE C.9: **xm** create REMOVED OPTIONS

<u>create</u> <b>Removed Options</b>	
<i>Options</i>	<i>Task</i>
(-) <u>-s</u> , <u>--skipdtd</u>	Skip DTD checking - skips checks on XML before creating
(-) <u>-x</u> , <u>--xmldryrun</u>	XML dry run
(-) <u>-F=FILE</u> , <u>--config=FILE</u>	Use the given <i>SXP</i> formatted configuration script
(-) <u>--path</u>	Search path for configuration scripts
(-) <u>--help_config</u>	Print the available configuration variables (vars) for the configuration script
(-) <u>-n</u> , <u>--dryrun</u>	Dry run — prints the configuration in <i>SXP</i> but does not create the domain
(-) <u>-c</u> , <u>--console_autoconnect</u>	Connect to the console after the domain is created
(-) <u>-q</u> , <u>--quiet</u>	Quiet mode
(-) <u>-p</u> , <u>--paused</u>	Leave the domain paused after it is created



TABLE C.10: **xl create** ADDED OPTIONS

<u>create</u> Added Options	
Options	Task
(+) <u>-V</u> , <u>--vncviewer</u>	Attach to domain's VNC server, forking a vncviewer process
(+) <u>-A</u> , <u>--vncviewer-autopass</u>	Pass VNC password to vncviewer via STDIN

### C.3.5.2 console

**xl console** *OPTIONS* *DOMAIN*



Note: libvirt Equivalent

virsh console

TABLE C.11: **xl console** ADDED OPTIONS

<u>console</u> Added Option	
Option	Task
(+) <u>-t</u> [pv serial]	Connect to a PV console or connect to an emulated serial console. PV consoles are the only consoles available for PV domains while HVM domains can have both

### C.3.5.3 info

**xl info**

TABLE C.12: **xm info** REMOVED OPTIONS

<u>info</u> Removed Options	
Options	Task
(-) <u>-n</u> , <u>--numa</u>	NUMA info

<u>info</u> <b>Removed Options</b>	
<b>Options</b>	<b>Task</b>
(-) <u>-c</u> , <u>--config</u>	List Xend configuration parameters

#### C.3.5.4 **dump-core**

**xl dump-core** DOMAIN FILENAME



**Note: libvirt Equivalent**

virsh dump

TABLE C.13: **xm dump-core** REMOVED OPTIONS

<u>dump-core</u> <b>Removed Options</b>	
<b>Options</b>	<b>Task</b>
(-) <u>-L</u> , <u>--live</u>	Dump core without pausing the domain
(-) <u>-C</u> , <u>--crash</u>	Crash domain after dumping core
(-) <u>-R</u> , <u>--reset</u>	Reset domain after dumping core

#### C.3.5.5 **list**

**xl list** options DOMAIN



**Note: libvirt Equivalent**

virsh list --all

TABLE C.14: `xm list` REMOVED OPTIONS

<code>list</code> Removed Options	
Options	Task
(-) <code>-l</code> , <code>--long</code>	The output for <code>xm list</code> presents the data in <code>SXP</code> format
(-) <code>--state==STATE</code>	Output information for VMs in the specified state

TABLE C.15: `xl list` ADDED OPTIONS

<code>list</code> Added Options	
Options	Task
(+) <code>-Z</code> , <code>--context</code>	Also prints the security labels
(+) <code>-v</code> , <code>--verbose</code>	Also prints the domain UUIDs, the shutdown reason and security labels

### C.3.5.6 `mem-*`



#### Note: libvirt Equivalent

`virsh setmem`

`virsh setmaxmem`

TABLE C.16: `xl mem-*` CHANGED OPTIONS

<code>mem-*</code> Changed Options	
Options	Task
<code>mem-max DOMAIN_ID MEM</code>	Appending <code>t</code> for terabytes, <code>g</code> for gigabytes, <code>m</code> for megabytes, <code>k</code> for kilobytes and <code>b</code> for bytes. Specify the maximum amount of memory the domain can use.

<u>mem - *</u> <b>Changed Options</b>	
<b>Options</b>	<b>Task</b>
<u>mem-set</u> <u>DOMAIN_ID</u> <u>MEM</u>	Set the domain's used memory using the balloon driver

### C.3.5.7 **migrate**

**xl migrate** OPTIONS DOMAIN HOST



#### Note: libvirt Equivalent

**virsh migrate --live hvm-sles11-qcow2 xen+ CONNECTOR://USER@IP\_ADDRESS/**

TABLE C.17: **xm migrate REMOVED OPTIONS**

<u>migrate</u> <b>Removed Options</b>	
<b>Options</b>	<b>Task</b>
(-) <u>-l, --live</u>	Use live migration. This will migrate the domain between hosts without shutting down the domain
(-) <u>-r, --resource</u> <u>Mbs</u>	Set maximum Mbs allowed for migrating the domain
(-) <u>-c, --change_home_server</u>	Change home server for managed domains
(-) <u>--max_iters=</u> <u>MAX_ITERS</u>	Number of iterations before final suspend (default:30)
(-) <u>--max_factor=</u> <u>MAX_FACTOR</u>	Max amount of memory to transfer before final suspend (default: 3*RAM).
(-) <u>--min_remaining=</u> <u>MIN_REMAINING</u>	Number of dirty pages before final suspend (default:50)

<u>migrate</u> <b>Removed Options</b>	
<b>Options</b>	<b>Task</b>
(-) <u>--abort_if_busy</u>	Abort migration instead of doing final suspend
(-) <u>--log_progress</u>	Log progress of migration to <u>xend.log</u>
(-) <u>-s</u> , <u>--ssl</u>	Use SSL connection for migration

TABLE C.18: **xl migrate** ADDED OPTIONS

<u>migrate</u> <b>Added Options</b>	
<b>Options</b>	<b>Task</b>
(+) <u>-s</u> <u>SSHCOMMAND</u>	Use <sshcommand> instead of <u>ssh</u>
(+) <u>-e</u>	On the new host, do not wait in the background (on <host>) for the death of the domain
(+) <u>-C</u> <u>CONFIG</u>	Send <config> instead of a configuration file from creation

### C.3.5.8 Domain Management

**xl** reboot OPTIONS DOMAIN



**Note:** libvirt Equivalent

virsh reboot

TABLE C.19: **xm reboot** REMOVED OPTIONS

<u>reboot</u> <b>Removed Options</b>	
<b>Options</b>	<b>Task</b>
(-) <u>-a</u> , <u>--all</u>	Reboot all domains

<u>reboot</u> <b>Removed Options</b>	
<b>Options</b>	<b>Task</b>
(-) <u>-w</u> , <u>--wait</u>	Wait for reboot to complete before returning. This may take a while, as all services in the domain need to be shut down cleanly

TABLE C.20: **xl reboot** ADDED OPTIONS

<u>reboot</u> <b>Added Options</b>	
<b>Option</b>	<b>Task</b>
(+) <u>-F</u>	Fallback to ACPI reset event for HVM guests with no PV drivers

xl save OPTIONS DOMAIN CHECK\_POINT\_FILE CONFIG\_FILE



Note: libvirt Equivalent

virsh save

TABLE C.21: **xl save** ADDED OPTIONS

<u>save</u> <b>Added Options</b>	
<b>Option</b>	<b>Task</b>
(+) <u>-c</u>	Leave domain running after creating the snapshot

xl restore OPTIONS CONFIG\_FILE CHECK\_POINT\_FILE



Note: libvirt Equivalent

virsh restore

TABLE C.22: **xl restore** ADDED OPTIONS

<u>restore</u> <b>Added Options</b>	
<i>Options</i>	<i>Task</i>
(+) <u>-p</u>	Do not unpause domain after restoring it
(+) <u>-e</u>	Do not wait in the background for the death of the domain on the new host
(+) <u>-d</u>	Enable debug messages
(+) <u>-V</u> , <u>--vncviewer</u>	Attach to domain's VNC server, forking a vncviewer process
(+) <u>-A</u> , <u>--vncviewer-autopass</u>	Pass VNC password to vncviewer via STDIN

**xl shutdown** *OPTIONS DOMAIN*



Note: libvirt Equivalent

virsh shutdown

TABLE C.23: **xm shutdown** REMOVED OPTIONS

<u>shutdown</u> <b>Removed Options</b>	
<i>Options</i>	<i>Task</i>
(-) <u>-w</u> , <u>--wait</u>	Wait for the domain to complete shutdown before returning
(-) <u>-a</u>	Shutdown all guest domains
(-) <u>-R</u>	
(-) <u>-H</u>	

TABLE C.24: **xl shutdown** ADDED OPTIONS

<u>shutdown</u> Added Options	
Option	Task
(+) <u>-F</u>	If the guest does not support PV shutdown control then fallback to sending an ACPI power event

TABLE C.25: **xl trigger** CHANGED OPTIONS

<u>trigger</u> Changed Options	
Option	Task
<u>_ trigger DOMAIN</u> <nmi reset init power sleep s3resume> <u>VCPU</u>	Send a trigger to a domain. Only available for HVM domains

### C.3.5.9 **xl sched-\***

**xl sched-credit** OPTIONS



Note: libvirt Equivalent

virsh schedinfo

TABLE C.26: **xm sched-credit** REMOVED OPTIONS

<u>sched-credit</u> Removed Options	
Options	Task
<u>-d DOMAIN</u> , <u>--domain= DOMAIN</u>	Domain
<u>-w WEIGHT</u> , <u>--weight= WEIGHT</u>	A domain with a weight of 512 will get twice as much CPU as a domain with a weight of 256 on a contended host. Legal weights range from 1 to 65535 and the default is 256



<u>sched-credit</u> <b>Removed Options</b>	
<i>Options</i>	<i>Task</i>
<u>-c CAP</u> , <u>--cap= CAP</u>	The CAP optionally fixes the maximum amount of CPU a domain can consume

TABLE C.27: **xl** sched-credit **ADDED OPTIONS**

<u>sched-credit</u> <b>Added Options</b>	
<i>Options</i>	<i>Task</i>
(+) <u>-p CPUP00L</u> , <u>--cpupool= CPUP00L</u>	Restrict output to domains in the specified cpupool
(+) <u>-s</u> , <u>--schedparam</u>	Specify to list or set pool-wide scheduler parameters
(+) <u>-t TSLICE</u> , <u>--tslice_ms= TSLICE</u>	Timeslice tells the scheduler how long to allow VMs to run before pre-empting
(+) <u>-r RLIMIT</u> , <u>--ratelimit_us= RLIMIT</u>	Ratelimit attempts to limit the number of schedules per second

**xl** sched-credit2 OPTIONS



## Note: libvirt Status

virsh only supports credit scheduler, not credit2 scheduler

TABLE C.28: **xm** sched-credit2 **REMOVED OPTIONS**

<u>sched-credit2</u> <b>Removed Options</b>	
<i>Options</i>	<i>Task</i>
<u>-d DOMAIN</u> , <u>--domain= DOMAIN</u>	Domain
<u>-w WEIGHT</u> , <u>--weight= WEIGHT</u>	Legal weights range from 1 to 65535 and the default is 256

TABLE C.29: **xl** sched-credit2 ADDED OPTIONS

sched-credit2 Added Options	
Option	Task
(+) <u>-p CPUP00L</u> , <u>--cpupool= CPUP00L</u>	Restrict output to domains in the specified cpupool

**xl** sched-sedf OPTIONSTABLE C.30: **xm** sched-sedf REMOVED OPTIONS

sched-sedf Removed Options	
Options	Task
<u>-p PERIOD</u> , <u>--period= PERIOD</u>	The normal EDF scheduling usage in milliseconds
<u>-s SLICE</u> , <u>--slice= SLICE</u>	The normal EDF scheduling usage in milliseconds
<u>-l LATENCY</u> , <u>--latency= LATENCY</u>	Scaled period if domain is doing heavy I/O
<u>-e EXTRA</u> , <u>--extra= EXTRA</u>	Flag for allowing domain to run in extra time (0 or 1)
<u>-w WEIGHT</u> , <u>--weight= WEIGHT</u>	Another way of setting CPU slice

TABLE C.31: **xl** sched-sedf ADDED OPTIONS

sched-sedf Added Options	
Options	Task
(+) <u>-c CPUP00L</u> , <u>--cpupool= CPUP00L</u>	Restrict output to domains in the specified cpupool
(+) <u>-d DOMAIN</u> , <u>--domain= DOMAIN</u>	Domain

### C.3.5.10 **xl cpupool -\***

**xl** `cpupool-cpu-remove` CPU\_POOL <CPU nr> |node:<node nr>

**xl** `cpupool-list` [-c|--cpus] CPU\_POOL

TABLE C.32: **xm cpupool-list** REMOVED OPTIONS

<u>cpupool-*</u> <b>Removed Options</b>	
<b>Option</b>	<b>Task</b>
(-) <u>-l</u> , <u>--long</u>	Output all CPU pool details in <i>SXP</i> format

**xl** `cpupool-cpu-add` CPU\_POOL cpu-nr|node:node-nr

**xl** `cpupool-create` OPTIONS CONFIG\_FILE [Variable=Value ...]

TABLE C.33: **xm cpupool-create** REMOVED OPTIONS

<u>cpupool-create</u> <b>Removed Options</b>	
<b>Options</b>	<b>Task</b>
(-) <u>-f</u> <u>FILE</u> , <u>--defconfig=</u> <u>FILE</u>	Use the given Python configuration script. The configuration script is loaded after arguments have been processed
(-) <u>-n</u> , <u>--dryrun</u>	Dry run - prints the resulting configuration in <i>SXP</i> but does not create the CPU pool
(-) <u>--help_config</u>	Print the available configuration variables (vars) for the configuration script
(-) <u>--path=</u> <u>PATH</u>	Search path for configuration scripts. The value of PATH is a colon-separated directory list
(-) <u>-F=</u> <u>FILE</u> , <u>--config=</u> <u>FILE</u>	CPU pool configuration to use ( <i>SXP</i> )

### C.3.5.11 **PCI and Block Devices**

**xl** `pci-detach` [-f] DOMAIN\_ID <BDF>



## Note: libvirt Equivalent

**virsh detach-device**

TABLE C.34: **xl pci-detach** ADDED OPTIONS

<u>pci-detach</u> Added Options	
Option	Task
(+) <u>-f</u>	If <u>-f</u> is specified, <u>xl</u> is going to forcefully remove the device even without guest's collaboration

TABLE C.35: **xm block-list** REMOVED OPTIONS

<u>block-list</u> Removed Options	
Option	Task
(-) <u>-l</u> , <u>--long</u>	List virtual block devices for a domain

TABLE C.36: OTHER OPTIONS

Option	<u>libvirt</u> equivalent
<u>xl</u> <u>block-attach</u> <u>DOMAIN</u> <disk-spec-component(s)>	<u>virsh</u> <u>attach-disk/attach-device</u>
<u>xl</u> <u>block-list</u> <u>DOMAIN_ID</u>	<u>virsh</u> <u>domblklist</u>

### C.3.5.12 Network

TABLE C.37: NETWORK OPTIONS

Option	<u>libvirt</u> equivalent
<u>xl</u> <u>network-list</u> <u>DOMAIN(s)</u>	<u>virsh</u> <u>domiflist</u>
<u>xl</u> <u>network-detach</u> <u>DOMAIN_ID</u> devid mac	<u>virsh</u> <u>detach-interface</u>

Option	<u>libvirt</u> <b>equivalent</b>
<u>xl</u> <u>network-attach</u> <u>DOMAIN(s)</u>	<u>virsh</u> <u>attach-interface/attach-device</u>

TABLE C.38: **xl** network-attach REMOVED OPTIONS

Removed Options	
Option	Task
(-) <u>-l</u> , <u>--long</u>	

## C.3.6 New Options

TABLE C.39: **NEW OPTIONS**

Options	Task
<u>config-update</u> <u>DOMAIN</u> <u>CONFIG_FILE</u> <u>OPTIONS</u> <u>VARs</u>	Update the saved configuration for a running domain. This has no immediate effect but will be applied when the guest is next restarted. This command is useful to ensure that runtime modifications made to the guest will be preserved when the guest is restarted
<u>migrate-receive</u>	
<u>sharing</u> <u>DOMAIN</u>	List count of shared pages. List specifically for that domain. Otherwise, list for all domains
<u>vm-list</u>	Prints information about guests. This list excludes information about service or auxiliary domains such as Dom0 and stubdoms
<u>cpupool-rename</u> <u>CPU_POOL</u> <u>NEWNAME</u>	Renames a CPU pool to newname
<u>cpupool-numa-split</u>	Splits up the machine into one CPU pool per NUMA node

Options	Task
<code>cd-insert</code> <i>DOMAIN</i> <VirtualDevice> <type:path>	Insert a CD-ROM into a guest domain's existing virtual CD drive. The virtual drive must already exist but can be current empty
<code>cd-eject</code> <i>DOMAIN</i> <VirtualDevice>	Eject a CD-ROM from a guest's virtual CD drive. Only works with HVM domains
<code>pci-assignable-list</code>	List all the assignable PCI devices. These are devices in the system which are configured to be available for pass-through and are bound to a suitable PCI back-end driver in Dom0 rather than a real driver
<code>pci-assignable-add</code> <BDF>	Make the device at PCI Bus/Device/Function <i>BDF</i> assignable to guests. This will bind the device to the pciback driver
<code>pci-assignable-remove</code> <i>OPTIONS</i> <BDF>	Make the device at PCI Bus/Device/Function <i>BDF</i> assignable to guests. This will at least unbind the device from pciback
<code>loadpolicy</code> <i>POLICY_FILE</i>	Load <i>FLASK</i> policy from the given policy file. The initial policy is provided to the hypervisor as a multiboot module; this command allows runtime updates to the policy. Loading new security policy will reset runtime changes to device labels

## C.4 External links

For more information on Xen tool stacks, refer to the following online resources:

### XL in Xen

XL in Xen 4.2 ([http://wiki.xenproject.org/wiki/XL\\_in\\_Xen\\_4.2](http://wiki.xenproject.org/wiki/XL_in_Xen_4.2)) 

## xl command

xl (<http://xenbits.xen.org/docs/unstable/man/xl.1.html>)  command line.


## xl.cfg

xl.cfg (<http://xenbits.xen.org/docs/unstable/man/xl.cfg.5.html>)  domain configuration file syntax.

## xl disk

xl disk (<https://xenbits.xen.org/docs/4.3-testing/misc/xl-disk-configuration.txt>)  configuration option.

## XL vs Xend

XL vs Xend ([http://wiki.xenproject.org/wiki/XL\\_vs\\_Xend\\_Feature\\_Comparison](http://wiki.xenproject.org/wiki/XL_vs_Xend_Feature_Comparison))  feature comparison.

## BDF doc

BDF documentation ([http://wiki.xen.org/wiki/Bus:Device.Function\\_%28BDF%29\\_Notation](http://wiki.xen.org/wiki/Bus:Device.Function_%28BDF%29_Notation)) .

## libvirt

virsh (<https://libvirt.org/manpages/virsh.html>)  command.

# C.5 Saving a Xen Guest Configuration in an xm Compatible Format

Although xl is now the current toolkit for managing Xen guests (apart from the preferred libvirt), you may need to export the guest configuration to the previously used xm format. To do this, follow these steps:

1. First export the guest configuration to a file:

```
virsh dumpxml guest_id > guest_cfg.xml
```

2. Then convert the configuration to the xm format:

```
virsh domxml-to-native xen-xm guest_cfg.xml > guest_xm_cfg
```

# D GNU licenses

## This appendix contains the GNU Free Documentation License version 1.2.

### GNU Free Documentation License

Copyright (C) 2000, 2001, 2002 Free Software Foundation, Inc. 51 Franklin St, Fifth Floor, Boston, MA 02110-1301 USA. Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

#### 0. PREAMBLE

The purpose of this License is to make a manual, textbook, or other functional and useful document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or non-commercially. Secondly, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

#### 1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The "Document", below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as "you". You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

A "Modified Version" of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A "Secondary Section" is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The "Invariant Sections" are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

The "Cover Texts" are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A "Transparent" copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. A copy that is not "Transparent" is called "Opaque".

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary

formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The "Title Page" means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

A section "Entitled XYZ" means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as "Acknowledgements", "Dedications", "Endorsements", or "History".) To "Preserve the Title" of such a section when you modify the Document means that it remains a section "Entitled XYZ" according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

#### 2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or non-commercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

#### 3. COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.



## 4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

- A. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.
- B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.
- C. State on the Title page the name of the publisher of the Modified Version, as the publisher.
- D. Preserve all the copyright notices of the Document.
- E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.
- F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.
- G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.
- H. Include an unaltered copy of this License.
- I. Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.
- J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.
- K. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.
- L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.
- M. Delete any section Entitled "Endorsements". Such a section may not be included in the Modified Version.
- N. Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.
- O. Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties—for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

## 5. COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections Entitled "History" in the various original documents, forming one section Entitled "History"; likewise combine any sections Entitled "Acknowledgements", and any sections Entitled "Dedications". You must delete all sections Entitled "Endorsements".

## 6. COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

## 7. AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an "aggregate" if the copyright resulting from the compilation is not used to limit the legal rights of the compilation's users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

## 8. TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled "Acknowledgements", "Dedications", or "History", the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

## 9. TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

## 10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See <https://www.gnu.org/copyleft/>.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation.

### ADDENDUM: How to use this License for your documents

```
Copyright (c) YEAR YOUR NAME.
Permission is granted to copy, distribute and/or modify this document
under the terms of the GNU Free Documentation License, Version 1.2
or any later version published by the Free Software Foundation;
with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts.
A copy of the license is included in the section entitled "GNU
Free Documentation License".
```

If you have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the "with...Texts." line with this:

```
with the Invariant Sections being LIST THEIR TITLES, with the
Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.
```

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.