

# openSUSE

[www.suse.com](http://www.suse.com)

September 09, 2012

Virtualization with KVM



# Virtualization with KVM

Copyright © 2006–2012 Novell, Inc. und Beteiligte. Alle Rechte vorbehalten.

Es wird die Genehmigung erteilt, dieses Dokument unter den Bedingungen der GNU Free Documentation License, Version 1.2 oder (optional) Version 1.3 zu vervielfältigen, zu verbreiten und/oder zu verändern; die unveränderlichen Abschnitte hierbei sind der Urheberrechtshinweis und die Lizenzbedingungen. Eine Kopie dieser Lizenz (Version 1.2) finden Sie im Abschnitt “GNU Free Documentation License”.

Hinweise zu Novell-Marken finden Sie in der Novell Trademark and Service Mark-Liste <http://www.novell.com/company/legal/trademarks/tmlist.html>. Alle anderen Drittanbieter-Marken sind das Eigentum der jeweiligen Inhaber. Ein Markensymbol (®, ™ usw.) kennzeichnet eine Novell-Marke. Ein Sternchen (\*) kennzeichnet eine Drittanbieter-Marke.

Alle Informationen in diesem Buch wurden mit größter Sorgfalt zusammengestellt. Doch auch dadurch kann hundertprozentige Richtigkeit nicht gewährleistet werden. Weder Novell, Inc., noch die SUSE LINUX GmbH noch die Autoren noch die Übersetzer können für mögliche Fehler und deren Folgen haftbar gemacht werden.

# Contents

<b>About This Manual</b>	<b>vii</b>
<b>Part I Requirements, Limitations, and Support Status</b>	<b>1</b>
<b>1 KVM Installation and Requirements</b>	<b>3</b>
1.1 Hardware Requirements. . . . .	3
1.2 Supported Guest Operating Systems. . . . .	4
1.3 The <code>kvm</code> package. . . . .	7
1.4 Installing KVM. . . . .	8
<b>2 KVM Limitations</b>	<b>9</b>
2.1 General Limitations. . . . .	9
2.2 Hardware Limitations. . . . .	10
2.3 Performance Limitations. . . . .	11
<b>3 KVM Support Status</b>	<b>13</b>
3.1 Supported Features and Tools. . . . .	13
3.2 Unsupported Features and Tools. . . . .	15
<b>Part II Managing Virtual Machines with <code>libvirt</code></b>	<b>17</b>
<b>4 Overview</b>	<b>19</b>
<b>5 Guest Installation</b>	<b>23</b>
5.1 Guest Installation with Virtual Machine Manager. . . . .	23
5.2 Installing from the Command Line with <code>vm-install</code> . . . . .	29
5.3 Advanced Guest Installation Scenarios. . . . .	33
<b>6 Basic VM Guest Management</b>	<b>35</b>

6.1	Listing VM Guests. . . . .	35
6.2	Opening a Graphical Console. . . . .	36
6.3	Changing a VM Guest's State: Start, Stop, Pause. . . . .	38
6.4	Saving and Restoring VM Guests. . . . .	40
6.5	Deleting a VM Guest. . . . .	42
<b>7</b>	<b>Connecting and Authorizing</b>	<b>43</b>
7.1	Authentication. . . . .	43
7.2	Configuring Remote Connections. . . . .	52
7.3	Connecting to a VM Host Server. . . . .	60
<b>8</b>	<b>Managing Storage</b>	<b>65</b>
8.1	Managing Storage with Virtual Machine Manager. . . . .	67
8.2	Managing Storage with <code>virsh</code> . . . . .	73
<b>9</b>	<b>Configuring Virtual Machines</b>	<b>79</b>
9.1	Enabling Seamless and Synchronized Cursor Movement. . . . .	80
9.2	Adding a CD/DVD-ROM Device with Virtual Machine Manager. . . . .	80
9.3	Adding a Floppy Device with Virtual Machine Manager. . . . .	81
9.4	Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager. . . . .	82
9.5	Clock Settings. . . . .	83
<b>10</b>	<b>Administrating VM Guests</b>	<b>85</b>
10.1	Migrating VM Guests. . . . .	85
10.2	Monitoring. . . . .	88
<b>Part III</b>	<b>Managing Virtual Machines with QEMU</b>	<b>91</b>
<b>11</b>	<b>QEMU Overview</b>	<b>93</b>
<b>12</b>	<b>Guest Installation</b>	<b>95</b>
12.1	Basic Installation with <code>qemu-kvm</code> . . . . .	96
12.2	Managing Disk Images with <code>qemu-img</code> . . . . .	97
<b>13</b>	<b>Running Virtual Machines with <code>qemu-kvm</code></b>	<b>111</b>
13.1	Basic <code>qemu-kvm</code> Invocation. . . . .	111
13.2	General <code>qemu-kvm</code> Options. . . . .	112
13.3	Using Devices in QEMU. . . . .	115
13.4	Networking in QEMU. . . . .	124

13.5	Viewing a VM Guest with VNC. . . . .	130
13.6	VirtFS: Sharing Folders between Host and Guests. . . . .	134
13.7	KSM: Sharing Memory Pages between Guests. . . . .	135
<b>14</b>	<b>Administrating Virtual Machines with QEMU Monitor</b>	<b>137</b>
14.1	Accessing Monitor Console. . . . .	137
14.2	Getting Information about the Guest System. . . . .	137
14.3	Changing VNC Password. . . . .	140
14.4	Managing Devices. . . . .	140
14.5	Controlling Keyboard and Mouse. . . . .	141
14.6	Changing Available Memory. . . . .	141
14.7	Dumping Virtual Machine Memory. . . . .	142
14.8	Managing Virtual Machine Snapshots. . . . .	143
14.9	Suspending and Resuming Virtual Machine Execution. . . . .	144
14.10	Live Migration. . . . .	144
<b>A</b>	<b>Appendix</b>	<b>147</b>
A.1	Installing Para-Virtualized Drivers. . . . .	147
A.2	Generating x509 Client/Server Certificates. . . . .	152
A.3	QEMU Command Line Options. . . . .	153
<b>B</b>	<b>GNU Licenses</b>	<b>161</b>
B.1	GNU General Public License. . . . .	161
B.2	Freie GNU-Dokumentationslizenz (GNU Free Documentation License). . .	164



# About This Manual

This manual offers an introduction to setting up and managing virtualization with KVM (Kernel-based Virtual Machine) on openSUSE. The first part introduces KVM by describing its requirements and SUSE's support status. The second part deals with managing KVM with `libvirt`, while the last part covers management with QEMU.

Many chapters in this manual contain links to additional documentation resources. This includes additional documentation that is available on the system as well as documentation available on the Internet.

For an overview of the documentation available for your product and the latest documentation updates, refer to <http://www.suse.com/documentation>.

## 1 Verfügbare Dokumentation

Wir stellen Ihnen unsere Handbücher in verschiedenen Sprachen in den Formaten HTML und PDF zur Verfügung. Die folgenden Handbücher für Benutzer und Administratoren sind für dieses Produkt verfügbar:

### Start-Up (↑Start-Up)

Führt Sie Schritt für Schritt durch die Installation von openSUSE von DVD oder von einem ISO-Image. Bietet kurze Einführungen in die Desktops von GNOME und KDE und einige der auf diesen Desktops laufenden Hauptanwendungen. Bietet außerdem einen Überblick zu LibreOffice und seinen Modulen zur Textproduktion, Arbeit mit Spreadsheets oder Erstellung von Grafiken und Präsentationen.

### Reference (↑Reference)

Vermittelt Ihnen ein grundlegendes Verständnis von openSUSE und deckt erweiterte Aufgaben der Systemverwaltung ab. Es richtet sich in der Hauptsache an Systemadministratoren und andere Benutzer mit Grundkenntnissen der Systemadministration. Es enthält ausführliche Informationen über erweiterte Einsatzmöglichkeiten, Administration Ihres Systems, Interaktion von Schlüsselsystemkomponenten sowie die Einrichtung verschiedener Netzwerk- und Dateidienste, die openSUSE bietet.

### Security Guide (↑Security Guide)

Zudem werden grundlegende Konzepte der Systemsicherheit vorgestellt, die sowohl lokale als auch netzwerkbezogene Aspekte abdecken. Sie erfahren, wie Sie die einem Produkt inhärente Sicherheitssoftware wie AppArmor verwenden können (diese ermöglicht es Ihnen, für jedes Programm einzeln festzulegen, für welche Dateien Lese-, Schreib- und Ausführungsberechtigungen bestehen) oder das Prüfsystem nutzen können, das zuverlässig Daten zu sicherheitsrelevanten Ereignissen sammelt.

### System Analysis and Tuning Guide (↑System Analysis and Tuning Guide)

Ein Administratorhandbuch zur Problemsuche, Fehlerbehebung und Optimierung. Erfahren Sie, wie Sie Ihr System mithilfe von Überwachungswerkzeugen prüfen und optimieren können und wie Sie Ihre Ressourcen effizient verwalten. Es enthält zudem einen Überblick über häufige Probleme und Lösungen sowie weitere Hilfequellen und Dokumentationsressourcen.

### Virtualization with KVM (page i)

Enthält eine Einführung für das Einrichten und Verwalten der Virtualisierung mit KVM (Kernel-based Virtual Machine) auf openSUSE. Demonstriert zudem die Verwaltung von VM Guests mit `libvirt` und `QEMU`.

HTML-Versionen der meisten Produkthandbücher finden Sie auf dem installierten System im Verzeichnis `/usr/share/doc/manual` bzw. in den Hilfezentren Ihres Desktops. Die neuesten Dokumentationsaktualisierungen finden Sie unter <http://www.suse.com/documentation>, von wo Sie PDF- oder HTML-Versionen der Handbücher für Ihr Produkt herunterladen können.

## 2 Rückmeldungen

Für Rückmeldungen stehen mehrere Kanäle zur Verfügung:

### Fehler und Verbesserungsanforderungen

Verwenden Sie zum Melden von Fehlern für eine Produktkomponente oder zum Einreichen von Verbesserungsvorschlägen die Option <https://bugzilla.novell.com/>. Reichen Sie bei Fehlern in der Dokumentation einen Fehlerbericht zur Komponente *Dokumentation* für das entsprechende Produkt ein.

Wenn Sie zum ersten Mal mit Bugzilla arbeiten, können Sie nützliche Informationen dazu in den folgenden Artikeln finden:



- [http://en.opensuse.org/openSUSE:Submitting\\_bug\\_reports](http://en.opensuse.org/openSUSE:Submitting_bug_reports)
- [http://en.opensuse.org/openSUSE:Bug\\_reporting\\_FAQ](http://en.opensuse.org/openSUSE:Bug_reporting_FAQ)

#### Anregungen und Kritik unserer Leser

Wir freuen uns über Ihre Kommentare und Vorschläge zu diesem Handbuch und den anderen Teilen der Dokumentation dieses Produkts. Verwenden Sie die Funktion „Benutzerkommentare“ unten auf den einzelnen Seiten der Online-Dokumentation oder geben Sie Ihre Kommentare auf der Seite <http://www.suse.com/documentation/feedback.html> ein.

#### Mail

Für Feedback zur Dokumentation dieses Produkts können Sie auch eine E-Mail an [doc-team@suse.de](mailto:doc-team@suse.de) senden. Geben Sie auf jeden Fall auch den Titel der Dokumentation, die Produktversion und das Datum der Veröffentlichung der Dokumentation an. Geben Sie eine genaue Beschreibung des Problems an und beziehen Sie sich auf die entsprechende Abschnittsnummer und Seite (oder URL), wenn Sie Fehler melden oder Verbesserungen vorschlagen.

## 3 Konventionen in der Dokumentation

In diesem Handbuch werden folgende typografische Konventionen verwendet:

- `/etc/passwd`: Verzeichnisnamen und Dateinamen
- *Platzhalter*: Ersetzen Sie *Platzhalter* durch den tatsächlichen Wert.
- `PATH`: die Umgebungsvariable `PATH`
- `ls, --help`: Kommandos, Optionen und Parameter
- `Benutzer`: Benutzer oder Gruppen
- `, + F1`: Eine Taste oder Tastenkombination. Tastennamen werden wie auf der Tastatur in Großbuchstaben dargestellt.
- *Datei*, *Datei* > *Speichern unter*: Menüoptionen, Schaltflächen

- *Tanzende Pinguine* (Kapitel *Pinguine*, ↑Anderes Handbuch): Dies ist ein Verweis auf ein Kapitel in einem anderen Handbuch.

## 4 Informationen über die Herstellung dieses Handbuchs

Dieses Handbuch wurde in Novdoc, einem Teilsatz von DocBook (siehe <http://www.docbook.org>), geschrieben. Die XML-Quelldateien wurden mit `xmllint` überprüft, von `xsltproc` verarbeitet und mit einer benutzerdefinierten Version der Stylesheets von Norman Walsh in XSL-FO konvertiert. Die endgültige PDF-Datei wurde mit XEP von RenderX formatiert. Die Open-Source-Werkzeuge und die zum Erstellen dieses Handbuchs verwendete Umgebung sind im Paket `daps` verfügbar, das im Lieferumfang von openSUSE enthalten ist. Die Startseite des Projekts finden Sie unter <http://daps.sf.net/>.

## 5 Quellcode

Der Quellcode von openSUSE ist öffentlich verfügbar. Download-Links und weitere Informationen finden Sie unter [http://en.opensuse.org/Source\\_code](http://en.opensuse.org/Source_code).

## 6 Acknowledgments

With a lot of voluntary commitment, the developers of Linux cooperate on a global scale to promote the development of Linux. We thank them for their efforts—this distribution would not exist without them. Furthermore, we thank Frank Zappa and Pawar. Special thanks, of course, goes to Linus Torvalds.

Have a lot of fun!

Your SUSE Team

# **Part I. Requirements, Limitations, and Support Status**



# KVM Installation and Requirements

KVM is a full virtualization solution for x86 processors supporting hardware virtualization (Intel VT or AMD-V). It consists of two main components: A set of Kernel modules (`kvm.ko`, `kvm-intel.ko`, and `kvm-amd.ko`) providing the core virtualization infrastructure and processor specific drivers and a userspace program (`qemu-kvm`) 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 reference the userspace component.

VM Guests (virtual machines), virtual storage and networks can be managed with `libvirt`-based and QEMU tools. `libvirt` is a library that provides an API to manage VM Guests based on different virtualization solutions, among them KVM and Xen. It offers a graphical user interface as well as a command line program. The QEMU tools are KVM/QEMU specific and are only available for the command line.

## 1.1 Hardware Requirements

Currently, SUSE only supports KVM full virtualization on x86\_64 hosts. 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:

```
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.

The following Web site identifies processors which support hardware virtualization: [http://wiki.xensource.com/xenwiki/HVM\\_Compatible\\_Processors](http://wiki.xensource.com/xenwiki/HVM_Compatible_Processors)

---

## NOTE

The KVM Kernel modules will not load if the CPU does not support hardware virtualization or if this feature is not enabled in the BIOS.

---

The general minimum hardware requirements for the VM Host Server are the same as for openSUSE. 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.

# 1.2 Supported Guest Operating Systems

The following table lists guest operating systems tested and their support status offered by SUSE. All operating systems listed are supported in both 32 and 64-bit x86 versions.

Para-virtualized drivers (PV drivers) are listed where available.

### *Para-virtualized drivers for KVM*

- `virtio-net`: Virtual network driver.
- `virtio-blk`: Virtual block device driver for para-virtualized block devices.
- `virtio-balloon`: Memory driver for dynamic memory allocation. Allows to dynamically change the amount of memory allocated to a guest.

- `kvm-clock`: Clock synchronization driver.

**Table 1.1** *Supported KVM Guest Operating Systems on openSUSE*

<b>SLES 12.2 / SLES 11 SP1 / SLES 10 SP4</b>	
<i>PV drivers:</i>	kvm-clock, virtio-net, virtio-blk, virtio-balloon
<i>Support Status:</i>	Fully supported (fully virtualized)
<b>SLES 9 SP4</b>	
<i>Support Status:</i>	Fully Supported (fully virtualized)
<i>Note:</i>	<ul style="list-style-type: none"> <li>• 32-bit Kernel: specify <code>clock=pmtmr</code> on Linux boot line</li> <li>• 64-bit Kernel: specify <code>ignore_lost_ticks</code> on Linux boot line</li> </ul>
<b>SLED 12.2 / SLED 11 SP1</b>	
<i>PV drivers:</i>	kvm-clock, virtio-net, virtio-blk, virtio-balloon
<i>Support Status:</i>	Technology Preview (fully virtualized)
<b>OES 2 SP3 / OES 11</b>	
<i>PV drivers:</i>	kvm-clock, virtio-net, virtio-blk, virtio-balloon
<i>Support Status:</i>	Fully supported (fully virtualized)
<b>RedHat Enterprise Linux 4.8+ / 5.5+ / 6.0+</b>	
<i>PV drivers:</i>	See <a href="http://www.redhat.com/">http://www.redhat.com/</a>
<i>Support Status:</i>	Best Effort (fully virtualized)
<i>Note:</i>	Refer to the RHEL Virtualization guide for more information.

### Windows 2003 SP2+ / Windows 2008 SP2+ / Windows 2008 R2+

<i>PV drivers:</i>	virtio-net, virtio-blk, virtio-balloon; drivers from the Virtual Machine Driver Pack ( <a href="http://www.suse.com/products/vmdriverpack/">http://www.suse.com/products/vmdriverpack/</a> ) are preferred
<i>Support Status:</i>	Fully supported with Server Virtualization Validation Program (SVVP) certification (fully virtualized)

### Windows XP SP3+ / Windows Vista SP2+ / Windows 7 SP1+

<i>PV drivers:</i>	virtio-net, virtio-blk, virtio-balloon; drivers from the Virtual Machine Driver Pack ( <a href="http://www.suse.com/products/vmdriverpack/">http://www.suse.com/products/vmdriverpack/</a> ) are preferred
<i>Support Status:</i>	Best effort (fully virtualized)

## IMPORTANT

Guest images created under SUSE Linux Enterprise Server 11 SP1 are supported, but guest images created under a previous SUSE Linux Enterprise version are not supported.

## 1.2.1 Availability of Para-Virtualized Drivers

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

SUSE Linux Enterprise Server 11 SP1 / SP2  
included in Kernel

SUSE Linux Enterprise Server 10 SP4  
included in Kernel



SUSE Linux Enterprise Server 9 SP4  
not available

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). These drivers are preferred over the drivers provided in the `/usr/share/qemu-kvm/win-virtio-drivers.iso` image file (the latter being deprecated and will probably not be provided in future releases). See <http://www.suse.com/products/vmdriverpack/> for more information.

## 1.3 The `kvm` package

The `kvm` package provides `qemu-kvm`, the program that performs the actual emulation. In addition to the `qemu-kvm` program, the `kvm` package also comes with a debug level monitoring utility (`kvm-stat`), firmware components, key-mapping files, scripts, and deprecated para-virtualized Windows drivers (`/usr/share/qemu-kvm/win-virtio-drivers.iso`).

Originally, the `kvm` package also provided the KVM Kernel modules. Now, these modules are included with the Kernel and only userspace components are included in the current `kvm` package.

Using the `libvirt`-based tools is the recommended way of managing VM Guests. Interoperability with other virtualization tools has been tested and is an essential part of SUSE's support stance. All tools are provided by packages carrying the tool's name.

- `libvirt`: A toolkit that provides management of VM Guests, virtual networks, and storage. `libvirt` provides an API, a daemon, and a shell (`virsh`).
- `virt-manager` (Virtual Machine Manager): A graphical management tool for VM Guests.
- `vm-install`: Define a VM Guest and install its operating system.
- `virt-viewer`: An X viewer client for VM Guests which supports TLS/SSL encryption of x509 certificate authentication and SASL authentication.

Support for creating and manipulating file-based virtual disk images is provided by `qemu-img`. `qemu-img` is provided by the package `virt-utils`.

## 1.4 Installing KVM

KVM is not installed by default. To install KVM and all virtualization tools, proceed as follows:

- 1 Start YaST and choose *Virtualization > Installing Hypervisor and Tools*.
- 2 Select *KVM* and confirm with *Accept*.
- 3 Confirm the list of packages that is to be installed with *Install*.
- 4 Agree to set up a network bridge by clicking *Yes*. It is recommended using a bridge on a VM Host Server (virtual machine host). If you prefer to manually configure a different network setup, you can safely skip this step by clicking *No*.
- 5 After the setup has been finished, reboot the machine as YaST suggests. Alternatively load the required kernel modules manually and start `libvirtd` to avoid a reboot:

```
modprobe kvm-intel # on Intel machines only
modprobe kvm-amd   # on AMD machines only
modprobe vhost-net
rclibvirtd start
```

---

### NOTE: The `vhost-net` Kernel Module

The `vhost-net` kernel module allows for a more efficient network transport to the guest. It is automatically used by `libvirt` if loaded, or when using the `qemu-kvm` commandline, by adding `,vhost=on` to the networking option.

---

# KVM Limitations

Although virtualized machines behave almost like physical machines, some limitations apply. These affect both, the VM Guest as well as the VM Host Server system.

## 2.1 General Limitations

The following general restrictions apply when using KVM:

### Overcommits

KVM allows for both memory and disk space overcommit. It is up to the user to understand the implications of doing so. However, hard errors resulting from exceeding available resources will result in guest failures. CPU overcommit is also supported but carries performance implications.

### Time Synchronization

Most guests require some additional support for accurate time keeping. Where available, `kvm-clock` is to be used. NTP or similar network based time keeping protocols are also highly recommended (for VM Host Server and VM Guest) to help maintain a stable time. Running NTP inside the guest is not recommended when using the `kvm-clock`. Refer to Section 9.5, “Clock Settings” (page 83) for details.

### MAC addresses

If no MAC address is specified for a NIC, a default MAC address will be assigned. This may result in network problems when more than one NIC receives

the same MAC address. It is recommended to always assure a unique MAC address has been assigned for each NIC.

Live Migration

Live Migration is only possible between VM Host Servers with the same CPU features and no physical devices passed from host to guest. Guest storage has to be accessible from both VM Host Servers and guest definitions need to be compatible. VM Host Server and VM Guests need to have proper timekeeping installed.

User Permissions

The management tools (Virtual Machine Manager, `virsh`, `vm-install`) need to authenticate with `libvirt`—see Chapter 7, *Connecting and Authorizing* (page 43) for details. In order to invoke `qemu-kvm` from the command line, a user has to be a member of the group `kvm`.

Suspending/Hibernating the VM Host Server

Suspending or hibernating the VM Host Server system while guests are running is not supported.

# 2.2 Hardware Limitations

The following virtual hardware limits for guests have been tested. We ensure host and VMs install and work successfully, even when reaching the limits and there are no major performance regressions (CPU, memory, disk, network) since the last release (openSUSE 11 SP1).

<i>Max. Guest RAM Size</i>	512 GB
<i>Max. Virtual CPUs per Guest</i>	64
<i>Max. Virtual Network Devices per Guest</i>	8
<i>Max. Block Devices per Guest</i>	4 emulated (IDE), 20 para-virtual (using <code>virtio-blk</code> )

<i>Max. Number of VM Guests per VM Host Server</i>	Limit is defined as the total number of virtual CPUs in all guests being no greater than 8 times the number of CPU cores in the host
--	--

## 2.3 Performance Limitations

Basically, workloads designed for physical installations can be virtualized and therefore inherit the benefits of modern virtualization techniques. However, virtualization comes at the cost of a slight to moderate performance impact. You should always test your workload with the maximum anticipated CPU and I/O load to verify if it is suited for being virtualized. Although every reasonable effort is made to provide a broad virtualization solution to meet disparate needs, there will be cases where the workload itself is unsuited for KVM virtualization.

We therefore propose the following performance expectations for guests performance to be used as a guideline. The given percentage values are a comparison of performance achieved with the same workload under non-virtualized conditions. The values are rough approximations and cannot be guaranteed.

Category	Fully Virtual-ized	Paravirtual-ized	Host Pass-through
<i>CPU, MMU</i>	7%	not applicable	97% (Hardware Virtualization with Extended Page Tables(Intel) or Nested Page Tables (AMD) 85% (Hardware Virtualization with shadow page tables)
<i>Network I/O (1GB LAN)</i>	60% (e1000 emulated NIC)	75% (virtio-net)	95%

<b>Category</b>	<b>Fully Virtualized</b>	<b>Paravirtualized</b>	<b>Host Pass-through</b>
<i>Disk I/O</i>	40% (IDE emulation)	85% (virtio-blk)	95%
<i>Graphics (non-accelerated)</i>	50% (VGA or Cirrus)	not applicable	not applicable
<i>Time accuracy (worst case, using recommended settings without NTP)</i>	95% - 105% (where 100% = accurate)	100% (kvm-clock)	not applicable

# KVM Support Status

The following list contains features and tools as supported by SUSE—this does not necessarily reflect the support status of the software itself. For a list of `qemu-kvm` command switches supported by SUSE, refer to Section A.3, “QEMU Command Line Options” (page 153).

## 3.1 Supported Features and Tools

### `vm-install`

Define and install VM Guests via `vm-install` including specifying the number of virtual processors, RAM, disk type and location, video type, keyboard mapping, NIC type, binding, MAC address, and boot method.

*Restrictions:* Currently only the `raw`, `qcow2` and `qed` disk formats are supported. NIC creation is restricted to using Realtek, `e1000` or `virtio` NICs.

### Virtual Machine Manager

Manage guests via Virtual Machine Manager using the following functions: `autostart`, `start`, `stop`, `restart`, `pause`, `unpause`, `save`, `restore`, `clone`, `migrate`, special key sequence insertion, guest console viewers, performance monitoring, and CPU pinning. Furthermore, static modifications of CPU, RAM, boot method, disk, NIC, mouse, display, video and host PCI and USB assignments are supported.

*Restrictions:* The following features are currently not supported: sound devices, `qxl`, `vmvga` (vmware), Xen video, emulated SCSI and SATA disks, `vmrk` storage

format, Spice graphics, eepr100, ne2k\_pci, pcnet, Smartcard and USB redirection.

#### `virsh`

Manage guests via the command line.

*Restrictions:* Requires XML descriptions as created by `vm-install` or `virt-manager`. Altering these descriptions via `virsh edit` is not supported. The supported `virsh` functionality is restricted to life cycle functions.

#### `qemu-kvm`

Manage guests via the command line. Although managing via Virtual Machine Manager should be the preferred option, `qemu-kvm` may be used for greater flexibility. See Section A.3.1, “Supported `qemu-kvm` Command Line Options” (page 153) for a list of supported options.

*Restrictions:* See Section A.3.2, “Unsupported `qemu-kvm` Command Line Options” (page 155) for a list of not supported options.

#### `kvm_stat`

Debugging and monitoring tool.

### USB Host Device Pass-through

A physical USB device may be passed from the VM Host Server to the VM Guest.

### PCI Pass-through

PCI Pass-through improves performance of PCI devices. It requires an AMD CPU with IOMMU (I/O Memory Mapping Unit) or an Intel CPU with VT-d (Virtualization Technology for Directed I/O). VT-d requires the Kernel parameter “`intel_iommu=on`”. Many PCIe cards from major vendors should be supportable. Refer to system level certifications for specific details, or contact the vendor for support statements.

### Device hotplugging

Dynamically adding or removing emulated or pass-through physical devices in the VM Guest is supported.

### Sharing Folders between VM Host Server and VM Guest

Sharing folders between host and guest is supported via VirtFs.



### Kernel Samepage Merging (KSM)

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.

### Transparent Huge Pages (THP)

THP allows CPUs to address memory using pages larger than the default 4 KB. This helps reducing memory consumption and CPU cache usage. KVM is optimized to use THP (via `madvise` and opportunistic methods) if enabled on the VM Host Server.

### Non-Uniform Memory Access (NUMA)

NUMA machines are supported. Using `numactl` to pin `qemu-kvm` processes to specific nodes is recommended.

## 3.2 Unsupported Features and Tools

### CPU hotplugging

Dynamically changing the number of virtual CPUs assigned to the guest is currently not supported.

### AHCI guest storage

The AHCI interface for SATA storage provides fast I/O performance. It is currently not supported.

### Online Disk resizing

Online Disk resizing is currently not supported.

### KVM Kernel Module Parameters

Specifying parameters for the KVM Kernel modules is currently not supported unless done under the direction of SUSE support personnel.

### Guest Agent

The guest agent (`qemu-ga`) allows programs on the VM Host Server to directly communicate with a guest via an emulated or para-virtualized serial console. This feature is currently not supported.

### Using QEMU without KVM

`qemu-kvm` can be invoked with the `-no-kvm` parameter. In this case guest CPU instructions are emulated instead of being executed directly by the processor. This mode is not supported, but may be useful for problem resolution.

## **Part II. Managing Virtual Machines with `libvirt`**



# Overview

`libvirt` is a library that provides a common API for managing popular virtualization solutions, among them KVM 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 and x509 certificates as well as authentication with SASL.

The communication between the virtualization solutions and `libvirt` is managed by the daemon `libvirtd`. It is also used by the management tools. `libvirtd` needs to run on the VM Host Server and on any remote machine on which the `libvirt`-based tools are started. Use the following commands to start, stop it or check its status:

```
~ # rclibvirtd start
Starting libvirtd                               done
~ # rclibvirtd status
Checking status of libvirtd                     running
~ # rclibvirtd stop
Shutting down libvirtd                         done
~ # rclibvirtd status
Checking status of libvirtd                     unused
```

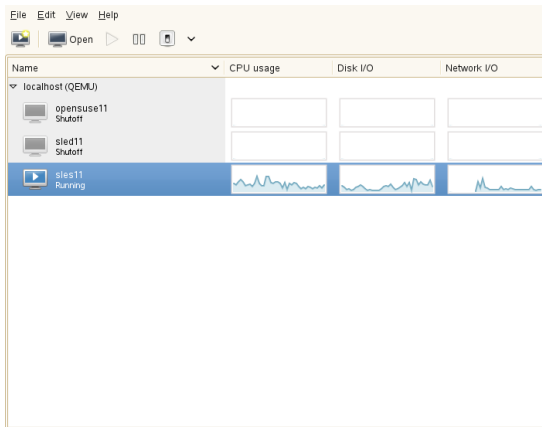
To automatically start `libvirtd` at boot time, either activate it using the YaST *System Services (Runlevel)* module or by entering the following command:

```
insserv libvirtd
```

The following `libvirt`-based tools are available on openSUSE:

### Virtual Machine Manager (`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 (bootup/shutdown, pause/resume, suspend/restore). It lets you create new VM Guests and various types of storage, and manage virtual networks. Access the graphical console of VM Guests with the built-in VNC viewer, and view performance statistics, all done locally or remotely.

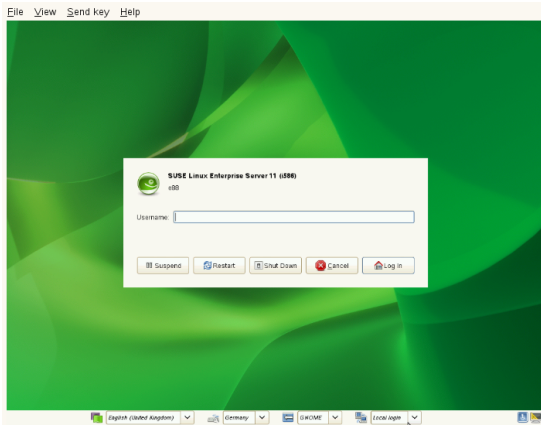


The Virtual Machine Manager does not need to run on the VM Host Server, it also lets you control VM Guests via remote connections. This enables you to manage VM Guests centrally from a single workstation without having to log in on the VM Host Server.

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

### `virt-viewer`

A viewer for the graphical console of a VM Guest. It uses the VNC protocol 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.



## vm-install

A tool to set up a VM Guest, configure its devices and start the operating system installation. Starts a GUI wizard when called from a graphical user interface. When invoked on a terminal, starts the wizard in command-line mode. `vm-install` is also started when creating a new virtual machine in the Virtual Machine Manager.

## virsh

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 and to edit existing configurations. `virsh` is also useful to script VM Guest management operations.

`virsh` basically works like Subversion's `svn` command or `zypper`: it takes the first arguments as a command and further arguments as options to this command:

```
virsh [-c URI] command domain-id [OPTIONS]
```

Just 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://root@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



# Guest Installation

A VM Guest is comprised 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.

## 5.1 Guest Installation with Virtual Machine Manager

Clicking *New* in the Virtual Machine Manager launches `vm-install`. It provides the graphical *Create Virtual Machine Wizard* that guides you through the guest installation. `vm-install` can also be run directly from the command-line or from YaST by choosing *Virtualization > Create Virtual Machine*.

- 1 Start the *Create Virtual Machine Wizard* as described above and click *Forward*.
- 2 Choose whether to install an operation system or an already existing image or disk.
- 3 Select the operating system you want to install from the list. Each entry provides reasonable defaults for the chosen operating system.
- 4 The *Summary* page shows the default configuration for the chosen operating system. Edit the configuration by clicking on a headline. When having chosen to install a system, you at least have to specify either an image or a CD/DVD device from which to boot or choose PXE boot. When accepting the configuration with *OK*, the guest system boots to start the installation.

## 5.1.1 Customizing the Default Settings

Change the proposed configuration by clicking on a headline in the Summary page of the Create Virtual Machine Wizard:

**Summary**

Click any headline to make changes. When the settings are correct, click **OK** to create the VM.

**Name of Virtual Machine**

sles11

**Hardware**

**Initial Memory:** 512 MB  
**Maximum Memory:** 512 MB  
**Virtual Processors:** 2

**Graphics and Keyboard**

Cirrus Logic GD5446 VGA

**Disks**

1: 8.0 GB Hard Disk (file:/var/lib/kvm/images/sles11/disk0.raw)

**Network Adapters**

1: QEMU Virtualized NIC Card; Randomly generated MAC address

**Operating System Installation**

**Operating System:** SUSE Linux Enterprise Server 11  
**Installation Source:**

Cancel

Back

OK

### 5.1.1.1 Name of Virtual Machine

Specify a *Name* and an optional *Description* for the guest. The *Name* must contain only alphanumeric and `_` `.` `:` `+` characters. It must be unique among all VM Guests on

the VM Host Server. It is used to create and name the guest's configuration file and you will be able to access the guest with this name from `virsh`.

### 5.1.1.2 *Hardware*

Change memory and CPU assignments in this screen. It is recommended not to specify values larger than the resources the VM Host Server can provide (overcommit), since it may result in errors or performance penalties.

The *Advanced Settings* lets you activate or deactivate ACPI, APIC, and PAE. It is recommended not to change the default settings. You can also enable or disable para-virtualized I/O with `virtio` or choose to execute the kernel on boot (linux only) here.

---

#### **IMPORTANT: Para-Virtualized I/O**

If you enable para-virtualized I/O by activating *virtio*, all hard disks you create will be configured as `virtio` disks. If your operating system does not have appropriate drivers, the installation will fail. A Windows operating system installation even fails if providing a driver. By default, this feature is only activated for operating systems known to ship with `virtio` drivers.

---

### 5.1.1.3 *Peripheral Devices*

Configure the type of virtualized graphics hardware, the keymap and sound device in this dialog. If you disable the graphics card support, the machine is only accessible via network services (ssh) or serial port. Sound in VM Guests is currently not supported by SUSE, therefore *Sound* should be set to `None`.

### 5.1.1.4 *Disks*

*Disks*: Manage virtual hard disks and CD/DVD drives in this dialog. A VM Guest must have at least one virtual disk—either an existing one or a newly created disk. Virtual disks can be:

- a single file with a fixed size
- a single file that grows on demand (`Sparse Image File`)

---

### IMPORTANT: Sufficient Space for Sparse Image Files

When creating sparse image files, the partition on which you create them always needs sufficient free space. The VM Guest has no means to check the VM Host Server disk space. Having no space left on the host partition causes write errors and loss of data on the guest system.

---

- a block device, such as an entire disk, partition, or a network volume.

For best performance, create each virtual disk from an entire disk or a partition. For the next best performance, create an image file but do not create it as a sparse image file. A virtual disk based on a sparse image file delivers the most disk space flexibility but slows installation and disk access speeds.

---

### TIP: Live Migration

If you need to be able to migrate your VM Guest to another host without shutting it down (live migration), all disks must reside on a network resource (network file system or iSCSI volume) that is accessible from both hosts.

---

By default, a single sparse raw disk image file is created in `/var/lib/kvm/images/VM_NAME/` where `VM_NAME` is the name of the virtual machine.

---

### NOTE: Supported Disk format

Currently, only the disk formats `raw`, `qed` and `qcow2` are supported by SUSE.

---

### **Procedure 5.1** *Creating a Virtual Disk*

- 1 Click *Harddisk*.
- 2 Enter a *Source*. If creating a file-backed disk, either enter the path directly or click *New*. When creating a disk from a device, enter the device node, for example `/dev/disk/by-path/path`. It is strongly recommended not to use the simple device paths such as `/dev/sdb` or `/dev/sda5`, since they may change (by adding a disk or by changing the disk order in the BIOS).
- 3 Specify the *Protocol*. For creating `raw` disks, choose either *file* for file-backed virtual disks or *phy* for device-backed disks. `qcow2` or `qed` disks can be created by choosing the corresponding value.

- 4 Enter a *Size* in GB. This option is only available for file-backed disks.
- 5 Choose whether to create a *Sparse Image File*. This option is only available for file-backed disks. If you want to disable write-access to the disk, choose *Read-Only Access*.

If you want to install from DVD or CD-ROM, add the drive to the list of available hard disks. To learn about device nodes of the available optical drives, run:

```
hwinfo --cdrom | egrep "(Device File:|Model:)"
```

Instead of the real DVD or CD-ROM drive, you can also add the ISO image of an installation medium. Note that each CD-Rom drive or ISO image can only be used by one guest at the same time.

To add a CD/DVD-ROM device or an ISO image, proceed as follows:

- 1 Click *CD-ROM*.
- 2 Enter a *Source*. If adding a device, enter its node. If adding an ISO image, either enter the path directly or click *Browse* to open a file browser.
- 3 Specify the *Protocol*. Choose *file* for an ISO image and *phy* for a device.

The disks are listed in the order in which they have been created. This order also represents the boot order. Use the *Up* and *Down* arrows to change the disk order.

### 5.1.1.5 Network Adapters

By default, a single virtual network card is created for the virtual machine. It has a randomly generated MAC address that you can change to fit your desired configuration. If a bridge exists on the VM Host Server, the virtual network card will be attached to it, otherwise it will be attached to the `libvirt`'s default virtual bridge (`virbr1`).

To add a new network adapter or edit an existing one, proceed as follows:

- 1 Click *New* to add a card or *Edit* to change the configuration of the selected card.
- 2 Choose a *Type* from the drop-down list.

---

**NOTE: Supported Virtual Network Adapter Types**

Currently, only *Fully Virtualized Realtek 8139*, *Fully Virtualized Intel e1000* or the paravirtualized *QEMU Virtualized NIC Card* (`virtio`) are supported by SUSE.

---

- 3 Choose a *Source* from the drop-down list.
- 4 Choose whether to assign a randomly generated MAC address or manually specify an address.

---

**NOTE: MAC addresses need to be unique**

When choosing to manually specify a MAC address, make sure it is not already used in your network. If so, it may result in network problems, especially when using DHCP. Therefore avoid specifying obvious MAC addresses such as 52:54:00:12:34:56 or 52:54:00:11:22:33, because they may already be in use. It is strongly recommended to always use a randomly generated MAC address for each adapter.

---

### 5.1.1.6 *Operating System Installation*

This dialog is only available when having chosen to install an operating system. The installation can be booted from a virtual disk, from a CD/DVD device, from an ISO image, a network resource or via PXE boot—use this dialog to configure the boot device.

Also use this dialog to configure the behavior of the VM Guest when the operating system is powered off, rebooted or if it crashes. The following options are available

*destroy*

normal cleanup

*restart*

a new VM Guest is started in place of the old one

*preserve*

no cleanup, do not delete temporary, configuration and image files

*rename-restart*

the VM Guest is not cleaned up but is renamed and a new domain started in its place

*coredump-destroy*

a crashed machine's core is dumped before a normal cleanup is performed

*coredump-restart*

a crashed machine's core is dumped before a normal restart is performed

## 5.2 Installing from the Command Line with `vm-install`

If `$DISPLAY` is not set (for example, when operating on a console or on an ssh shell with no X-forwarding), `vm-install` offers a command-line wizard to interactively set up a VM Guest for installation. Once the setup is completed, the newly created guest boots into the installation system which can be connected via VNC.

---

### **IMPORTANT: Graphical User Interface needed for Installation**

Once the VM Guest boots into the installation, you need to connect to the graphical console via VNC to attend the installation. Therefore, you need to start the viewer from a graphical user interface.

If you are working from a console with no access to a graphical user interface, you can set up the VM Guest configuration and start the installation at a later time. Refer to Section 5.2.1, “Defining a VM Guest without Starting the Installation” (page 33) for instructions.

---

To start the wizard, just type `vm-install` to start. For a lot of parameters, the installation wizard already provides reasonable defaults which you can confirm by just pressing `.` Here is a log of an interactive setup for a SUSE Linux Enterprise Server 11 installation:

### **Example 5.1** *Interactive Setup on the Command Line Using `vm-install`*

```
~ # vm-install
Gathering settings...
```

Please specify the type of operating system that will run within the virtual machine. This defines many defaults, and helps decide how to start

```

paravirtualized operating systems.
Press 'q' or the Escape key to exit.
  1: Novell Open Enterprise Server 2 (Linux)
  2: Novell Open Enterprise Server 2 (NetWare)
  3: Other operating system
  4: PXE
  5: RedHat (other)
  6: RedHat Enterprise Linux 3
  7: RedHat Enterprise Linux 4
  8: RedHat Enterprise Linux 5
  9: SUSE (other)
10: SUSE Linux Enterprise Desktop 10
11: SUSE Linux Enterprise Desktop 11
12: SUSE Linux Enterprise Server 8
13: SUSE Linux Enterprise Server 9
14: SUSE Linux Enterprise Server 10
15: SUSE Linux Enterprise Server 11
16: Solaris 9 and older
17: Solaris 10
18: Windows (other)
19: Windows (other, x64)
20: Windows NT
21: Windows Server 2008
22: Windows Server 2008 (x64)
23: Windows Vista, Windows 7
24: Windows Vista, Windows 7 (x64)
25: Windows XP, 2000, 2003
26: Windows XP, 2003 (x64)
27: openSUSE
28: openSUSE 11
[15] >

PXE Boot
(Y / N) [N] >
Please choose a name for the virtual machine.
[sles11] >

Description > SLES 11 SP1

Specify the amount of memory and number of processors to allocate for the
VM.
Initial Memory [512] >
Maximum Memory [512] > 768
Warning: Setting the maximum memory greater than the initial memory requires
the VM operating system to have a memory balloon driver.
Virtual Processors [2] >

Please specify the type of virtualized graphics hardware.
  1: Cirrus Logic GD5446 VGA
  2: No Graphics Support
  3: VESA VGA
[1] >

```



Virtual Disks:

(None)

Do you want to add another virtual disk?

(Y / N) [Y] >

Create a virtual disk based on a device (CD or other block device), an existing image file (ISO), or a new file. Specify a device by its device node, such as /dev/cdrom, not its mount point.

What type of virtual disk do you want to add?

1: CD-ROM or DVD

2: Floppy

3: Hard Disk

[3] > 3

Where will the virtual disk physically reside?

[/var/lib/kvm/images/sles11/hda] >

Size (GB) [4.0] > 8.0

Create a sparse image file for the virtual disk?

(Y / N) [Y] >

Virtual Disks:

8.0 GB Hard Disk (file:/var/lib/kvm/images/sles11/hda)

Do you want to add another virtual disk?

(Y / N) [N] > y

Create a virtual disk based on a device (CD or other block device), an existing image file (ISO), or a new file. Specify a device by its device node, such as

/dev/cdrom, not its mount point.

What type of virtual disk do you want to add?

1: CD-ROM or DVD

2: Floppy

3: Hard Disk

[3] > 1

Where will the virtual disk physically reside?

[/var/lib/kvm/images/sles11/hdb] > /isos/SLES-11-SP1-CD-i386-GM-CD1.iso

Virtual Disks:

8.0 GB Hard Disk (file:/var/lib/kvm/images/sles11/hda)

2.9 GB CD-ROM or DVD (file:/isos/SLES-11-SP1-DVD-x86\_64-GM-DVD1.iso)

Do you want to add another virtual disk?

(Y / N) [N] >

Network Adapters

(None)

Do you want to add another virtual network adapter?

(Y / N) [Y] >

What type of virtual network adapter do you want to add?

1: Fully Virtualized AMD PCnet 32

2: Fully Virtualized Intel e100

3: Fully Virtualized Intel e1000

```

4: Fully Virtualized NE2000 (ISA Bus)
5: Fully Virtualized NE2000 (PCI Bus)
6: Fully Virtualized Realtek 8139
7: Paravirtualized
[6] > 7

Network Adapters
  Paravirtualized; Randomly generated MAC address
Do you want to add another virtual network adapter?
(Y / N) [N] >

```

Preparing to start the installation...

Installing...

You may also provide parameters on the command line. The wizard will then prompt you for any missing parameters. In the following all parameters from Example 5.1, “Interactive Setup on the Command Line Using `vm-install`” (page 29) for which a command line switch exists, are specified. See `man 8 vm-install` for a full list of parameters.

### Example 5.2 *vm-install command line switches*

```

vm-install --os-type sles11❶ --name "sles11_test"❷ \
--vcpus 2❸ --memory 512❹ --max-memory 768❺ \
--disk /var/lib/kvm/images/sles11/hda,0,disk,w,8000,sparse=1❻ \
--disk /iso/SLES-11-SP1-DVD-x86_64-GM-DVD1.iso,1,cdrom❼ \
--nic mac=52:54:00:05:11:11,model=virtio❽ \
--graphics cirrus❾ --config-dir "/etc/libvirt/qemu"❿

```

- ❶ Specifies the guest operating system to define suitable defaults. A list of valid values can be obtained with `vm-install -O`.
- ❷ Name of the VM Guest. This name must be unique.
- ❸ Number of virtual processors.
- ❹ Initial amount of memory.
- ❺ Maximum amount of memory. Requires an operating system with a para-virtualized *virtio-balloon* driver.
- ❻ Defines a virtual hard disk. The file is located at `/var/lib/kvm/images/sles11/hda`. It is configured as the first (0) hard disk (`disk`). It is writable (`w`) with a size of 8 GB (8000). The file on the VM Host Server is a sparse file (`sparse=1`).
- ❼ Defines an ISO image for a CD-ROM as the second (1) block device.
- ❽ Configures a para-virtualized network device with the MAC address `52:54:00:05:11:11`.
- ❾ Specifies the graphics card.
- ❿ Specifies the directory for the VM configuration files.

- ⑩ The directory in which the XML configuration file for the virtual machine will be stored. It is strongly recommended to use the default directory `/etc/libvirt/qemu`.

## 5.2.1 Defining a VM Guest without Starting the Installation

`vm-install` provides the `--no-install` parameter. With this parameter the XML configuration file defining the VM Guest is created, but the guest is not booted automatically. You may use it regardless whether you start `vm-install` in wizard mode or whether you specify all other options in the command line. You can start the installation.

---

### **WARNING: No Virtual Disk Creation**

When using the `--no-install` parameter with `vm-install`, no virtual disks will be created. Therefore, you have to create the disks in advance using either `qemu-img` or `virsh`.

---

Once the VM Guest XML configuration file is successfully created, you need to “register” it so it is recognized by Virtual Machine Manager or `virsh`. Do so by running:

```
virsh -c qemu:///system define PATH_TO_XMLFILE
```

## 5.3 Advanced Guest Installation Scenarios

This section provides instructions for operations exceeding the scope of a normal installation, such as including add-on packages.

### 5.3.1 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 images and the image for the add-on product.

First add the standard installation image, and second the physical CD/DVD-ROM or add-on image. The image or device added first is automatically chosen as the boot image. In case you install SUSE Linux Enterprise Server, it will be configured as `/dev/sr0`, while the add-on product source will be configured as `/dev/sr1`.

# Basic VM Guest Management

Basic 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.

## 6.1 Listing VM Guests

In order to be able to list VM Guests, you need to connect to a VM Host Server first. If you start the management tool on the VM Host Server itself, you are automatically connected. When operating from remote, refer to Section 7.3, “Connecting to a VM Host Server” (page 60) for instructions.

### 6.1.1 Listing VM Guests with Virtual Machine Manager

The main Window of the Virtual Machine Manager shows a list of 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 icon and literal, and a CPU usage bar.

### 6.1.2 Listing VM Guests with `virsh`

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

List running guests on localhost

```
virsh -c qemu:///system list
```

List running and inactive guests as user `roots` on a remote host over a TLS connection

```
virsh -c qemu+tls://root@mercury.example.com/system list --all
```

List running and inactive guests as user `tux` on a remote host over an SSH tunnel

```
virsh -c qemu+ssh://tux@mercury.example.com/system list --inactive
```

## 6.2 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.

Once you click into the VNC console, the cursor is “grabbed” and cannot be used outside the console anymore. To release it, press `+`.

---

### TIP: Seamless (Absolute) Cursor Movement

In order 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 9.1, “Enabling Seamless and Synchronized Cursor Movement” (page 80) for more information.

---

Certain key combinations such as `++` 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`

---

### NOTE: Supported VNC Viewer

Principally all VNC viewers are able to 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 become limited. Common VNC viewers such

as `tightvnc` or `tigervnc` support neither SASL authentication or TLS/SSL. The only supported alternative to Virtual Machine Manager and `virt-viewer` is `vinagre`.

---

## 6.2.1 Opening a Graphical Console with Virtual Machine Manager

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

## 6.2.2 Opening a Graphical Console with `virt-viewer`

`virt-viewer` is a simple VNC viewer with added functionality for displaying VM Guest consoles. It can, for example, 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, either use the ID, UUID, or name. VM Guests that are shut off do not have an ID—you can only connect by UUID or name.

Local connect to guest with ID 8

```
virt-viewer -c qemu:///system 8
```

Local connect to the inactive guest `sles11`; will connect once the guest starts

```
virt-viewer -c qemu:///system --wait sles11
```

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

Remote connect via ssh:

```
virt-viewer -c qemu+ssh://root@mercury.example.com/system -w sles11
```

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

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

Starting, stopping or pausing a VM Guest can either be done with 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

In order to be able to perform a graceful shutdown, the VM Guest must be configured to support ACPI. If you have created the guest with `vm-install` or with Virtual Machine Manager, ACPI should be available. Use the following procedure in Virtual Machine Manager to check:

Double-click the VM Guest entry in Virtual Machine Manager. Choose *View > Details* and then *Overview > Machine Settings*. *ACPI* should be checked.

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

If ACPI was enabled during a Windows XP/Server 2003 guest installation, turning it on in the VM Guest configuration alone is not sufficient. See the following articles for more information:

<http://support.microsoft.com/kb/314088/EN-US/>  
<http://support.microsoft.com/?kbid=309283>

A graceful shutdown is of course always possible from within the guest operating system, regardless of the VM Guest's configuration.

---



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

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

### **Procedure 6.1** *State Change from the Virtual Machine Manager Window*

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

### **Procedure 6.2** *State change from the VNC Window*

- 1 Open a VNC Window as described in Section 6.2.1, “Opening a Graphical Console with Virtual Machine Manager” (page 37).
- 2 Choose *Run*, *Pause*, or one of the *Shut Down* options either from the toolbar or from the *Virtual Machine* menu.

### 6.3.1.1 Autostarting a VM Guest

Automatically starting a guest when the VM Host Server boots is not enabled by default. This feature needs to be turned on 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*.

## 6.3.2 Changing a VM Guest's State with virsh

In the following examples the state of a VM Guest named “sles11” is changed.

### Start

```
virsh -c qemu:///system start sles11
```

### Pause

```
virsh -c qemu:///system suspend sles11
```

### Reboot

```
virsh -c qemu:///system reboot sles11
```

### Graceful shutdown

```
virsh -c qemu:///system shutdown sles11
```

### Force shutdown

```
virsh -c qemu:///system destroy sles11
```

### Turn on autostart

```
virsh -c qemu:///system autostart sles11
```

### Turn off autostart

```
virsh -c qemu:///system autostart --disable sles11
```

## 6.4 Saving and Restoring VM Guests

Saving a VM Guest preserves the exact state of the guest's memory. The operation is slightly 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 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 rather resumes at the point where it was previously saved. The operation is slightly 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. Issue the following command on the guest to get a rough estimation of the file size in megabytes to be expected:

```
free -m | awk '/^Mem:/ {print $3}'
```

---

## WARNING

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

---

## 6.4.1 Saving / Restoring with Virtual Machine Manager

### **Procedure 6.3** *Saving a VM Guest*

- 1 Open a VNC connection window to a VM Guest. Make sure the guest is running.
- 2 Choose *Virtual Machine > Save*
- 3 Choose a location and a file name.
- 4 Click *Save*. Saving the guest's state may take some time. After the operation has finished, the VM Guest will automatically shut down.

### **Procedure 6.4** *Restoring a VM Guest*

- 1 Start the Virtual Machine Manager.
- 2 Type `+ R` or choose *File > Restore Saved Machine*.
- 3 Choose the file you want to restore and proceed with *Open*. Once the file has been successfully loaded, the VM Guest is up and running.

## 6.4.2 Saving / Restoring with virsh

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

Save the guest named `opensuse11`

```
virsh save opensuse11 /virtual/saves/opensuse11.vmsav
```

Save the guest with the ID `37`

```
virsh save 37 /virtual/saves/opensuse11.vmsave
```

To restore it, use `virsh restore`:

```
virsh restore /virtual/saves/opensuse11.vmsave
```

## 6.5 Deleting a VM Guest

Deleting a VM Guest removes its XML configuration by default. Since the attached storage is not deleted by default, you will be able to use it with another VM Guest. With Virtual Machine Manager you may also delete a guest's storage files as well—this will completely erase the guest.

In order to delete a VM Guest, it has to be shut down first (refer to Section 6.3, “Changing a VM Guest's State: Start, Stop, Pause” (page 38) for instructions). It is not possible to delete a running guest.

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

- 1 In the Virtual Machine Manager, right-click on a VM Guest entry.
- 2 Choose *Delete* from the pop-up menu.
- 3 A confirmation window opens. Clicking *Delete* will permanently erase the VM Guest. The deletion is not recoverable.

You may also choose to permanently delete the guest's virtual disk by ticking *Delete Associated Storage Files*. The deletion is not recoverable either.

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

To delete a VM Guest with `virsh` run `virsh undefine VM_NAME`. There is no option to automatically delete the attached storage files.

# Connecting and Authorizing

Having to manage several VM Host Servers, each hosting a couple of VM Guests, quickly becomes difficult to handle. One of the major benefits 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.

In order 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, PolicyKit, SASL and Kerberos).

## 7.1 Authentication

The power to manage VM Guests and to access their graphical console obviously is something that should be restricted to a well defined circle of persons. In order 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 PolicyKit. This method is available for local `libvirtd` connections only.
- Username and password authentication with SASL (Simple Authentication and Security Layer). This method is available for both, `libvirtd` and VNC connections.

tions. Using SASL does not require real user accounts on the server, since it uses its own database to store usernames and passwords. Connections authenticated with SASL are encrypted.

- Kerberos authentication. This method, available for `libvirtd` connections only, is not covered in this manual. Please refer to [http://libvirt.org/auth.html#ACL\\_server\\_kerberos](http://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 management functions (via `libvirtd`) on the one hand and to their graphical console on the other hand, always needs to be configured separately. When restricting the 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 7.2.2.5, “Restricting Access (Security Considerations)” (page 58) for details.

## 7.1.1 `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 learn how to configure access permissions for the read-write socket. The same instructions also apply to the read-only socket. All configuration steps have to be carried out on the VM Host Server.

---

**NOTE: Default Authentication Settings on openSUSE**

The default authentication method on openSUSE 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 PolicyKit once and are granted access for the current and for future sessions.

---

***Recommended Authorization Methods*****Local Connections**

Section 7.1.1.2, “Local Access Control for UNIX Sockets with PolicyKit” (page 46)

Section 7.1.1.1, “Access Control for UNIX Sockets with Permissions and Group Ownership” (page 45)

**Remote Tunnel over SSH**

Section 7.1.1.1, “Access Control for UNIX Sockets with Permissions and Group Ownership” (page 45)

**Remote TLS/SSL Connection**

Section 7.1.1.3, “Username and Password Authentication with SASL” (page 48)

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

## **7.1.1.1 Access Control for UNIX Sockets with Permissions and Group Ownership**

In order 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 which 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 -A 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`.
- ❷ Sets the access permissions for the socket (`srwxrwx---`).
- ❸ Disables other authentication methods (PolicyKit or SASL). Access is solely controlled by the socket permissions.

#### 4 Restart `libvirtd`:

```
rclibvirtd restart
```

## 7.1.1.2 Local Access Control for UNIX Sockets with PolicyKit

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

---

### IMPORTANT: PolicyKit Authentication for Local Connections Only

Authentication with PolicyKit can only be used for local connections on the VM Host Server itself, since PolicyKit 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 `root` password once and grant the privilege for the current and for future sessions (`auth_admin_keep_always`).

In order to grant users access to the read-write socket without having to provide the `root` password, there are two possibilities:

1. Using the `polkit-auth` command, you can grant the privilege without any restrictions:

```
polkit-auth --user tux --grant org.libvirt.unix.manage    # grant
privilege
polkit-auth --user tux --revoke org.libvirt.unix.manage   # revoke
privilege
```

2. Editing `/etc/PolicyKit/PolicyKit.conf` offers more advanced options. Add the following XML snippet in between the existing `<config version="0.1">` and `</config>` tags:

```
<match action="org.libvirt.unix.manage">❶
  <match user="tux">❷
    <return result="yes"/>❸
  </match>
</match>
```

- ❶ The name of the policy; `org.libvirt.unix.manage` stands for accessing the read-write socket.
- ❷ The username(s) which to grant the privilege. Use the `|` symbol to separate entries (`user="tux|wilber"`).
- ❸ The privilege that is granted. The following options exist: `yes` (no restrictions), `no` (block access completely), `auth_self` or `auth_admin` (authenticate with own password/root password every time the privilege is requested), `auth_self_keep_session` or `auth_admin_keep_session` (authenticate with own password/root password once per session) and `auth_self_keep_always` or `auth_admin_keep_always` (authenticate only once with own password/root password).

### 7.1.1.3 Username and Password Authentication with SASL

SASL provides username and password authentication as well as 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 unencrypted 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 a large number of clients. Utilizing 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:

**1a** To enable SASL for TCP connections:

```
auth_tcp = "sasl"
```

**1b** To enable SASL for TLS/SSL connections:

```
auth_tls = "sasl"
```

**2** Restart `libvirtd`:

```
rc libvirtd restart
```

**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 `mech_list`. For TCP connections this parameter must be set to `digest-md5`:

```
mech_list: digest-md5    # mandatory for TCP connections
#mech_list: digest-md5    # apply default (username+password) TLS/SSL
only!
```

- 4** By default, no SASL users are configured, so no logins are possible. Use the following commands to add, list, and delete users:

```
mercury:~ # saslpasswd2 -a libvirt tux                # add user tux
Password:
Again (for verification):
mercury:~ # sasldblistusers2 -f /etc/libvirt/passwd.db # list users
tux@mercury.example.com: userPassword
mercury:~ # saslpasswd2 -a libvirt -d tux             # delete user tux
```

---

### **TIP: `virsh` and SASL Authentication**

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

---

## **7.1.2 VNC Authentication**

Since access to the graphical console of a VM Guest is not controlled by `libvirt`, but rather by `QEMU`, it is always necessary to additionally configure VNC authentication. The main configuration file is `/etc/libvirt/qemu.conf`.

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 “VNC over TLS/SSL: Client Configuration” (page 57) for details.

### **7.1.2.1 Username and Password Authentication with SASL**

SASL provides username and password authentication as well as 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 “VNC over TLS/SSL: Client Configuration” (page 57) 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 username/password database, a simple link is suitable:

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

In case you are setting up SASL for VNC only or planning to use a different configuration than for `libvirt`, copy the existing file to use as a template and edit it according to your needs:

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

- 2 By default, no SASL users are configured, so no logins are possible. Use the following commands to add, list, and delete users:

```
mercury:~ # saslpasswd2 -a libvirt tux                # add user tux
Password:
Again (for verification):
mercury:~ # sasldblistusers2 -f /etc/libvirt/passwd.db # list users
tux@mercury.example.com: userPassword
mercury:~ # saslpasswd2 -a libvirt -d tux             # delete user tux
```

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

```
vnc_listen = "0.0.0.0"
vnc_sasl = 1
```

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.

- 4 Restart `libvirtd`:

```
rclibvirtd restart
```

- 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**

Currently only the same VNC viewers that also support TLS/SSL connections, support SASL authentication, namely Virtual Machine Manager, `virt-viewer`, and `vinagre`.

---

## 7.1.2.2 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 config files.

---

**NOTE: Always Set a Global Password**

If you are using the 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 7.1*** *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`:  

```
rc libvirtd restart
```
- 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 7.2*** *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 leave the editor. The maximum length of the password is eight characters.

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

- 5 Restart `libvirtd`:

```
rclibvirtd restart
```

- 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**

The VNC protocol is not considered to be safe. Although the password is sent encrypted, it might be vulnerable, when an attacker is able to 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`, as well as the Virtual Machine Manager and `vinagre` from version 2.30 on, support both methods.

---

## 7.2 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.

## 7.2.1 Remote Tunnel over SSH (`qemu+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 (`rcsshd status`) 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 7.1.1.1, “Access Control for UNIX Sockets with Permissions and Group Ownership” (page 45). Connecting as user `root` (`qemu+ssh://root@mercury.example.com/system`) works out of the box and does not require additional configuration on the `libvirt` side.

When connecting via SSH `qemu+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 Section “Copying an SSH Key” (Chapter 12, *SSH: Secure Network Operations*, ↑Security Guide). Using an `ssh-agent` on the machine from which you are connecting adds even more convenience—see Section “Using the `ssh-agent`” (Chapter 12, *SSH: Secure Network Operations*, ↑Security Guide) for instructions.

## 7.2.2 Remote TLS/SSL Connection with x509 Certificate (`qemu+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 have to manage several VM Host Servers with a varying number of administrators.

### 7.2.2.1 Basic concept

Basically, TLS (Transport Layer Security) encrypts the communication between two computers by using certificates. The computer starting the connection is always considered as the “client” using a “client certificate”, while the receiving computer is always considered as 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 is able to identify itself correctly. In order to assure that a certificate was issued by the assumed owner, it is signed and issued by a central certificate called certification 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 basically 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. Refer to Section 7.2.2.5, “Restricting Access (Security Considerations)” (page 58) for details. `libvirt` also supports user authentication on the server with SASL. Read more in Section 7.2.2.6, “Central User Authentication with SASL for TLS Sockets” (page 59).

---

## **7.2.2.2 Configuring the VM Host Server**

The VM Host Server is the machine receiving connections. Therefore, the *server* certificates have to be installed. The CA certificate needs to be installed, as well. Once 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 A.2, “Generating x509 Client/Server Certificates” (page 152).

- 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 7.2.2.5, “Restricting Access (Security Considerations)” (page 58).

---



- 3 Enable TLS support by editing `/etc/libvirt/libvirtd.conf` and setting `listen_tls = 1`. Restart `libvirtd`:  

```
rclibvirtd restart
```
- 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.

---

### 7.2.2.3 Configuring the Client and Testing the Setup

The client is the machine initiating connections. Therefore the *client* certificates have to be installed. The CA certificate needs to be installed, as well.

- 1 Create the client certificate and export it together with the CA certificate as described in Section A.2, “Generating x509 Client/Server Certificates” (page 152).
- 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 7.2.2.5, “Restricting Access (Security Considerations)” (page 58).

---

- 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 full qualified hostname as used when creating the server certificate.

```
virsh -c qemu+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.

## 7.2.2.4 Enabling VNC for TLS/SSL connections

Currently, VNC communication over TLS is only supported by few tools. The widespread `tightvnc` or `tigervnc` viewer, for example, do not support TLS. Known to work are the Virtual Machine Manager (`virt-manager`), `virt-viewer` and the GNOME VNC viewer `vinagre`.

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

In order 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`:

```
relibvirtd restart
```

---

#### 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.

---

## 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**)

In order to connect to the remote host, Virtual Machine Manager requires the setup explained in Section 7.2.2.3, “Configuring the Client and Testing the Setup” (page 55). In order 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
```

### **vinagre**

System wide location

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

Per user location

```
$HOME/.pki/CA/cacert.pem
```

```
~/ .pki/vinagre/clientcert.pem  
~/ .pki/vinagre/private/clientkey.pem
```

---

### **IMPORTANT: Restrict Access to Certificates**

Make sure to restrict access to certificates as explained in Section 7.2.2.5, “Restricting Access (Security Considerations)” (page 58).

---

## **7.2.2.5 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 openSUSE QEMU processes started from `libvirt` tools are owned by `root`, so it is sufficient if `root` is able to read them 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 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 the group ownership of the `clientkey.pem` and its parent directory is set to `libvirt`. Afterwards, the access permissions are restricted to owner and group. Finally the user `tux` is added to the group `libvirt`, so he will be able to 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 -A 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 users home directory in `~/.pki`. Contrary to, for example, the VNC viewer using these certificates do not check the access permissions of the private key file. Therefore, it is solely on the user's responsibility to make sure the key file is not readable by others.

## 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 7.1.1.3, “Username and Password Authentication with SASL” (page 48).

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

Add a list of allowed DNs to `tls_allowed_dn_list` in `/etc/libvirt/libvirtd.conf`. This list may contain wildcards. 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:

```
rclibvirtd restart
```

## 7.2.2.6 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 7.2.2.5,

“Restricting Access (Security Considerations)” (page 58). 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 7.1.1.3, “Username and Password Authentication with SASL” (page 48) for configuration details.

## 7.2.2.7 Troubleshooting

### 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 hostname 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?

### VNC Connection fails

Ensure that you can basically 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 “sles11”.

```
ps ax | grep qemu | grep "\-name sles11" | 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
```

## 7.3 Connecting to a VM Host Server

In order 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 Ma-

chine 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 7.3.1, “Managing Connections with Virtual Machine Manager” (page 62) for details.

`HYPERVISOR①+PROTOCOL②:://USER@REMOTE③/CONNECTION_TYPE④`

- ① Specify the hypervisor. openSUSE currently supports the following hypervisors: `test` (dummy for testing), `qemu` (KVM), and `xen` (Xen). This parameter is mandatory.
- ② When connecting to a remote host, specify the protocol here. 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).
- ③ When connecting to a remote host, specify the user and the remote hostname. If no user is specified, the username that has called the command (`$USER`) is used. Please see below for more information. For TLS connections the hostname has to be specified exactly as in the x509 certificate.
- ④ When connecting to QEMU hypervisor, two connections types are accepted: `system` for full access rights, or `session` for restricted access. Since `session` access is not supported on openSUSE, this documentation focuses on `system` access.

### *Example Hypervisor Connection URIs*

`test:///default`

Connect to the local dummy hypervisor. Useful for testing.

`qemu:///system`

Connect to the QEMU hypervisor on the local host having full access (type `system`). This usually requires that the command is issued by the user `root`.

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

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

`qemu+tls://saturn.example.com/system`

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

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

---

**NOTE: Usernames in URIs**

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

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

---

## 7.3.1 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 localhost 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 in order 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. In order 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 Choose a *Connection* type—either *Local* for connecting to the host the Virtual Machine Manager was started on, or one of the remote connections (see Section 7.2, “Configuring Remote Connections” (page 52) for more information).



- 4 In case of a remote connection, enter the *Hostname* of the remote machine as `USERNAME@REMOTE_HOST`. Usernames must be specified for local connections as well as for SSH

---

**IMPORTANT: Specifying a Username**

There is no need to specify a username for TCP and TLS connections; it will not be evaluated anyway. A username must be specified for local connections as well as for SSH connections—if not, the default user `root` will be used.

---

- 5 If you do not want the connection to be automatically activated when starting the Virtual Machine Manager, remove the tick from *Autoconnect*.
- 6 Finish the configuration by clicking *Connect*.



# Managing Storage

When managing a VM Guest on the VM Host Server itself, it is possible to access the complete file system of the VM Host Server in order 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**

In order 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 basically 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 the fact 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 into the volume once before, in order to use it with `libvirt`. 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-
ign.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 a LVM volume group as a pool. You may either use a pre-defined 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 the fact that `libvirt` takes care of mounting the directory. Supported protocols are NFS and glusterfs.

### SCSI Host Adapter (*scsi*)

Use an SCSI host adapter in almost the same way as an iSCSI target. It is recommended to use a device name from `/dev/disk/by-*` rather than the simple `/dev/sdX`, since the latter may 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**

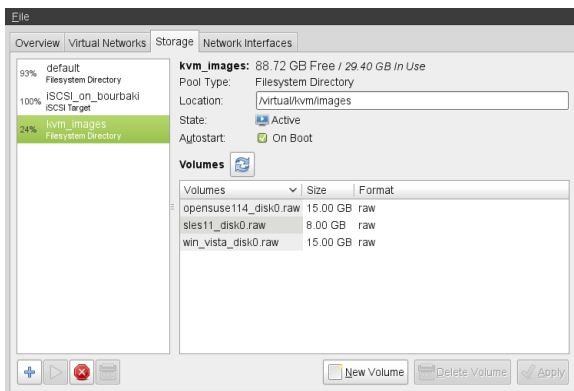
In order to avoid data loss or data corruption, do not attempt to use resources such as LVM volume groups, iSCSI targets, etc. that are used to build storage pools on the VM Host Server, as well. There is no need to connect to these resources from the VM Host Server or to mount them on the VM Host Server—`libvirt`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

---

## **8.1 Managing Storage with Virtual Machine Manager**

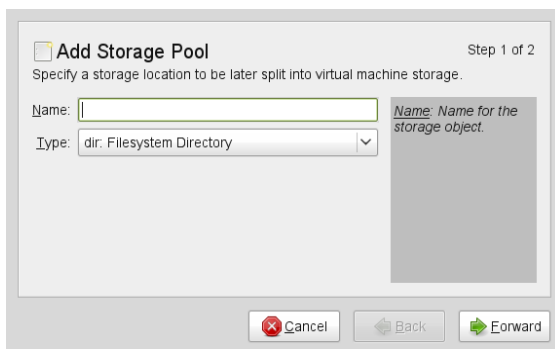
The Virtual Machine Manager provides a graphical interface—the Storage Manager—to manage storage volumes and pools. To access it, either right-click on a connection and choose *Details*, or highlight a connection and choose *Edit > Connection Details*. Select the *Storage* tab.



## 8.1.1 Adding a Storage Pool

To add a storage pool, proceed as follows:

- 1 Click the plus symbol in the bottom left corner to open the *Add a New Storage Pool Window*.
- 2 Provide a *Name* for the pool (consisting of alphanumeric characters plus \_-.) and select a *Type*. Proceed with *Forward*.



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

**Add Storage Pool** Step 2 of 2

Specify a storage location to be later split into virtual machine storage.

Target Path:   Format: Type of network filesystem.

Format:

Host Name:

Source Path:

Build Pool: ☒

### Typedir:

- *Target Path:* Specify an existing directory.

### Typedisk:

- *Target Path:* The directory which hosts the devices. The default value `/dev` should fit in most cases.
- *Format:* Format of the device's partition table. Using `auto` should work in most cases. If not, get the needed 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 may 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 the simple `/dev/sdX`, since the latter may 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 highlighted with a bold font are the ones needed:

```
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).

#### **Typelogical:**

- *Target Path:* In case you use an existing volume group, specify the existing device path. In case of 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.

#### **Typepath:**

- *Target Path:* Support of multipathing is currently limited to making all multipath devices available. Therefore you may enter an arbitrary string here (needed, otherwise the XML parser will fail), it will be ignored anyway.

#### **Typevfs:**

- *target Path:* Mount point on the VM Host Server file system.



- *Format*: Network file system protocol
- *Host Name*: IP address or hostname 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 on *Browse* is not possible when operating from remote.

---

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

## **8.1.2 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.

### **8.1.2.1 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. In order to make a pool temporarily inaccessible from remote, you may *Stop* it by clicking on the stop symbol 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 on the play symbol 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, you can *Delete* it by clicking on the shredder symbol 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 in case the pool will be 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 be 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.

---

## 8.1.2.2 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 both cases, select a *Storage Pool* and then click *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.

Specify a *Max Capacity* and the amount of space that should initially be allocated. If both values differ, a `sparse` image file, growing on demand, will be created.

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

### 8.1.2.3 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*. Use this function with extreme care!

---

**WARNING: No Checks Upon Volume Deletion**

A volume will be deleted in any case, regardless 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 is indicated in the *Used By* column in the Storage Manager.

---

## 8.2 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 document 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.

### 8.2.1 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 8.1*** *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>    </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
```

## **8.2.2 Starting, Stopping and Deleting Pools**

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

## Stopping a Pool

```
virsh pool-destroy POOL
```

---

### **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 POOL
```

---

### **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 in case the pool will be 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 be 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.

---

## Starting a Pool

```
virsh pool-start POOL
```

## Enable Autostarting a Pool

```
virsh pool-autostart POOL
```

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

## Disable Autostarting a Pool

```
virsh pool-autostart POOL --disable
```

## 8.2.3 Adding Volumes to a Storage Pool

`virsh` offers two ways to create 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 POOL❶ NAME❷ 12G --format❸ raw/qcow2/qed❹ --allocation  
4G❺
```

- 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 gigabyte. 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 gigabyte 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. If you want to create a non-sparse volume, specify the whole image size with this parameter (would be 12G in this example).

### 8.2.3.1 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.

```
vol-clone NAME_EXISTING_VOLUME❶ NAME_NEW_VOLUME❷ --pool POOL❸
```

- 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.

## 8.2.4 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 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 8.1, “Listing all Storage Volumes Currently Used on a VM Host Server” (page 74).

---

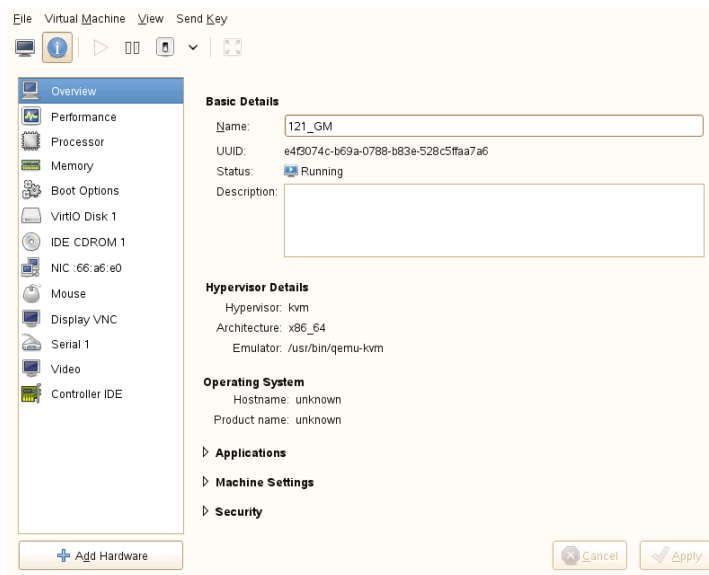




# Configuring Virtual Machines

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 guests console in Virtual Machine Manager and either choose *View > Details* from the menu, or click on the blue information icon in the toolbar.

**Figure 9.1** *Details View of a VM Guest*



## 9.1 Enabling Seamless and Synchronized Cursor Movement

When you click within a VM Guest's console with the mouse, the cursor is captured by the console window and cannot be used outside the console unless it is explicitly released (by pressing `+`). To prevent the console from grabbing the key and to enable seamless cursor movement between host and guest instead, add a tablet to the VM Guest.

Adding a tablet has the additional advantage of synchronizing the cursor 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 cursor symbols 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 In case you tried to add the tablet while the guest was still running, you will be asked whether to enable the tablet after the next reboot. Confirm with *Yes*.
- 4 Once you (re)start the VM Guest the tablet is available in the VM Guest.

## 9.2 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. Proceed with *Forward*.
- 3 Change the *Device Type* to *IDE CDROM*.
- 4 Select *Select Managed or Other Existing Storage*.
  - 4a 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 the *Browse* button. Alternatively you may use the *Browse* button 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.
  - 4b To assign the device to an existing image, click *Browse* to choose an image from a storage pool. If the Virtual Machine Manager was started on the VM Host Server, you may 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 Proceed with *Forward* to review the settings. Apply them with *Finish*, *Yes*, and *Apply*.
- 6 Reboot the VM Guest to make the new device available. For further information also see Section 9.4, “Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager” (page 82).

## 9.3 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. Proceed with *Forward*.
- 3 Change the *Device Type* to *Floppy Disk*.
- 4 Choose *Select Managed or Other Existing Storage* and click *Browse* to choose an existing image from a storage pool. If Virtual Machine Manager was started on the VM Host Server, you may 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 Proceed with *Forward* to review the settings. Apply them with *Finish*, *Yes*, and *Apply*.
- 6 Reboot the VM Guest to make the new device available. For further information also see Section 9.4, “Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager” (page 82).

## 9.4 Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager

Regardless 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 media by clicking *Disconnect*.

**3** To “insert” a new media, click *Connect*.

**3a** If using the VM Host Server’s physical CD/DVD-ROM device, first change the media in the device (this may require to unmount 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 list.

**3b** If using an ISO image, choose *ISO image Location* and select an image by clicking *Browse*. 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.

## 9.5 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: Time Keeping on the VM Host Server

It is strongly recommended to ensure the VM Host Server keeps the correct time as well, for example, by utilizing NTP (see Chapter 14, *Time Synchronization with NTP* (↑Reference) for more information).

---

### 9.5.1 Using `kvm_clock`

KVM provides a para-virtualized clock which is currently supported by SUSE Linux Enterprise Server 10 SP3 and newer and RedHat Enterprise Linux 5.4 and newer via the `kvm_clock` driver. It is strongly recommended to use `kvm_clock` when available.

Use the following command inside a VM Guest running Linux to check whether the driver `kvm_clock` has been loaded:

```
~ # 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`:

```
cat /sys/devices/system/clocksource/clocksource0/current_clocksource
```

---

**IMPORTANT: `kvm-clock` and NTP**

When using `kvm-clock`, it is not recommended to use NTP in the VM Guest, as well. Using NTP on the VM Host Server, however, is still recommended.

---

## 9.5.2 Other Time Keeping Methods

The para-virtualized `kvm-clock` is currently not available for SUSE Linux Enterprise Server 9 and 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).

Correct time keeping in SUSE Linux Enterprise Server 9 SP4 can be achieved by using special boot parameters:

*32-bit Kernel:*`clock=pmtmr`

*64-bit Kernel:*`ignore_lost_ticks`

# Administering VM Guests

## 10.1 Migrating VM Guests

One of the major advantages of virtualization is the fact 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.

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

- Host and target must have same processor manufacturer (Intel or AMD).
- VM Guests running a 64-bit operating system can only be migrated to a 64-bit host (whereas 32-bit VM Guests can be moved to a 64 or 32-bit host).
- 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 (see Chapter 8, *Managing Storage* (page 65) for more information). This is also true for CD-ROM or floppy images that are connected during the move (however, you may disconnect them prior to the move as described in Section 9.4, “Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager” (page 82)).

- `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 7.2, “Configuring Remote Connections” (page 52) 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.
- 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.

## 10.1.1 Migrating with virt-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 on the VM Guest that is to be migrated and choose *Migrate*. Make sure the guest is running or paused - it is not possible to migrate guests that are shut off.
- 3 Choose a *New Host* for the VM Guest. If the desired target host does not show up, make sure a connection to this host has been established.

By default, a “live” migration is performed. If you prefer an “offline” migration where the VM Guest is paused during the migration, tick *Migrate offline*.

- 4 Click *Migrate* to start a migration with the default port and bandwidth.

In order to change these defaults, make the advanced options available by clicking the triangle at *Advanced Options*. Here you can enter the target host's *Address* (IP



address or hostname), a port and the bandwidth in megabit per second (Mbps). If you specify a *Port*, you must also specify an *Address*; the *Bandwidth* is optional.

- 5 Once 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 state shut off).

## 10.1.2 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. Basically the migration command looks like this

```
virsh migrate [OPTIONS] VM_ID_or_NAMECONNECTION 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, an offline migration where the VM Guest is paused during the migration, will be performed.

`--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 transient, 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 `opensuse11` with Id 37.

Offline migration with default parameters

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

### Transient live migration with default parameters

```
virsh migrate --live opensuse11 qemu+ssh://root@jupiter.example.com/  
system
```

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

```
virsh migrate --live --persistent --undefinesource 37 \  
qemu+tls://root@jupiter.example.com/system
```

### Offline migration using port 49152

```
virsh migrate opensuse11 qemu+ssh://root@jupiter.example.com/system \  
--migrateuri tcp://@jupiter.example.com:49152
```

---

#### **NOTE: Transient vs. 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 once it is shut down.

In order 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.

---

## 10.2 Monitoring

### 10.2.1 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 the *Preferences*:

- 1 Run `virt-manager`.
- 2 Select *Edit > Preferences*.
- 3 Change the tab from *General* to *Stats*.
- 4 Activate the check boxes for *Disk I/O* and *Network I/O*.
- 5 If desired, also change the update interval or the number of samples that are kept in the history.
- 6 Close the *Preferences* dialog.
- 7 Activate the graphs that should be displayed under *View > Graph*.

Afterwards, 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 6.2, “Opening a Graphical Console” (page 36). Choose *Details* from the toolbar or the *View* menu. The statistics are displayed from the *Performance* entry of the left-hand tree menu.

## 10.2.2 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 openSUSE it should be mounted by default. In case it is not mounted, use the following command:

```
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 -1             # 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.

## **Part III. Managing Virtual Machines with QEMU**



## 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, PowerPC, Sparc ...)
- emulated devices (graphic card, network card, hard drives, 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

As a virtualization solution, QEMU can be run together with the KVM kernel module. If the VM Guest hardware architecture is the same as VM Host Server's architecture, QEMU can take advantage of the KVM acceleration.





## Guest Installation

A virtual machine is comprised of data and operating system files that define the virtual environment. Virtual machines are hosted and controlled by the VM Host Server. This chapter provides generalized instructions for installing virtual machines.

Before creating a virtual machine, consider the following:

- If you want to use an automated installation file (AutoYaST, NetWare® Response File, or RedHat Kickstart), you need to download it to a directory on the host machine server, or make it available through a network filesystem.
- When creating sparse image files, make sure the partition on which you create them always has sufficient free space. The guest system has no means to check the host's disk space. Having no space left on the host partition causes write errors and loss of data on the guest system.
- NetWare and OES Linux virtual machines need a static IP address for each virtual machine you create.
- If you are installing Open Enterprise Server (OES) 2 Linux, you need a network installation source for OES 2 Linux software.

For further prerequisites, consult the manuals of the respective operating system to install.

# 12.1 Basic Installation with qemu-kvm

The `libvirt`-based tools such as `virt-manager` or `vm-install` offer convenient interfaces to set up and manage virtual machines. They act as a kind of wrapper for `qemu-kvm`. However, it is also possible to utilize `qemu-kvm` directly without using `libvirt`-based tools at all.

---

## WARNING

Virtual machines created with `qemu-kvm` are not "visible" for the `libvirt`-based tools.

---

In the following example, a virtual machine with the same parameters as in Example 5.1, “Interactive Setup on the Command Line Using `vm-install`” (page 29) will be set up using `qemu-kvm`. For detailed information on the commands, refer to the respective man pages.

If you do not already have an image of a system which 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 create❶ -f raw❷ /images/sles11/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 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-kvm` that will boot into the installation system:

```
qemu-kvm -name "sles11"❶ -M pc-0.12❷ -m 768❸ \  
-smp 2❹ -boot d❺ \  
-drive file=/images/sles11/hda,if=virtio,index=0,media=disk,format=raw❻ \  
\
```

```
-drive file=/isos/SLES-11-SP1-DVD-x86_64-GM-DVD1.iso,index=1,media=cdrom7 \
-net nic,model=virtio,macaddr=52:54:00:05:11:118 \
-vga cirrus9 -balloon virtio10
```

- ❶ Name of the virtual machine that will be displayed in the window caption and also used for the VNC server. This name must be unique.
- ❷ Specifies the machine type (*Standard PC*, *ISA-only PC*, or *Intel-Mac*). Use `qemu-kvm -M ?` to display a list of valid parameters. `pc-0.12` is the default *Standard PC*.
- ❸ Maximum amount of memory for the virtual machine.
- ❹ Defines an SMP system with two processors.
- ❺ Specifies the boot order. Valid values are `a`, `b` (floppy 1 and 2), `c` (first hard-disk), `d` (first CDROM), or `n` to `p` (Ether-boot from network adapter 1-3). Defaults to `c`.
- ❻ Defines the first (`index=0`) hard disk. It will be accessed as a paravirtualized (`if=virtio`) drive in raw format.
- ❼ The second (`index=1`) image drive will act as a CD-ROM.
- ❽ 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.
- ❾ Specifies the graphic card. If you specify *none*, the graphic card will be disabled.
- ❿ 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 easily start the related virtual machine without the need to specify the CD-ROM device:

```
qemu-kvm -name "sles11" -M pc-0.12 -m 768 \
-smp 2 -boot c \
-drive file=/images/sles11/hda,if=virtio,index=0,media=disk,format=raw \
-net nic,model=virtio,macaddr=52:54:00:05:11:11 \
-vga cirrus -balloon virtio
```

## 12.2 Managing Disk Images with `qemu-img`

In the previous section (see Section 12.1, “Basic Installation with `qemu-kvm`” (page 96), 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 useful `qemu-img` subcommands to help manage the disk images flexibly.

## 12.2.1 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 of these options are general and used by more of these subcommands, while some of them are unique to the related subcommand. See the `qemu-img` manual page (`man 1 qemu-img`) for a complete list of all supported options. `qemu-img` uses the following general syntax:

```
qemu-img subcommand [options]
```

and supports the following subcommands:

`create`

Creates a new disk image on the filesystem.

`check`

Checks an existing disk image for errors.

`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.

## 12.2.2 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.

### 12.2.2.1 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:

```
qemu-img create -f fmt❶ -o options❷ fname❸ size❹
```

- ❶ The format of the target image. To get a complete list of image formats supported by QEMU, run `qemu-img -h` and look at the last line of the output.
- ❷ Some of the 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 `sles11sp1.raw` in the directory `/images` growing up to a maximum size of 4 GB, run the following command:

```
tux@venus:~> qemu-img create -f raw -o size=4G /images/sles11sp1.raw
Formatting '/images/sles11sp1.raw', fmt=raw size=4294967296
```

```
tux@venus:~> ls -l /images/sles11sp1.raw
-rw-r--r-- 1 tux users 4294967296 Nov 15 15:56 /images/sles11sp1.raw
```

```
tux@venus:~> qemu-img info /images/sles11sp1.raw
image: /images/sles11sp1.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.

## 12.2.2.2 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:

```
qemu-img convert -c❶ -f fmt❷ -O out_fmt❸ -o options❹ fname❺ out_fname❻
```

- 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 autodetected in most cases 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@venus:~> qemu-img convert -O vmdk /images/sles11sp1.raw \
/images/sles11sp1.vmdk
```

```
tux@venus:~> ls -l /images/
-rw-r--r-- 1 tux users 4294967296 16. lis 10.50 sles11sp1.raw
-rw-r--r-- 1 tux users 2574450688 16. lis 14.18 sles11sp1.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@venus:~> qemu-img convert -O vmdk /images/sles11sp1.raw \
/images/sles11sp1.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
```

## 12.2.2.3 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:

```
qemu-img check -f fmt❶ fname❷
```

- ❶ The format of the source disk image. It is autodetected in most cases 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@venus:~> qemu-img check -f qcow2 /images/sles11sp1.qcow2
ERROR: invalid cluster offset=0x2af0000
[...]
ERROR: invalid cluster offset=0x34ab0000
378 errors were found on the image.
```

## 12.2.2.4 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 12.2.2.1, “`qemu-img create`” (page 99)). After you install and run VM Guest for some time, the initial size of the image may no longer be sufficient and you need to add more space to it.

To increase the size of an existing disk image by 2 Gigabytes, use

```
qemu-img resize /images/sles11sp1.raw +2GB
```

---

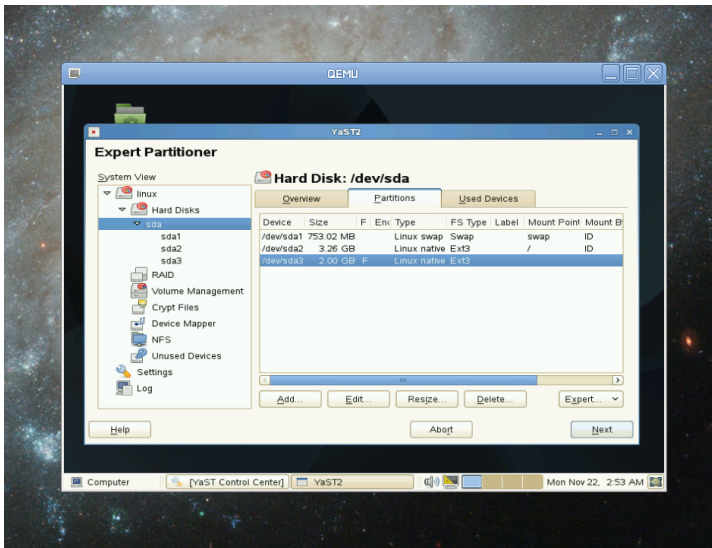
### NOTE

You can resize the `raw` disk images only. To resize other image formats, convert it to `raw` 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 12.1** *New 2GB Partition in Guest YaST Partitioner*



## 12.2.3 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 14, *Administering Virtual Machines with QEMU Monitor* (page 137).

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. You can assign a 'tag' to each snapshot which makes its identifica-



tion easier. For more information on QEMU monitor, see Chapter 14, *Administrating Virtual Machines with QEMU Monitor* (page 137).

Once your qcow2 disk image contains saved snapshots, you can inspect them with the `qemu-img snapshot` command.

---

## WARNING

Do not create or delete virtual machine snapshots with the `qemu-img snapshot` command while the virtual machine is running. Otherwise, you can damage the disk image with the state of the virtual machine saved.

---

### 12.2.3.1 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@venus:~> qemu-img snapshot -l /images/sles11sp1.qcow2
Snapshot list:
ID❶      TAG❷          VM SIZE❸      DATE❹          VM CLOCK❺
1        booting        4.4M 2010-11-22 10:51:10    00:00:20.476
2        booted         184M 2010-11-22 10:53:03    00:02:05.394
3        logged_in     273M 2010-11-22 11:00:25    00:04:34.843
4        ff_and_term_running 372M 2010-11-22 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.

### 12.2.3.2 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 which was previously powered off.

```
tux@venus:~> qemu-img snapshot -c backup_snapshot /images/sles11sp1.qcow2
tux@venus:~> qemu-img snapshot -l /images/sles11sp1.qcow2
```

```
Snapshot list:
ID      TAG              VM SIZE      DATE          VM CLOCK
1       booting            4.4M 2010-11-22 10:51:10    00:00:20.476
2       booted             184M 2010-11-22 10:53:03    00:02:05.394
3       logged_in          273M 2010-11-22 11:00:25    00:04:34.843
4       ff_and_term_running 372M 2010-11-22 11:12:27    00:08:44.965
5       backup_snapshot    0    2010-11-22 14:14:00    00:00:00.000
```

Once 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 do the following:

```
tux@venus:~> qemu-img snapshot -a 5 /images/sles11sp1.qcow2
```

Next time you run the virtual machine with `qemu-kvm`, 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 14, *Administrating Virtual Machines with QEMU Monitor* (page 137)). For example, you cannot apply a snapshot with `qemu-img snapshot -a` on a snapshot created with `savevm` in QEMU's monitor.

---

### 12.2.3.3 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@venus:~> qemu-img snapshot -d 2 /images/sles11sp1.qcow2
```

## 12.2.4 Manipulate Disk Images Effectively

Imagine the following real-life situation: you are a server administrator who runs and manages a number of virtualized operating systems. One group of these systems are 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. And 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 different setup and services than a Web server does, while both may still be based on SUSE® Linux Enterprise Server 11 SP1.

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.

### 12.2.4.1 Base and Derived Images

First, build a disk image as usual and install the target system on it. For more information, see Section 12.1, “Basic Installation with `qemu-kvm`” (page 96) and Section 12.2.2, “Creating, Converting and Checking Disk Images” (page 99). 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.

### 12.2.4.2 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/sles11sp1_base.raw` is the base image holding a freshly installed system.

```
tux@venus:~> qemu-img info /images/sles11sp1_base.raw
image: /images/sles11sp1_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/sles11sp1_base.raw` base image with:

```
tux@venus:~> qemu-img create -f qcow2 /images/sles11sp1_derived.qcow2 \
-o backing_file=/images/sles11sp1_base.raw
Formatting '/images/sles11sp1_derived.qcow2', fmt=qcow2 size=4294967296 \
backing_file='/images/sles11sp1_base.raw' encryption=off cluster_size=0
```

Look at the derived image details:

```
tux@venus:~> qemu-img info /images/sles11sp1_derived.qcow2
image: /images/sles11sp1_derived.qcow2
file format: qcow2
virtual size: 4.0G (4294967296 bytes)
disk size: 140K
cluster_size: 65536
backing file: /images/sles11sp1_base.raw \
(actual path: /images/sles11sp1_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@venus:~> qemu-img info /images/sles11sp1_derived.qcow2
image: /images/sles11sp1_derived.qcow2
file format: qcow2
virtual size: 4.0G (4294967296 bytes)
disk size: 1.1G
cluster_size: 65536
backing file: /images/sles11sp1_base.raw \
(actual path: /images/sles11sp1_base.raw)
```

The `disk size` value has grown to 1.1 GB, which is the disk space occupied by the changes on the filesystem compared to the base image.

### 12.2.4.3 Rebasing Derived Images

Once you modify the derived image (apply patches, install specific applications, or change the environment settings etc.) into a satisfactory shape, at some point you probably want to create a new base image 'merged' from the base image and the derived one. Your first base image (`/images/sles11sp1_base.raw`) holds a freshly installed system and 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 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@venus:~> qemu-img convert /images/sles11sp1_derived.qcow2 \
-O raw /images/sles11sp1_base2.raw
```

This command created the new base image `/images/sles11sp1_base2.raw` using the `raw` format.

```
tux@venus:~> qemu-img info /images/sles11sp1_base2.raw
image: /images/sles11sp1_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.

## 12.2.4.4 Mounting an Image on a VM Host Server

Sometimes it is useful to mount a virtual disk image under the host system. For example, if VM Host Server does not have a network support, this can be the only way to transfer files in and out of a VM Guest.

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 12.1*** *Mounting Disk Image by Calculating Partition Offset*

- 1 Set a *loop* device on the disk image whose partition you want to mount.

```
tux@venus:~> losetup /dev/loop0 /images/sles11sp1_base.raw
```

- 2 Find the *sector size* and the starting *sector number* of the partition you want to mount.

```
tux@venus:~> 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 bytes
Disk identifier: 0x000ceca8
```

Device	Boot	Start	End	Blocks	Id	System
/dev/loop0p1		63	1542239	771088+	82	Linux swap
/dev/loop0p2	*	1542240 <sup>❶</sup>	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@venus:~> losetup -d /dev/loop0
tux@venus:~> mount -o loop,offset=789626880 \
/images/sles11sp1_base.raw /mnt/sles11sp1/
tux@venus:~> ls -l /mnt/sles11sp1/
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@venus:~> cp /etc/X11/xorg.conf /mnt/sles11sp1/root/tmp
tux@venus:~> ls -l /mnt/sles11sp1/root/tmp
tux@venus:~> umount /mnt/sles11sp1/
```

## **Procedure 12.2** *Mounting Disk Image while Utilizing kpartx*

### 1 Set a *loop* device on the disk image whose partition you want to mount.

```
tux@venus:~> losetup /dev/loop0 /images/sles11sp1_base.raw
```

### 2 Create a device map from the disk image's partitions.

```
tux@venus:~> kpartx -a /dev/loop0
```

### 3 Mount any partition of the disk image on a prepared mount point.

```
tux@venus:~> mount /dev/mapper/loop0p1 /mnt/p1
```

You can replace `loop0p1` with the number of the partition you want to mount, for example `loop0p3` to mount the third partition on the disk image.

### 4 Copy or move files or directories to and from the mounted partition as you like. Once you finish, unmount the partition and delete the loop.

```
tux@venus:~> umount /mnt/p1  
tux@venus:~> losetup -d /dev/loop0
```

---

## **WARNING**

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.

---





# Running Virtual Machines with qemu-kvm

Once you have a virtual disk image ready (for more information on disk images, see Section 12.2, “Managing Disk Images with `qemu-img`” (page 97)), it is time to start the related virtual machine. Section 12.1, “Basic Installation with `qemu-kvm`” (page 96) introduced simple commands to install and run a VM Guest. This chapter focuses on a more detailed explanation of `qemu-kvm` usage, and shows solutions of more specific tasks. For a complete list of `qemu-kvm`'s options, see its manual page (`man 1 qemu-kvm`).

## 13.1 Basic qemu-kvm Invocation

The `qemu-kvm` command uses the following syntax:

```
qemu-kvm options❶ disk_img❷
```

- ❶ `qemu-kvm` understands a large number of 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-kvm` supports a large number of 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 have to use the `-drive file=` option.

## 13.2 General qemu-kvm Options

This section introduces general `qemu-kvm` options and options related to the basic emulated hardware, such as 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 also 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' stands 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-kvm [...] -boot order=ndc` first tries to boot from network, then from the first CD-ROM drive, and finally from the first hard disk.

`-pidfile fname`

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.

### 13.2.1 Basic Virtual Hardware

`-M machine_type`

Specifies the type of the emulated machine. Run `qemu-kvm -M ?` to view a list of supported machine types.

```
tux@venus:~> qemu-kvm -M ?
Supported machines are:
pc          Standard PC (alias of pc-0.12)
pc-0.12     Standard PC (default)
pc-0.11     Standard PC, qemu 0.11
pc-0.10     Standard PC, qemu 0.10
isapc       ISA-only PC
```

---

## NOTE

Currently, SUSE supports only `pc-0.12` and `pc-0.14` machine types.

---

`-m megabytes`

Specifies how many megabytes are used for the virtual RAM size. Default is 512 MB.

`-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`.

`-cpu cpu_model`

Specifies the type of the processor (CPU) model. Run `qemu-kvm -cpu ?` to view a list of supported CPU models.

```
tux@venus:~> qemu-kvm -cpu ?
x86          qemu64
x86          phenom
x86          core2duo
x86          kvm64
x86          qemu32
x86          coreduo
x86          486
x86          pentium
x86          pentium2
x86          pentium3
x86          athlon
x86          n270
```

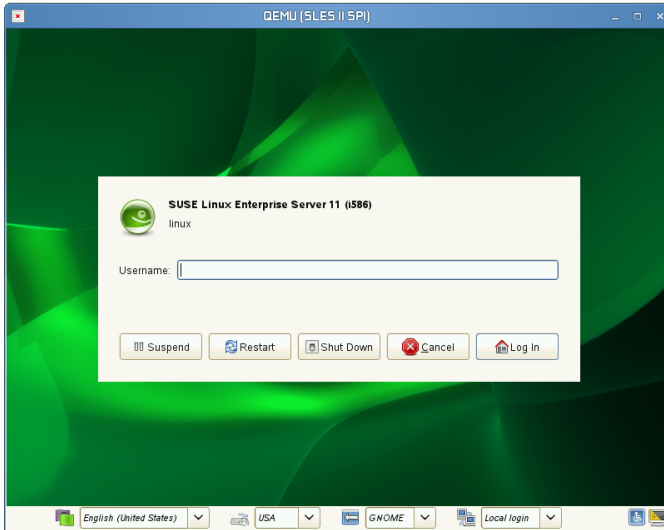
`-smp number_of_cpus`

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.

Following is an example of a working `qemu-kvm` command line:

```
qemu-kvm -name "SLES 11 SP1" -M pc-0.12 -m 512 -cpu kvm64 \
-smp 2 /images/sles11sp1.raw
```

**Figure 13.1** *QEMU Window with SLES 11 SP1 as VM Guest*



`-no-acpi`

Disables ACPI support. Try to use it if VM Guest reports problems with ACPI interface.

`-S`

QEMU starts with CPU stopped. To start CPU, enter `c` in QEMU monitor. For more information, see Chapter 14, *Administrating Virtual Machines with QEMU Monitor* (page 137).

## 13.2.2 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-kvm` can read it from a file which was either previously saved with `-writeconfig` or edited manually.

`-writeconfig cfg_file`

Dumps the current virtual machine devices configuration to a text file. It can be consequently re-used with the `-readconfig` option.

```
tux@venus:~> qemu-kvm -name "SLES 11 SP1" -M pc-0.12 -m 512 -cpu kvm64 \
-smp 2 /images/sles11sp1.raw -writeconfig /images/sles11sp1.cfg
(exited)
tux@venus:~> more /images/sles11sp1.cfg
# qemu config file

[drive]
  index = "0"
  media = "disk"
  file = "/images/sles11sp1_base.raw"
```

This way you can effectively manage the configuration of your virtual machines' devices in a well-arranged way.

## 13.2.3 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 a 'starting point' for VM Guest clock with the `base` option:

```
qemu-kvm [...] -rtc clock=vm,base=2010-12-03T01:02:00
```

Instead of a timestamp, 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.

## 13.3 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). For satisfactory operation and performance of the

virtual machine, some or all of these devices must be configured correctly. This section introduces options to configure various types of supported devices.

## 13.3.1 Block Devices

Block devices are vital for virtual machines. In general, these are fixed or removable storage media usually referred to as 'drives'. One of the connected hard drives typically holds the guest operating system to be virtualized.

Virtual machine drives are defined with `-drive`. This option uses many suboptions, some of which are described in this section. For their complete list, see the manual page (`man 1 qemu-kvm`).

### *Sub-options for the `-drive` Option*

`file=image_fname`

Specifies the path to the disk image which 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`, `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 the 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`, or `none`. For the `qcow2` image format, choose

`writeback` if you care about performance. `none` disables the host page cache and, therefore, is the safest option. Default is `writethrough`.

---

## TIP

To simplify defining of block devices, QEMU understands several shortcuts which you may find handy when entering the `qemu-kvm` command line.

You can use

```
qemu-kvm -cdrom /images/cdrom.iso
```

instead of

```
qemu-kvm -drive file=/images/cdrom.iso,index=2,media=cdrom
```

and

```
qemu-kvm -hda /images/image1.raw -hdb /images/image2.raw -hdc \
/images/image3.raw -hdd /images/image4.raw
```

instead of

```
qemu-kvm -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

Normally you will use disk images (see Section 12.2, “Managing Disk Images with `qemu-img`” (page 97)) as disk drives of the virtual machine. However, 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 filenames.

To access the host CD-ROM drive, use

```
qemu-kvm [...] -drive file=/dev/cdrom,media=cdrom
```

To access the host hard disk, use

```
qemu-kvm [...] -drive file=/dev/hdb,media=disk
```

When accessing the host hard drive from VM Guest, always make sure the access is *read-only*. You can do so by modifying the host device permissions.

---

## 13.3.2 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.

### 13.3.2.1 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 QEMU monitor and 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.

---

### 13.3.2.2 Display Options

The following options affect the way VM Guest graphical output is displayed.

`-nographic`

Disables QEMU's graphical output. The emulated serial port is redirected to the console.

After starting the virtual machine with `-nographic`, press `+ 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@venus:~> qemu-kvm -hda /images/sles11sp1_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 0.12.5 monitor - type 'help' for more information
(qemu)
```

**-no-frame**

Disables decorations for the QEMU window. Convenient for dedicated desktop workspace.

**-full-screen**

Starts QEMU graphical output in full screen mode.

**-no-quit**

Disables the 'close' button of QEMU window and prevents it from being closed by force.

**-alt-grab, -ctrl-grab**

By default QEMU window releases the 'captured' mouse after Ctrl + Alt is pressed. You can change the key combination to either Ctrl + Alt + Shift (**-alt-grab**), or Right Ctrl (**-ctrl-grab**).

## 13.3.3 USB Devices

There are basically 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.

### 13.3.3.1 Emulating USB Devices in VM Guest

Although QEMU supports much more types of USB devices, SUSE currently only supports the types `mouse` and `tablet`.

## *Types of USB devices for the `-usbdevice` Option*

### `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-kvm [...] -usbdevice mouse`:

```
tux@venus:~> 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 13.5, “Viewing a VM Guest with VNC” (page 130) for more information.

## 13.3.3.2 USB Pass-Through

To assign an existing host USB device to a VM Guest, you need to find out its host bus and device ID.

```
tux@vmhost:~> lsusb
[...]
Bus 002 Device 005: ID 12d1:1406 Huawei Technologies Co., Ltd. E1750
[...]
```

In the above example, we want to assign a USB stick connected to the host's USB bus number 2 with device number 5. Now run the VM Guest with the following additional options:

```
qemu-kvm [...] -usb -device usb-host,hostbus=2,hostaddr=5
```

After the guest is booted, check that the assigned USB device is present on it.

```
tux@vmguest:~> lsusb
[...]
Bus 001 Device 002: ID 12d1:1406 Huawei Technologies Co., Ltd. E1750
[...]
```

---

## NOTE

The guest operating system must take care of mounting the assigned USB device so that it is accessible for the user.

---

## 13.3.4 PCI Pass-Through

PCI Pass-Through is a technique to give your VM Guest exclusive access to a PCI device.

---

## NOTE

To make use of PCI Pass-Through, your motherboard chipset, BIOS, and CPU must have support for AMD's IOMMU (or VT-d in Intel speak) virtualization technology. To make sure that your computer supports this feature, ask your supplier specifically to deliver a system that supports PCI Pass-Through.

---

---

## NOTE

Assignment of graphics cards is not supported by SUSE.

---

### ***Procedure 13.1*** *Configuring PCI Pass-Through*

- 1 Make sure that `CONFIG_DMAR_DEFAULT_ON` is set in the host's running Kernel:

```
grep CONFIG_DMAR_DEFAULT_ON /boot/config-`uname -r`
```

If this option is not set, edit your boot loader configuration and add `intel_iommu=on` (Intel machines) or `iommu=pt iommu=1` (AMD machines). Then reboot the host machine.

- 2 Check that IOMMU is actively enabled and recognized on the host. Run `dmesg | grep -e DMAR -e IOMMU` on Intel machines, or `dmesg | grep AMD-Vi` on AMD machines. If you get no output, check carefully if your hardware supports IOMMU (VT-d) and check that it has been enabled in BIOS.
- 3 Identify the host PCI device to assign to the guest.

```
tux@vmhost:~> lspci -nn
[... ] 00:1b.0 Audio device [0403]: Intel Corporation 82801H (ICH8 Family)
\
```

```
HD Audio Controller [8086:284b] (rev 02) [...]
```

Note down the device (00:1b.0) and vendor (8086:284b) ID.

#### 4 Unbind the device from host Kernel driver and bind it to the PCI stub driver.

```
tux@vmhost:~> modprobe pci_stub
tux@vmhost:~> echo "8086 284b" > /sys/bus/pci/drivers/pci-stub/new_id
tux@vmhost:~> echo "0000:00:1b.0" > /sys/bus/pci/devices/0000:00:1b.0/
driver/unbind
tux@vmhost:~> echo "0000:00:1b.0" > /sys/bus/pci/drivers/pci-stub/bind
```

#### 5 Now run the VM Guest with the PCI device assigned.

```
qemu-kvm [...] -device pci-assign,host=00:1b.0
```

---

### NOTE

If the PCI device shares IRQ with other devices, it cannot be assigned to a VM Guest.

---

KVM also supports PCI device hotplugging to a VM Guest. To achieve this, you need to switch to a QEMU monitor (see Chapter 14, *Administrating Virtual Machines with QEMU Monitor* (page 137) for more information) and issue the following commands:

- hot add:

```
device_add pci-assign,host=00:1b.0,id=new_pci_device
```

- hot remove:

```
device_del new_pci_device
```

## 13.3.5 Character Devices

Use `-chardev` to create a new character device. The option uses the following general syntax:

```
qemu-kvm [...] -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 backend's suboptions, see the manual page (man 1 qemu-kvm). A brief description of the available backends follows:

`null`

Creates an empty device which 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-kvm [...] -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-kvm [...] -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-kvm [...] -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-kvm [...] -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-kvm [...] -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. You can, however, create your own character devices and use them for just 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 suboptions. See the manual page `man 1 qemu-kvm` for their complete list.

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.

## 13.4 Networking in QEMU

Use the `-net` option to define a network interface and a specific type of networking for your VM Guest. Currently, SUSE supports the following options: *none*, *nic*, *user*, and *tap*. For a complete list of `-net` suboptions, see the manual page (`man 1 qemu-kvm`).

### *Supported -net Suboptions*

*none*

Disables a network card emulation on VM Guest. Only the loopback `lo` network interface is available.

`nic`

Creates a new Network Interface Card (NIC) and connects it to a specified Virtual Local Area Network (VLAN). For more information, see Section 13.4.1, “Defining a Network Interface Card” (page 125)

`user`

Specifies a user-mode networking. For more information, see Section 13.4.2, “User-mode Networking” (page 125).

`tap`

Specifies a bridged or routed networking. For more information, see Section 13.4.3, “Bridged Networking” (page 127).

## 13.4.1 Defining a Network Interface Card

Use `-net nic` to add a new emulated network card:

```
qemu-kvm [...] -net nic,vlan=1❶,macaddr=00:16:35:AF:94:4B❷,\  
model=virtio❸,name=ncard1❹
```

- ❶ 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.
- ❷ 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.
- ❸ Specifies the model of the network card. Use `-net nic,model=?` to get the list of all network card models supported by QEMU on your platform:

Currently, SUSE supports the models `rtl8139` and `virtio`.

## 13.4.2 User-mode Networking

The `-net user` option instructs QEMU to use a user-mode networking. This is the default if no networking mode is selected. Therefore, these command lines are equivalent:

```
qemu-kvm -hda /images/sles11sp1_base.raw
```

```
qemu-kvm -hda /images/sles11spi_base.raw -net nic -net user
```

This mode is useful if you want to allow the VM Guest to access the external network resources, such as 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 to do a 'network-booting' 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.

## 13.4.2.1 Command Line Examples

This section shows several examples on how to set up user-mode networking with QEMU.

### **Example 13.1** *Restricted User-mode Networking*

```
qemu-kvm [...] -net user❶,vlan=1❷,name=user_net1❸,restrict=yes❹
```

- ❶ Specifies user-mode networking.
- ❷ Connect 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 will not be able to communicate with VM Host Server and no network packets will be routed to the external network.

### **Example 13.2** *User-mode Networking with Custom IP Range*

```
qemu-kvm [...] -net  
user,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 hostname that the built-in DHCP server will assign to VM Guest.



### **Example 13.3** *User-mode Networking with Network-boot and TFTP*

```
qemu-kvm [...] -net user,tftp=/images/tftp_dir❶,bootfile=/images/boot/pxelinux.0❷
```

- ❶ 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.
- ❷ Broadcasts the specified file as a BOOTP (a network protocol which 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 13.4** *User-mode Networking with Host Port Forwarding*

```
qemu-kvm [...] -net user,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 hostname or IP address of the host system, to get a SSH prompt from VM Guest.

## **13.4.3 Bridged Networking**

With the `-net 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 has 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 *Network Devices > Network Settings*.
- 2 Click *Add* and select *Bridge* from the *Device Type* drop-down list 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.

**Figure 13.2** *Configuring Network Bridge with YaST*

The screenshot shows the 'Network Card Setup' window in YaST, with the 'Address' tab selected. The 'Device Type' is set to 'Bridge' and the 'Configuration Name' is 'br0'. Under 'Dynamic Address', 'DHCP' is selected, and 'DHCP both version 4 and 6' is also selected. The 'Statically assigned IP Address' option is unselected. The 'IP Address', 'Subnet Mask', and 'Hostname' fields are empty. In the 'Bridged Devices' section, 'eth0 - N10/ICH 7 Family LAN Controller (configuration)' is checked. At the bottom are 'Help', 'Cancel', 'Back', and 'Next' buttons.

Click *Next*. When asked about adapting an already configured device, click *Continue*.

- 5 Click *OK* to apply the changes. Check if the bridge is created:

```
tux@venus:~> brctl show
bridge name bridge id        STP enabled  interfaces
br0          8000.001676d670e4  no          eth0
```

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

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=br0❶
```

```

tap=$(sudo tuncctl -u $(whoami) -b)❷
sudo ip link set $tap up❸
sleep 1s❹
sudo brctl addif $bridge $tap❺
qemu-kvm -m 512 -hda /images/sles11sp1_base.raw \
-net nic,vlan=0,model=virtio,macaddr=00:16:35:AF:94:4B \
-net tap,vlan=0,ifname=$tap❻,script=no❼,downscript=no
sudo brctl delif $bridge $tap❽
sudo ip link set $tap down❾
sudo tuncctl -d $tap❿

```

- 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-kvm` connects to a network bridge, it checks the `script` and `downscript` values. If it finds the specified scripts on the VM Host Server filesystem, 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 deconfigure them. By default, `/etc/qemu-ifup` and `/etc/qemu-ifdown` are examined. If `script=no` and `downscript=no` are specified, the script execution is disabled and you have to take care manually.
- ❽ Deletes the TAP interface from a network bridge `br0`.
- ❾ Sets the state of the TAP device to 'down'.
- ❿ Deconfigures the TAP device.

## 13.4.4 Accelerated Networking with `vhost-net`

The `vhost-net` module is used to accelerate KVM's paravirtualized network drivers. It provides better latency and greater throughput for network.

To make use of the module, verify that the host's running Kernel has `CONFIG_VHOST_NET` turned on or enabled as a module:

```
grep CONFIG_VHOST_NET /boot/config-`uname -r`
```

Also verify that the guest's running Kernel has CONFIG\_PCI\_MSI enabled:

```
grep CONFIG_PCI_MSI /boot/config-`uname -r`
```

If both conditions are met, use the `vhost-net` driver by starting the guest with the following example command line:

```
qemu-kvm [...] -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.

## 13.5 Viewing a VM Guest with VNC

QEMU normally uses an SDL (a cross-platform multimedia 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`

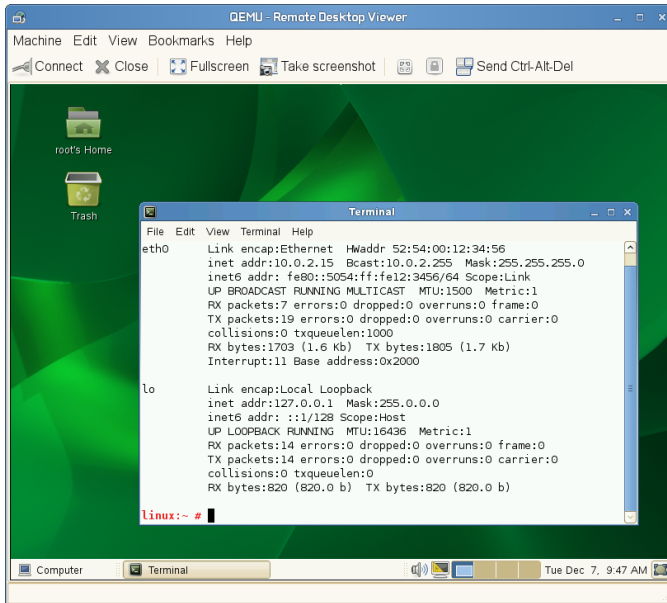
The VNC server listens for connections on Unix domain sockets. The `path` option specifies the location of the related Unix socket.

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 14, *Administrating Virtual Machines with QEMU Monitor* (page 137).

```
tux@venus:~> qemu-kvm [...] -vnc :5
(on the client:)
wilber@jupiter:~> vinagre venus:5905 &
```

**Figure 13.3** *QEMU VNC Session*



## 13.5.1 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 which 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 of these authentication methods in one QEMU command.

See Section A.2, “Generating x509 Client/Server Certificates” (page 152) 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 7.2.2, “Remote TLS/SSL Connection with x509 Certificate (`qemu+tls`)” (page 53) and Section 7.2.2.3, “Configuring the Client and Testing the Setup” (page 55).

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 13.5** *Password Authentication*

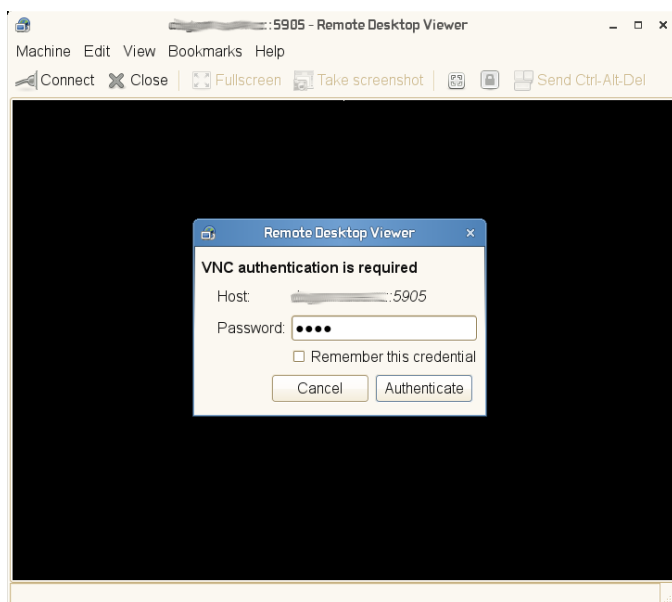
```
qemu-kvm [...] -vnc :5,password -monitor stdio
```

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 have to set one with the `change vnc password` command in QEMU monitor:

```
QEMU 0.12.5 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 13.4** *Authentication Dialog in Vinagre*



**Example 13.6** *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-kvm [...] -vnc :5,tls,x509verify=/etc/pki/qemu
```

**Example 13.7** *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-kvm [...] -vnc :5,password,tls,x509verify=/etc/pki/qemu -monitor stdio
```

**Example 13.8** *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-kvm [...] -vnc :5,tls,x509,sasl -monitor stdio
```

## 13.6 VirtFS: Sharing Folders between Host and Guests

VM Guests usually run in a separate computing space — they are provided their own memory range, dedicated CPUs, and filesystem space. Ability to share parts of VM Host Server's filesystem makes the virtualization environment more flexible by simplifying mutual data exchange. Network filesystems, such as CIFS and NFS, have been the traditional way of sharing folders. But as they are not specifically designed for virtualization purposes, they suffer from major performance and feature issues.

KVM introduces a new and more optimized tool called *VirtFS* (sometimes referred to as a “filesystem pass-through”). VirtFS uses a paravirtual filesystem driver, which avoids converting the guest application filesystem operations into block device operations, and then again into host filesystem operations. VirtFS uses Plan-9 network protocol for communication between the guest and the host.

You can typically use VirtFS to

- access a shared folder from several guests, or to provide guest-to-guest filesystem access.
- replace the virtual disk as the root filesystem to which the guest's ramdisk connects to during the guest boot process
- provide storage services to different customers from a single host filesystem in a cloud environment

### 13.6.1 Implementation

In QEMU, the implementation of VirtFS is facilitated 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 filesystem properties, such as filesystem type and security model.

### **Example 13.9** *Exporting Host's Filesystem with VirtFS*

```
qemu-kvm [...] -fsdev local,id=exp1❶,path=/tmp/❷,security_model=mapped❸
-device virtio-9p-pci,fsdev=exp1❹,mount_tag=v_tmp❺
```

- ❶ Identification of the filesystem to be exported.
- ❷ Filesystem path on the host to be exported.
- ❸ Security model to be used — `mapped` keeps the guest filesystem 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 filesystem ID defined before with `-fsdev id=.`
- ❺ Mount tag used later on the guest to mount the exported filesystem.

Such an exported filesystem can be mounted on the guest like this

```
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 filesystem.

## **13.7 KSM: Sharing Memory Pages between Guests**

Kernel SamePage Merging (KSM) is a Linux Kernel feature which 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 is the best solution for you.

To make use of KSM, do the following.

- 1 Verify that KSM is enabled in your running Kernel:

```
grep KSM /boot/config-`uname -r`
CONFIG_KSM=y
```

If KSM is enabled in the running Kernel, you will see the following files under the `/sys/kernel/mm/ksm` directory:

```
ls -l /sys/kernel/mm/ksm
total 0
drwxr-xr-x 2 root root    0 Nov  9 07:10 ./
drwxr-xr-x 6 root root    0 Nov  9 07:10 ../
-r--r--r-- 1 root root 4096 Nov  9 07:10 full_scans
-r--r--r-- 1 root root 4096 Nov  9 07:10 pages_shared
-r--r--r-- 1 root root 4096 Nov  9 07:10 pages_sharing
-rw-r--r-- 1 root root 4096 Nov  9 07:10 pages_to_scan
-r--r--r-- 1 root root 4096 Nov  9 07:10 pages_unshared
-r--r--r-- 1 root root 4096 Nov  9 07:10 pages_volatile
-rw-r--r-- 1 root root 4096 Nov  9 07:10 run
-rw-r--r-- 1 root root 4096 Nov  9 07:10 sleep_millisecs
```

## 2 Check if KSM feature is turned on.

```
cat /sys/kernel/mm/ksm/run
```

If the command returns 0, turn KSM on with

```
echo 1 > /sys/kernel/mm/ksm/run
```

## 3 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
```

For more information on the meaning of the `/sys/kernel/mm/ksm/*` files, see `/usr/src/linux/Documentation/vm/ksm.txt` (package `kernel-source`).

# Administrating Virtual Machines with QEMU Monitor

# 14

When QEMU is running, 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 several other aspects of the virtual machine.

## 14.1 Accessing Monitor Console

To access the monitor console from QEMU, press `Ctrl + Alt + 2`. To return back to QEMU from the monitor console, press `Ctrl + Alt + 1`.

To get help while using the console, use `help` or `?`. To get help for a specific command, use `help command`.

## 14.2 Getting Information about the Guest System

To get information about the guest system, use the `info option` command. 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 drives, 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 interrupts 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 is 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
```

## 14.3 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)
```

## 14.4 Managing Devices

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
```

## 14.5 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 Tab.

To control the mouse, the following commands can be used:

```
mouse_move dxdy [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.

## 14.6 Changing Available Memory

If the virtual machine was started with the `-balloon virtio` option and the paravirtualized balloon device that allows to dynamically change the amount of memory available is therefore enabled, it is possible to change the available memory dynamically. For more information about enabling the balloon device, see Section 12.1, “Basic Installation with `qemu-kvm`” (page 96).

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
```

# 14.7 Dumping Virtual Machine Memory

To save the content of the virtual machine memory to a disk or console output, use the following commands:

`memsave addrsizefilename`

Saves virtual memory dump starting at *addr* of size *size* to file *filename*

`pmemsave addrsizefilename`

Saves physical memory dump starting at *addr* of size *size* to file *filename*

`x/fmtaddr`

Makes a virtual memory dump starting at address *addr* and formatted according to the *fmt* string. The *fmt* string consists of three parameters *count**format**size*:

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. is the number of the items to be dumped.

`xp/fmtaddr`

Makes a physical memory dump starting at address *addr* and formatted according to the *fmt* string. The *fmt* string consists of three parameters *count**format**size*:

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. is the number of the items to be dumped.



# 14.8 Managing Virtual Machine Snapshots

---

## WARNING

Managing snapshots in QEMU monitor is not officially supported by SUSE yet. However, 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 configured network services on a virtualized server and want to quickly start the virtual machine in the same state that has been 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 12.2.3, “Managing Snapshots of Virtual Machines with `qemu-img`” (page 102).

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:
```

```
ID❶
```

```
TAG❷
```

```
VM SIZE❸
```

```
DATE❹
```

```
VM CLOCK❺
```

1	booting	4.4M	2010-11-22	10:51:10	00:00:20.476
2	booted	184M	2010-11-22	10:53:03	00:02:05.394
3	logged_in	273M	2010-11-22	11:00:25	00:04:34.843
4	ff_and_term_running	372M	2010-11-22	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.

## 14.9 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_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.

## 14.10 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 just during a maintenance. 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.

The requirements for the live migration:

- The virtual machine image must be accessible on both source and destination hosts. For example, it can be located on a shared NFS disk.
- The image directory should be located in the same path on both hosts.
- Both hosts must be located in the same subnet.
- The guest on the source and destination hosts must be started in the same way.

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.



# A

## Appendix

### A.1 Installing Para-Virtualized Drivers

#### A.1.1 Installing virtio Drivers for Microsoft Windows\*

Providing para-virtualized drivers during a Microsoft Windows installation does currently not work, since the installation refuses to boot from a para-virtualized hard disk. Therefore, the para-virtualized drivers need to be installed on a running Windows installation.

The following instructions assume that the existing Windows installation uses a single IDE hard disk and a single network adapter. An ISO image containing the virtio drivers for Windows is part of the `kvm` package and is available on the KVM host under `/usr/share/qemu-kvm/win-virtio-drivers.iso`. Make this ISO image available as a CD-ROM on your virtual machine as described in Section 9.4, “Ejecting and Changing Floppy or CD/DVD-ROM Media with Virtual Machine Manager” (page 82). In case your virtual machine is configured without a CD-ROM device or you prefer to add a second one, see Section 9.2, “Adding a CD/DVD-ROM Device with Virtual Machine Manager” (page 80) for setup instructions.

## ***Finding the virtio drivers for Windows***

### **Windows XP 32-bit**

*Memory Ballooning:* balloon\install\XP\x86\balloon.inf  
*Network:* NetKVM\install\XP\_Win2003\x86\netkvm.inf  
*Storage:* viostor\install\XP\x86\viostor.inf

### **Windows XP 64-bit**

*Memory Ballooning:* not available  
*Network:* NetKVM\install\XP\_Win2003\amd64\netkvm.inf  
*Storage:* viostor\install\XP\amd64\viostor.inf

### **Windows Server 2003 32-bit**

*Memory Ballooning:* balloon\install\Win2003\x86\balloon.inf  
*Network:* NetKVM\install\XP\_Win2003\x86\netkvm.inf  
*Storage:* viostor\install\Win2003\x86\viostor.inf

### **Windows Server 2003 64-bit**

*Memory Ballooning:* balloon\install\Win2003\amd64\balloon.inf  
*Network:* NetKVM\install\XP\_Win2003\amd64\netkvm.inf  
*Storage:* viostor\install\XP\amd64\viostor.inf

### **Windows Vista/Server 2008 32-bit**

*Memory Ballooning:* balloon\install\Vista\_Win2008\x86\balloon.inf  
*Network:* NetKVM\install\Vista\_Win2008\x86\netkvm.inf  
*Storage:* viostor\install\Vista\_Win2008\x86\viostor.inf

### **Windows Vista/Server 2008 64-bit**

*Memory Ballooning:* balloon\install\Vista\_Win2008\amd64\balloon.inf  
*Network:* NetKVM\install\Vista\_Win2008\amd64\netkvm.inf  
*Storage:* viostor\install\Vista\_Win2008\amd64\viostor.inf

## Windows 7 32-bit

*Memory Ballooning:* balloon\install\Win7\x86\balloon.inf

*Network:* NetKVM\install\Win7\x86\netkvm.inf

*Storage:* viostor\install\Win7\x86\viostor.inf

## Windows 7 64-bit

*Memory Ballooning:* balloon\install\Win7\amd64\balloon.inf

*Network:* NetKVM\install\Win7\amd64\netkvm.inf

*Storage:* viostor\install\Win7\amd64\viostor.inf

### A.1.1.1 Windows 7

The following instructions show how to install para-virtualized storage and network drivers for Windows 7. Please make sure to *exactly* follow the instructions for installing the storage drivers, otherwise your system will either completely refuse to boot or will boot into a “blue screen”!

---

#### IMPORTANT: Technical Support

The following instructions require to use `virsh edit`. Using this command in principle is not supported by the SUSE Technical Support. However, this special context (Installing Para-Virtualized Storage Drivers for Windows) is an exception from this rule. It will be supported with reasonable effort.

---

#### **Procedure A.1** *Installing Para-Virtualized Storage Drivers for Windows 7 32-bit*

- 1 Shut down the Windows 7 VM Guest and use Virtual Machine Manager to add an additional hard disk of type `virtio` (a para-virtualized hard disk). This disk is only temporarily needed and will be removed again from the VM Guest.
- 2 If necessary, use Virtual Machine Manager to adjust the *Boot Device Order*. It *must* start with *Hard Disk*, otherwise the system will not boot once the system disk is para-virtualized. You need to confirm your changes with *Apply*, otherwise they will not be written to the configuration.
- 3 Reboot the VM Guest. Once it has booted, open the *Device Manager*, for example, by opening the main menu and entering `devmgmt.msc` followed by *into the Start programs and files* field.

- 4 Search for the entry *Other devices > SCSI Controller*. The entry is marked with an exclamation mark as being problematic. Right-click this entry and choose *Update Driver Software*.
- 5 Install the driver. Choose to *Browse my computer for driver software*. Use the *Browse* button to select the directory on the driver CD containing the storage drivers for your operating system and architecture (`viostor\install\Win7\x86\`). Confirm the security exception by clicking *Install*.
- 6 Once the driver installation is finished, a new *Storage Controller* named *Novell VirtIO SCSI Adapter* is listed in the *Device Manager*. Additionally, the entry *Disk Drives* now contains the temporary para-virtualized disk. It is listed as *Novell VirtIO SCSI Disk Device*.
- 7 Shut down the Windows 7 VM Guest and use Virtual Machine Manager to remove the temporary para-virtualized disk added earlier.
- 8 Changing the type of a virtual hard disk is currently not supported by Virtual Machine Manager—therefore the XML configuration needs to be changed directly. Open a terminal and enter the following command (replace *NAME* with the name of your Windows 7 VM Guest). If operating from a remote host, also specify a connection URL with the `-c` parameter.

```
virsh edit NAME
```

An editor (`vi` by default) opens. Search for a block similar to the following:

```
<disk type='block' device='disk'>
  <driver name='qemu' type='raw'/>
  <source file='/var/lib/libvirt/images/win7.raw'/>
  <target dev='hda' bus='ide'/>
  <address type='drive' controller='0' bus='0' unit='0'/>
</disk>
```

Remove the `<address>` tag. Change the attributes of the `<target>` tag to `dev='vda'` and `bus='virtio'`:

```
<disk type='block' device='disk'>
  <driver name='qemu' type='raw'/>
  <source dev='/dev/Virtual/win7'/>
  <target dev='vda' bus='virtio'/>
</disk>
```

Save the file. A successful save results in Domain *NAME* XML configuration edited. In case an error is reported (for example, when having produced invalid XML), the configuration has not been changed.



- 9 Restart the VM Guest. If starting it via Virtual Machine Manager, make sure the hardware change is visible in the *Details* screen before you start (this may take a few seconds after you have saved the configuration changes from `virsh`). Otherwise your changes will be overwritten with the configuration last used by Virtual Machine Manager.

Your Windows 7 VM Guest now uses a para-virtualized system disk.

Installing para-virtualized network drivers is very similar to installing the storage drivers:

### **Procedure A.2** *Installing Para-Virtualized Network Drivers for Windows 7*

- 1 Shut down the Windows 7 VM Guest and use Virtual Machine Manager to add an additional network adapter of type `virtio` (a para-virtualized network adapter). This ensures that you still have network connectivity while installing the drivers.
- 2 Reboot the VM Guest and install the driver via the *Device Manager* as described above. The new network adapter can be found under *Other devices > Ethernet controller*. After a successful driver installation, a *Novell VirtIO Ethernet Adapter* is listed in the *Device Manager* under *Network Adapters*.
- 3 Shut down the VM Guest and remove the original, non-para-virtualized network adapter from the guest configuration using Virtual Machine Manager. Reboot the guest—now it uses a para-virtualized network adapter.

## **A.1.1.2 Other Windows Versions (XP, Server 2003/2008, Vista)**

Installing para-virtualized drivers for other Windows versions is very similar to installing them on Windows 7 (see Section A.1.1.1, “Windows 7” (page 149)). You do not need to manually start the *Device Manager*—Windows will rather prompt you to install the missing drivers. Make sure to manually choose the location of the driver during the installation process.

---

### **WARNING: Para-Virtualized Storage Drivers on Windows Vista**

Currently the para-virtualized storage drivers for Windows Vista do not support booting from a para-virtualized disk. Using para-virtualized storage devices for non-bootable disks is supported.

---

---

**NOTE: Para-Virtualized Storage Drivers on Windows XP not Recommended**

Using the para-virtualized storage drivers on Windows XP does not result in any performance gain—it may even result in performance penalties. Therefore, it is *not* recommended to use them. See <http://www.mail-archive.com/kvm@vger.kernel.org/msg22834.html> for technical details.

Note that this only affects para-virtualized *storage* drivers for Windows XP! Using para-virtualized storage drivers on other Windows versions will result in better performance. Using para-virtualized network drivers on Windows XP is also beneficial.

---

## A.2 Generating x509 Client/Server Certificates

In order 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 Section “Creating a Root CA” (Chapter 15, *Managing X.509 Certification*, ↑Security Guide).
- 2 Create a server and a client certificate as described in Section “Creating or Revoking User Certificates” (Chapter 15, *Managing X.509 Certification*, ↑Security Guide). The Common Name (CN) for the server certificate must be the full qualified hostname, 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:

**2a** Select the certificate on the *certificates* tab.

**2b** Choose *Export > Export to File > Certificate and the Key Unencrypted in PEM Format*, provide the *Certificate Password* and the full path and the

filename under *File Name*, for example, /tmp/x509/server.pem or /tmp/x509/client.pem.

- 2c** 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
```

- 2d** Repeat the procedure for each client and server certificate you would like to export.

- 3** Finally export the CA certificate by performing the following steps:

- 3a** Switch to the *Description* tab.

- 3b** Choose *Advanced > Export to File > Only the Certificate in PEM Format* and enter the full path and the filename under *File Name*, for example, /tmp/x509/cacert.pem.

## A.3 QEMU Command Line Options

### A.3.1 Supported qemu-kvm Command Line Options

```
-alt-grab
-append ...
-audio-help
-balloon ...
-boot ...
-cdrom ...
-chardev ..
-clock
-cpu [?|qemu64 ]
-ctrl-grab
-d ...
```

```
-daemonize
-debugcon ...
-device driver [isa-serial|isa-parallel|isa-fdc|ide-drive|
 ide-hd|ide-cd|pci-assign|VGA|cirrus-vga|rtl8139| virtio-net-pci|virtio-blk-pci|virtio-balloon-pci|virtio-9p-pci|
 usb-tablet|usb-storage|usb-mouse|usb-kbd|virtserial| virtconsole|virt-serial-pci|<all_the_supported_nics>|
 rtl8139| i82559er]
-display ...
-drive if=[ide|floppy|virtio] format=[raw|qcow2|qed]
snapshot=off ...
-echr ...
-enable-kvm
-fda/-fdb ...
-full-screen
-gdb ...
-global ...
-h
-hda/-hdb/-hdc/-hdd ...
-help
-incoming ...
-initrd ...
-k ...
-kernel ...
-loadvm ...
-m ...
-mem-path ...
-mem-prealloc
-mon ...
-monitor ...
-M [pc|pc-0.12|pc-0.14]
-name ...
-netdev ...
-net [nic|user|tap|none] mode=[rtl8139|virtio]
-no-acpi
-nodefualts
-nodefconfig
-no-frame
-nographic
-no-hpet
```

```
-no-quit  
-no-reboot  
-no-shutdown  
-parallel ...  
-pidfile ...  
-readconfig ...  
-rtc ...  
-runas ...  
-s  
-S  
-sdl  
-serial ...  
-smbios ...  
-smp ...  
-tdf  
-usb  
-usbdevice [tablet|mouse]  
-uuid ..  
-version  
-vga [std|cirrus|none]  
-vnc ...  
-watchdog ...  
-watchdog-action ...  
-writeconfig ...
```

---

### **NOTE: Deprecated Options**

The option `-pcidevice` no longer exists. Use `-device pci_assign` instead.

---

## **A.3.2 Unsupported qemu-kvm Command Line Options**

The following `qemu-kvm` command line options are *not* supported by SUSE:

```
-acpitable ...  
-bios ...  
-bt ...
```

```

-chroot ...
-cpu [phenom|core2duo|qemu32|kvm64|coreduo|486|pentium|
pentium2|pentium3|athlon|n270]
-curses
-device driver [ivshmem|smbus-EEPROM|scsi-disk| sc-
si-cd|scsi-hd|scsi-generic|usb-hub|usb-wacom-tablet|usb-
braille| usb-serial|usb-net|usb-bt-dongle|ioh3240|x3130-
upstream| xio3130-downstream|ich9-usb-uhci1|ich9-usb-uh-
ci2|ich9-usb-uhci3| vt82c686b-usb-uhci|piix3-usb-uhci|pi-
ix4-usb-uhci|sysbus-ohci|pci-ohci| ich9-usb-ehci1|usb-
ehci|SUNW|sysbus-fdc|isa-applesmc|usb-ccid| ccid-card-
passthru|i6300esb|ne2k_pci|i82801|i825*|pcnet|ne2k_isa|
ich9-ahci| lsi53c895a|isa-vga|vmware-svga|sb16|AC97|gus|
cs4231a|intel-hda| hda-duplex|hda-output|ib700|isa-debug-
con|testdev]
-drive if=[scsi|mtd|pflash], snapshot=on,
format=[anything besides from raw, qcow2, qed]
-enable-nesting
-g ...
-icount ...
-kvm-shadow-memory ...
-L ...
-M [pc-0.13|pc-0.11|pc-0.10|isapc]
-mtddblock ...
-net dump ...
-net socket ...
-no-fd-bootchk
-no-kvm
-no-kvm-irqchip
-no-kvm-pit
-no-kvm-pit-reinjection
-numa ...
-nvram ...
-old-param
-option-rom ...
-pflash ...
-portrait
-prom-env ...
-qmp ...
-rotate

```

```
-sd ...
-semihosting ...
-set ...
-show-cursor
-singlestep
-snapshot
-soundhw ...
-spice ...
-tb-size ...
-usbdevice [disk|host|serial|braille|net]
-vga [vmware|qxl|xenfb]
-virtioconsole ...
-win2k-hack
```

---

**NOTE: Deprecated options**

The options `-M mac` and `-osk` no longer exist.

---

## A.3.3 Supported qemu-kvm monitor Command Line Options

The following `qemu-kvm monitor` command line options are supported by SUSE:

```
?
balloon target ...
[c|cont]
change device ...
cpu ...
eject ...
gdbserver ...
help
info ...
logfile ...
logitem ...
mce ...
memsave ...
migrate ...
```

```
migrate_set_downtime ...
migrate_set_speed ...
mouse_button ...
mouse_move ...
mouse_set ...
pmemsave ...
[p|print] ...
q
sendkey ...
stop
system_powerdown
watchdog_action ...
x ...
xp ...
```

## A.3.4 Unsupported qemu-kvm monitor Command Line Options

The following `qemu-kvm monitor` command line options are *not* supported by SUSE:

```
acl_add ...
acl_policy ...
acl_remove ...
acl_reset ...
acl_show ...
block_passwd ...
block_resize ...
boot_set
close_fd ...
client_migrate_info ...
commit ...
cpu_set ...
delvm ...
device_add ...
device_del ...
drive_add ...
drive_del ...
```



expire\_password ...  
hostfwd\_add ...  
hostfwd\_remove ...  
host\_net\_add ...  
host\_net\_remove ...  
i ...  
loadvm ...  
migrate\_cancel  
netdev\_add ...  
netdev\_del ...  
nmi ...  
o ...  
pci\_add ...  
pci\_aer\_inject\_error ...  
pci\_del...  
savevm ...  
screendump ...  
set\_link ...  
set\_password ...  
singlestep ...  
snapshot\_blkdev ...  
stopcapture ...  
sum ...  
system\_reset  
usb\_add ...  
watchdog\_action ...  
wavcapture ...





# GNU Licenses

This appendix contains the GNU General Public License version 2 and the GNU Free Documentation License version 1.2.

## GNU General Public License

Version 2, June 1991

Copyright (C) 1989, 1991 Free Software Foundation, Inc. 59 Temple Place - Suite 330, Boston, MA 02111-1307, USA

Everyone is permitted to copy and distribute verbatim copies of this license document, but changing it is not allowed.

### Preamble

The licenses for most software are designed to take away your freedom to share and change it. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change free software--to make sure the software is free for all its users. This General Public License applies to most of the Free Software Foundation's software and to any other program whose authors commit to using it. (Some other Free Software Foundation software is covered by the GNU Library General Public License instead.) You can apply it to your programs, too.

When we speak of free software, we are referring to freedom, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for this service if you wish), that you receive source code or can get it if you want it, that you can change the software or use pieces of it in new free programs; and that you know you can do these things.

To protect your rights, we need to make restrictions that forbid anyone to deny you these rights or to ask you to surrender the rights. These restrictions translate to certain responsibilities for you if you distribute copies of the software, or if you modify it.

For example, if you distribute copies of such a program, whether gratis or for a fee, you must give the recipients all the rights that you have. You must make sure that they, too, receive or can get the source code. And you must show them these terms so they know their rights.

We protect your rights with two steps: (1) copyright the software, and (2) offer you this license which gives you legal permission to copy, distribute and/or modify the software.

Also, for each author's protection and ours, we want to make certain that everyone understands that there is no warranty for this free software. If the software is modified by someone else and passed on, we want its recipients to know that what they have is not the original, so that any problems introduced by others will not reflect on the original authors' reputations.

Finally, any free program is threatened constantly by software patents. We wish to avoid the danger that redistributors of a free program will individually obtain patent licenses, in effect making the program proprietary. To prevent this, we have made it clear that any patent must be licensed for everyone's free use or not licensed at all.

The precise terms and conditions for copying, distribution and modification follow.

## GNU GENERAL PUBLIC LICENSE TERMS AND CONDITIONS FOR COPYING, DISTRIBUTION AND MODIFICATION

**0.** This License applies to any program or other work which contains a notice placed by the copyright holder saying it may be distributed under the terms of this General Public License. The “Program”, below, refers to any such program or work, and a “work based on the Program” means either the Program or any derivative work under copyright law: that is to say, a work containing the Program or a portion of it, either verbatim or with modifications and/or translated into another language. (Hereinafter, translation is included without limitation in the term “modification”.) Each licensee is addressed as “you”.

Activities other than copying, distribution and modification are not covered by this License; they are outside its scope. The act of running the Program is not restricted, and the output from the Program is covered only if its contents constitute a work based on the Program (independent of having been made by running the Program). Whether that is true depends on what the Program does.

**1.** You may copy and distribute verbatim copies of the Program’s source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice and disclaimer of warranty; keep intact all the notices that refer to this License and to the absence of any warranty; and give any other recipients of the Program a copy of this License along with the Program.

You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a fee.

**2.** You may modify your copy or copies of the Program or any portion of it, thus forming a work based on the Program, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:

- a)** You must cause the modified files to carry prominent notices stating that you changed the files and the date of any change.
- b)** You must cause any work that you distribute or publish, that in whole or in part contains or is derived from the Program or any part thereof, to be licensed as a whole at no charge to all third parties under the terms of this License.
- c)** If the modified program normally reads commands interactively when run, you must cause it, when started running for such interactive use in the most ordinary way, to print or display an announcement including an appropriate copyright notice and a notice that there is no warranty (or else, saying that you provide a warranty) and that users may redistribute the program under these conditions, and telling the user how to view a copy of this License. (Exception: if the Program itself is interactive but does not normally print such an announcement, your work based on the Program is not required to print an announcement.)

These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Program, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Program, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Program.

In addition, mere aggregation of another work not based on the Program with the Program (or with a work based on the Program) on a volume of a storage or distribution medium does not bring the other work under the scope of this License.

**3.** You may copy and distribute the Program (or a work based on it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you also do one of the following:

- a)** Accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,
- b)** Accompany it with a written offer, valid for at least three years, to give any third party, for a charge no more than your cost of physically performing source distribution, a complete machine-readable copy of the corresponding source code, to be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange; or,
- c)** Accompany it with the information you received as to the offer to distribute corresponding source code. (This alternative is allowed only for noncommercial distribution and only if you received the program in object code or executable form with such an offer, in accord with Subsection b above.)

The source code for a work means the preferred form of the work for making modifications to it. For an executable work, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the executable. However, as a special exception, the source code distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

If distribution of executable or object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place counts as distribution of the source code, even though third parties are not compelled to copy the source along with the object code.

**4.** You may not copy, modify, sublicense, or distribute the Program except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense or distribute the Program 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.

5. You are not required to accept this License, since you have not signed it. However, nothing else grants you permission to modify or distribute the Program or its derivative works. These actions are prohibited by law if you do not accept this License. Therefore, by modifying or distributing the Program (or any work based on the Program), you indicate your acceptance of this License to do so, and all its terms and conditions for copying, distributing or modifying the Program or works based on it.

6. Each time you redistribute the Program (or any work based on the Program), the recipient automatically receives a license from the original licensor to copy, distribute or modify the Program subject to these terms and conditions. You may not impose any further restrictions on the recipients' exercise of the rights granted herein. You are not responsible for enforcing compliance by third parties to this License.

7. If, as a consequence of a court judgment or allegation of patent infringement or for any other reason (not limited to patent issues), conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot distribute so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not distribute the Program at all. For example, if a patent license would not permit royalty-free redistribution of the Program by all those who receive copies directly or indirectly through you, then the only way you could satisfy both it and this License would be to refrain entirely from distribution of the Program.

If any portion of this section is held invalid or unenforceable under any particular circumstance, the balance of the section is intended to apply and the section as a whole is intended to apply in other circumstances.

It is not the purpose of this section to induce you to infringe any patents or other property right claims or to contest validity of any such claims; this section has the sole purpose of protecting the integrity of the free software distribution system, which is implemented by public license practices. Many people have made generous contributions to the wide range of software distributed through that system in reliance on consistent application of that system; it is up to the author/donor to decide if he or she is willing to distribute software through any other system and a licensee cannot impose that choice.

This section is intended to make thoroughly clear what is believed to be a consequence of the rest of this License.

8. If the distribution and/or use of the Program is restricted in certain countries either by patents or by copyrighted interfaces, the original copyright holder who places the Program under this License may add an explicit geographical distribution limitation excluding those countries, so that distribution is permitted only in or among countries not thus excluded. In such case, this License incorporates the limitation as if written in the body of this License.

9. The Free Software Foundation may publish revised and/or new versions of the General Public 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.

Each version is given a distinguishing version number. If the Program specifies a version number of this License which applies to it and "any later version", you have the option of following the terms and conditions either of that version or of any later version published by the Free Software Foundation. If the Program does not specify a version number of this License, you may choose any version ever published by the Free Software Foundation.

10. If you wish to incorporate parts of the Program into other free programs whose distribution conditions are different, write to the author to ask for permission. For software which is copyrighted by the Free Software Foundation, write to the Free Software Foundation; we sometimes make exceptions for this. Our decision will be guided by the two goals of preserving the free status of all derivatives of our free software and of promoting the sharing and reuse of software generally.

## *NO WARRANTY*

11. BECAUSE THE PROGRAM IS LICENSED FREE OF CHARGE, THERE IS NO WARRANTY FOR THE PROGRAM, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE PROGRAM "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

12. IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL ANY COPYRIGHT HOLDER, OR ANY OTHER PARTY WHO MAY MODIFY AND/OR REDISTRIBUTE THE PROGRAM AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PROGRAM (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY YOU OR THIRD PARTIES OR A FAILURE OF THE PROGRAM TO OPERATE WITH ANY OTHER PROGRAMS), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

## *END OF TERMS AND CONDITIONS*

### **How to Apply These Terms to Your New Programs**

If you develop a new program, and you want it to be of the greatest possible use to the public, the best way to achieve this is to make it free software which everyone can redistribute and change under these terms.

To do so, attach the following notices to the program. It is safest to attach them to the start of each source file to most effectively convey the exclusion of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

one line to give the program's name and an idea of what it does.  
Copyright (C) yyyy name of author

This program is free software; you can redistribute it and/or  
modify it under the terms of the GNU General Public License  
as published by the Free Software Foundation; either version 2  
of the License, or (at your option) any later version.

This program is distributed in the hope that it will be useful,  
but WITHOUT ANY WARRANTY; without even the implied warranty of  
MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the  
GNU General Public License for more details.

You should have received a copy of the GNU General Public License  
along with this program; if not, write to the Free Software  
Foundation, Inc., 59 Temple Place - Suite 330, Boston, MA 02111-1307, USA.

Also add information on how to contact you by electronic and paper mail.

If the program is interactive, make it output a short notice like this when it starts in an interactive mode:

Gnomovision version 69, Copyright (C) year name of author  
Gnomovision comes with ABSOLUTELY NO WARRANTY; for details  
type `show w'. This is free software, and you are welcome  
to redistribute it under certain conditions; type `show c'  
for details.

The hypothetical commands `show w' and `show c' should show the appropriate parts of the General Public License. Of course, the commands you use  
may be called something other than `show w' and `show c'; they could even be mouse-clicks or menu items--whatever suits your program.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the program, if neces-  
sary. Here is a sample; alter the names:

Yoyodyne, Inc., hereby disclaims all copyright  
interest in the program `Gnomovision'  
(which makes passes at compilers) written  
by James Hacker.

signature of Ty Coon, 1 April 1989  
Ty Coon, President of Vice

This General Public License does not permit incorporating your program into proprietary programs. If your program is a subroutine library, you may  
consider it more useful to permit linking proprietary applications with the library. If this is what you want to do, use the GNU Lesser General Public  
License [<http://www.fsf.org/licenses/lgpl.html>] instead of this License.

## Freie GNU-Dokumentationslizenz (GNU Free Documentation License)

Version 1.2, November 2002

Copyright (C) 2000,2001,2002 Free Software Foundation, Inc. 59 Temple Place, Suite 330, Boston, MA 02111-1307 USA

Es ist jedermann gestattet, diese Lizenzurkunde zu vervielfältigen und unveränderte Kopien zu verbreiten; Änderungen sind jedoch nicht erlaubt.

### VORWORT

Der Zweck dieser Lizenz ist es, eine Dokumentation (Handbuch etc.) zu ermöglichen, die funktional, hilfreich und frei ist: damit jede Person sie  
sowohl kommerziell als auch nicht-kommerziell kopieren, weiterverteilen und ändern darf. Weiterhin sichert diese Lizenz einem Autor oder Verleger  
die Möglichkeit, Anerkennung für seine Arbeit zu erhalten, ohne für Änderungen durch Andere verantwortlich gemacht zu werden.

Diese Lizenz ist eine Art des „copyleft“, was bedeutet, dass von diesem Dokument abgeleitete Werke ihrerseits in derselben Weise frei sein müssen. Dies vervollständigt die „Allgemeine öffentliche GNU-Lizenz“ (GNU General Public License), die eine „copyleft“-Lizenz ist und für freie Software entworfen wurde.

Wir haben diese Lizenz entwickelt, um Sie für Handbücher für freie Software zu verwenden, da freie Software auch eine freie Dokumentation benötigt. Zu einem freien Programm gehören auch freie Handbücher, die die selben Freiheiten wie die Software bieten. Diese Lizenz ist aber nicht auf Softwarehandbücher beschränkt; vielmehr kann sie für jede Art von Textwerken verwendet werden, unabhängig davon, was das Thema ist oder ob es als gedrucktes Buch veröffentlicht wurde. Wir empfehlen diese Lizenz prinzipiell für Werke, die als Anleitungen oder Referenzen dienen sollen.

## ANWENDBARKEIT UND DEFINITIONEN

Diese Lizenz findet Anwendung auf jedes Handbuch oder andere Werk, unabhängig von dem Medium, auf dem es erscheint, das einen vom Rechteinhaber eingefügten Hinweis enthält, der besagt, dass das Werk unter den Bedingungen dieser Lizenz verbreitet werden darf. Ein solcher Hinweis gewährt eine weltweit gültige, tantiemfreie und zeitlich unbefristete Lizenz, die es gestattet, das Werk, unter den hier festgelegten Bedingungen zu nutzen. Der Begriff „Dokument“ wird im Folgenden für alle solche Handbücher und Werke verwendet. Jede Person kann Lizenznehmer sein und wird im Folgenden mit „Sie“ angesprochen. Sie akzeptieren diese Lizenz, wenn Sie ein Dokument derart kopieren, verändern oder verteilen, dass Sie gemäß den Gesetzen zum Copyright die Erlaubnis benötigen.

Eine „modifizierte Version“ des Dokuments steht für jedes Werk, das das Dokument als Ganzes oder in Teilen enthält, sowohl unverändert als auch mit Änderungen kopiert und/oder in andere Sprachen übersetzt.

Ein „zweitrangiger Abschnitt“ ist ein benannter Anhang oder eine Einleitung des Dokuments, der bzw. die sich ausschließlich mit dem Verhältnis des Autors oder Verlegers des Dokuments zu dem eigentlichen Thema des Dokuments (oder damit zusammenhängender Dinge) beschäftigt und der bzw. die nichts enthält, was direkt zu dem eigentlichen Thema gehört. (Wenn das Dokument beispielsweise ein Buch über Mathematik ist, dann darf ein zweitrangiger Abschnitt nichts über Mathematik enthalten). Dies kann eine historische Beziehung zu dem Thema oder damit zusammenhängender Dinge oder von gesetzlicher, gesellschaftlicher, philosophischer, ethischer oder politischer Art sein, die das Thema betreffen.

Die „unveränderlichen Abschnitte“ sind benannte zweitrangige Abschnitte, deren Titel als unveränderlicher Abschnitt in dem Lizenzhinweis, der das Dokument unter diese Lizenz stellt, aufgeführt sind. Wenn ein Abschnitt nicht in die oben stehende Definition eines zweitrangigen Abschnitts passt, dann ist es nicht erlaubt, diesen Bereich als unveränderlichen Bereich zu kennzeichnen. Das Dokument kann auch keine unveränderlichen Bereiche enthalten. Wenn das Dokument keine unveränderlichen Bereiche angibt, sind keine solchen darin enthalten.

Umschlagtexte“ sind bestimmte, kurze Textstücke, die als vorderer Umschlagtext oder als hinterer Umschlagtext in der Notiz benannt werden, die besagt, dass das Dokument unter dieser Lizenz freigegeben ist.“ Ein vorderer Umschlagtext kann bis zu 5 Worte enthalten, ein hinterer Umschlagtext bis zu 25 Worte.

Eine „transparente“ Kopie des Dokuments bezeichnet eine maschinenlesbare Kopie, dargestellt in einem Format, dessen Spezifikationen allgemein verfügbar sind und das geeignet ist, das Dokument auf einfache Weise mit einem allgemeinen Texteditor oder (für Bilder, die aus Pixeln bestehen) mit einem allgemeinen Bildbearbeitungsprogramm oder (für Zeichnungen) mit einem häufig verfügbaren Zeichenprogramm zu überarbeiten und es als Eingabe für Textformatierer zu verwenden oder als Eingabe für automatische Konvertierungsprogramme, die eine Reihe von unterschiedlichen Formaten erzeugen, die ihrerseits als Eingabe für Textformatierer verwendet werden können. Eine Kopie in ein anderes transparentes Dateiformat, dessen Auszeichnung oder Fehlen der Auszeichnung derart beschaffen sind, nachfolgende Modifikationen durch die Leser zu verhindern oder zu erschweren, ist nicht transparent. Ein Bildformat ist nicht transparent, wenn es für eine wesentliche Menge von Text verwendet wird. Eine Kopie, die nicht „transparent“ ist, wird als „opak“ bezeichnet.

Beispiele verwendbarer Formate für transparente Kopien schließen einfachen ASCII-Text ohne Auszeichnungen, Texinfo-Eingabeformat, LaTeX-Eingabeformat, SGML oder XML, sofern die verwendete DTD öffentlich verfügbar ist, sowie standardkonformes, einfaches HTML, Postscript oder PDF, die für Veränderungen durch Menschen entworfen sind, ein. Beispiele für transparente Bildformate sind u. a. PNG, XCF und JPG. Opake Formate sind unter anderem solche proprietären Formate, die nur von proprietären Textverarbeitungsprogrammen gelesen und bearbeitet werden können, SGML oder XML, deren DTD und/oder Verarbeitungswerkzeuge nicht allgemein verfügbar sind, und maschinengeneriertes HTML, PostScript oder PDF, das von manchen Textverarbeitungsprogrammen nur zu Ausgabezwecken erzeugt wird.

Mit „Titelseite“ werden in einem gedruckten Buch die eigentliche Titelseite sowie die direkt darauf folgenden Seiten bezeichnet, die all das in lesbarer Form enthalten, was in dieser Lizenz gefordert ist, dass es auf der Titelseite erscheinen muss. Für Werke, die in Formaten vorliegen, die keine Titelseiten haben, gilt als „Titelseite“ der Text, der der auffälligsten Darstellung des Titels des Werks direkt folgt, aber noch vor dem Inhalt des Werks steht.

Ein Abschnitt mit dem „Titel xyz“ bezeichnet einen benannten Unterbereich des Dokuments, dessen Titel entweder genau xyz ist oder der xyz in Anführungszeichen enthält, der einem Text folgt, der xyz in eine andere Sprache übersetzt. (Hier steht xyz für einen speziellen Abschnittsnamen, der im Folgenden erwähnt wird, wie „Danksagung“, „Widmung“, „Anmerkung“ oder „History“.) Den Titel eines Abschnitts erhalten“ bedeutet, dass beim Modifizieren des Dokuments dieser Abschnitt mit dem „Titel xyz“ bleibt, wie es in dieser Definition festgelegt ist.“

Das Dokument kann direkt hinter der Notiz, die besagt, dass das Dokument unter dieser Lizenz freigegeben ist, Garantiausschlüsse enthalten. Durch die Bezugnahme auf diese Haftungsausschlüsse werden selbige als in dieser Lizenz eingeschlossen angesehen, jedoch nur bezüglich des Ausschlusses von Garantien: Jede weitere etwaige Implizierung bzw. Interpretation dieser Haftungsausschlüsse ist ungültig und hat keinen Einfluss auf diese Lizenz.

## UNVERÄNDERTE KOPIEN

Sie dürfen das Dokument auf jedem Medium sowohl kommerziell als auch nicht kommerziell kopieren und verbreiten, vorausgesetzt, dass diese Lizenz, die Copyright-Hinweise sowie der Lizenzhinweis, der besagt, dass diese Lizenz auf das Dokument anzuwenden ist, in allen Kopien reproduziert wird und dass keine weiteren Bedingungen jeglicher Art zu denen dieser Lizenz hinzugefügt werden. Sie dürfen in den Kopien, die Sie erstellen oder verbreiten, keinerlei technische Maßnahmen treffen, um das Lesen oder das weitere Kopieren zu erschweren oder zu kontrollieren. Den-

noch dürfen Sie Gegenleistungen für Kopien akzeptieren. Wenn Sie eine ausreichend große Menge von Kopien verteilen, müssen Sie zusätzlich die Bestimmungen von Ziffer 3 beachten.

Sie können außerdem unter denselben Bedingungen, die oben angeführt sind, Kopien verleihen und Sie können Kopien auch öffentlich bewerben.

## KOPIEN IN MENGEN

Wenn Sie gedruckte Kopien des Dokuments (oder Kopien auf Medien, die üblicherweise gedruckte Umschläge haben), in einer Stückzahl von mehr als 100 veröffentlichen und der Lizenzhinweis des Dokuments Umschlagtexte verlangt, müssen die Kopien in Hüllen verpackt sein, die alle diese Umschlagtexte klar und lesbar enthalten (Frontseitentexte vorne, Rückseitentexte hinten). Beide Umschläge müssen Sie ausserdem klar und lesbar als den Herausgeber dieser Kopien benennen. Der vordere Umschlag muss den gesamten Titel darstellen, mit allen Worten gleich auffällig und sichtbar. Sie können weiteres Material den Umschlägen hinzufügen. Das Kopieren mit Änderungen, die auf Umschläge begrenzt sind, können, solange der Titel des Dokuments erhalten bleibt, ansonsten als unveränderte Kopien behandelt werden.

Wenn der vorgeschriebene Text für einen der Umschläge zu umfangreich ist, um lesbar zu bleiben, sollten Sie den ersten der aufgelisteten Texte auf den aktuellen Umschlag nehmen (so viel wie vernünftigerweise möglich ist) und den Rest auf direkt angrenzenden Seiten.

Wenn Sie mehr als 100 opake Kopien veröffentlichen oder verbreiten, müssen Sie entweder eine maschinenlesbare, transparente Kopie jeder opaken Kopie beilegen oder mit bzw. in jeder opaken Kopie eine Computer-Netzwerk-Adresse angeben, von wo die allgemeine, netzwerkbenutzende Öffentlichkeit Zugriff zum Download einer kompletten transparenten Kopie über öffentliche Standardnetzwerkprotokolle hat. Wenn Sie sich für die letztere Möglichkeit entscheiden, müssen Sie mit Beginn der Verbreitung der opaken Kopien in Stückzahlen, zumutbare und vernünftige Schritte unternehmen, um sicherzustellen, dass die transparenten Kopien mindestens ein Jahr nach der Auslieferung der letzten opaken Kopie (direkt oder über einen Agenten oder Händler) dieser Ausgabe an die Öffentlichkeit, an der genannten Adresse verfügbar bleiben.

Es wird gebeten, aber nicht gefordert, dass Sie ausreichend lange vor der Auslieferung einer größeren Menge von Kopien Kontakt mit den Autoren des Dokuments aufnehmen, um diesen die Möglichkeit zu geben, Ihnen eine aktualisierte Version des Dokuments zukommen zu lassen.

## MODIFIKATIONEN

Unter den obigen Bedingungen unter Ziffer 2 und 3 können Sie modifizierte Versionen kopieren und verbreiten, vorausgesetzt, dass Sie die modifizierte Version unter exakt dieser Lizenz herausgeben, wobei die modifizierte Version die Rolle des Dokuments einnimmt, und dadurch die weitere Modifikation und Verbreitung an jeden Lizenzieren, der eine Kopie davon besitzt. Zusätzlich müssen Sie die folgenden Dinge in der modifizierten Version beachten:

**Eine** Benutzen Sie auf der Titelseite (und auf Umschlägen, sofern vorhanden) einen Titel, der sich von dem Titel des Dokuments und von früheren Versionen unterscheidet. (Die früheren Versionen sollten, wenn es welche gibt, im Abschnitt History aufgelistet werden.) Sie können denselben Titel wie den einer Vorgängerversion verwenden, wenn der ursprüngliche Herausgeber damit einverstanden ist.

**B.** Geben Sie auf der Titelseite eine oder mehrere Personen oder Einheiten, die als Autoren auftreten können, als für die Modifikationen verantwortliche Autoren der modifizierten Version, zusammen mit mindestens fünf der ursprünglichen Autoren der Ursprungsversion, an (alle vorherige Autoren, wenn es weniger als fünf sind), es sei denn, diese befreien Sie von dieser Notwendigkeit.

**C.** Geben Sie auf der Titelseite den Namen des Herausgebers als Herausgeber an.

**D.** Erhalten Sie alle Copyright-Vermerke des Dokuments.

**E.** Setzen Sie einen passenden Copyright-Vermerk für Ihre Modifikationen direkt hinter die anderen Copyright-Vermerke.

**F.** Schließen Sie direkt hinter den Copyright-Vermerken einen Lizenzhinweis ein, der die öffentliche Erlaubnis erteilt, die modifizierte Version unter den Bedingungen dieser Lizenz zu benutzen, wie es im Anhang weiter unten beschrieben ist.

**G.** Erhalten Sie im Copyright-Vermerk die komplette Liste der unveränderlichen Abschnitte und obligatorischen Umschlagtexte, die in dem Lizenzvermerk des Dokuments aufgeführt sind.

**H.** Schließen Sie eine unveränderte Kopie dieser Lizenz mit ein.

**I.** Erhalten Sie den Abschnitt "History". Erhalten Sie den Titel und fügen Sie einen Punkt hinzu, der mindestens den Titel, das Jahr, die neuen Autoren und Herausgeber, wie sie auf der Titelseite aufgeführt sind, enthält. Sollte es keinen Abschnitt "History" geben, dann erstellen Sie einen, der Titel, Jahr, Autor und Herausgeber des Dokuments, wie auf der Titelseite angegeben, enthält und fügen Sie einen Punkt hinzu, der die modifizierte Version, wie oben dargestellt, beschreibt.

**J.** Erhalten Sie die Netzwerkadresse, die angegeben wurde, um Zugang zu einer transparenten Kopie zu gewähren, sowie entsprechend angegebene Adressen früherer Versionen, auf denen das Dokument aufbaute. Diese Angaben können in den Abschnitt "History" verschoben werden. Sie können die Netzwerkadresse weglassen, wenn sie sich auf ein Werk bezieht, das mindestens 4 Jahre vor dem Dokument selbst veröffentlicht wurde, oder wenn der ursprüngliche Herausgeber der Version, auf die sich die Adresse bezieht, seine Erlaubnis erteilt.

**K.** Erhalten Sie für alle Abschnitte, die als "Danksagungen" oder "Widmungen" überschrieben sind, den Titel sowie die Substanz und den Ton aller vom Geber gemachten Danksagungen und/oder Widmungen in diesem Abschnitt.

**L.** Erhalten Sie alle unveränderlichen Abschnitte unverändert, sowohl im Titel als auch im Text. Abschnittsnummern oder dergleichen gelten hierbei nicht als Teil des Titels.

**M.** Löschen Sie alle Abschnitte, die als "Anmerkungen" überschrieben sind. Ein solchen Abschnitt sollte nicht in der modifizierten Version enthalten sein.



**N.** Benennen Sie keinen Abschnitt in “Anmerkungen” um oder in einen Namen, der in Konflikt mit einem unveränderlichen Abschnitt gerät.

**O.** Erhalten Sie alle Garantieausschlüsse.

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. Diese Titel müssen sich von allen anderen Titeln unterscheiden.

Sie können einen Abschnitt “Anmerkungen” anfügen, sofern dieser nichts als Bemerkungen verschiedener Stellen zu der modifizierten Version enthält. Beispielsweise Publikumsreaktionen oder eine Mitteilung, dass der Text von einer Organisation als maßgebliche Definition eines Standards geprüft wurde.

Sie können einen Teil mit bis zu fünf Worten als vorderen Umschlagtext und einen mit bis zu 25 Worten als hinteren Umschlagtext an das Ende der Liste mit den Umschlagtexten der modifizierten Version hinzufügen. Nur je ein Teil für den vorderen Umschlagtext und den hinteren Umschlagtext können von jeder Einheit hinzugefügt (oder durch entsprechende Anordnung erstellt) werden. Wenn das Dokument bereits einen Umschlagtext für denselben Umschlag enthält, das von Ihnen oder der Einheit, in deren Namen Sie tätig sind, bereits früher eingefügt wurde, dürfen Sie keine neue hinzufügen. Sie können aber den alten ersetzen, wenn Sie die ausdrückliche Genehmigung des Herausgebers haben, der den früheren Text eingefügt hat.

Der/die Autor(en) und Herausgeber des Dokuments geben durch diese Lizenz weder implizit noch explizit die Erlaubnis, ihren Namen für Werbung in den Anmerkungen der modifizierten Version zu benutzen.

## KOMBINIEREN VON DOKUMENTEN

Sie können mehrere Dokumente, die unter dieser Lizenz freigegeben sind, gemäß den Bedingungen unter Ziffer 4 für modifizierte Versionen miteinander kombinieren, vorausgesetzt, dass in der Kombination alle unveränderlichen Abschnitte aller Originaldokumente enthalten sind und dass Sie diese alle in der Liste der unveränderlichen Abschnitte der Lizenzanmerkung des kombinierten Dokuments aufführen sowie alle Garantieausschlüsse erhalten.

Das kombinierte Werk braucht nur eine Kopie dieser Lizenz zu enthalten und mehrere identische unveränderliche Abschnitte können durch eine einzelne Kopie ersetzt werden. Wenn es mehrere unveränderliche Abschnitte mit unterschiedlichem Inhalt, aber gleichem Namen gibt, machen Sie den Namen eindeutig, indem Sie am Ende des Titels, in Anführungszeichen, den Namen des Originalautors oder Herausgebers, falls bekannt, oder anderenfalls eine eindeutige Nummer anhängen. Machen Sie dasselbe mit den Titeln der Abschnitte in der Liste der unveränderlichen Abschnitte im Lizenzhinweis des kombinierten Werks.

In der Kombination müssen Sie alle Abschnitte mit dem Titel “History” in den unterschiedlichen Dokumenten zu einem einzelnen Abschnitt “History” zusammenführen; entsprechend verfahren Sie mit den Abschnitten “Danksagungen” und “Widmungen”. Sie müssen alle Abschnitte mit dem Titel “Anmerkungen” löschen.

## SAMMLUNGEN VON DOKUMENTEN

Sie können eine Sammlung von Dokumenten erstellen, bestehend aus diesem Dokument und weiteren, unter dieser Lizenz stehenden Dokumenten, wobei Sie die einzelnen Kopien dieser Lizenz in den verschiedenen Dokumenten durch eine einzelne Kopie, die in der Sammlung enthalten ist, ersetzen, vorausgesetzt, Sie befolgen in allen andern Punkten, für jedes der Dokumente, die Regeln für unveränderte Kopien.

Sie können ein einzelnes Dokument aus einer solchen Sammlung herausziehen und einzeln unter dieser Lizenz verbreiten, vorausgesetzt, Sie fügen eine Kopie dieser Lizenz in das extrahierte Dokument ein und befolgen ansonsten die Bedingungen dieser Lizenz für unveränderte Kopien.

## AGGREGATION MIT UNABHÄNGIGEN WERKEN

Eine Zusammenstellung des Werks, oder von Ableitungen davon, mit anderen, separaten und unabhängigen Dokumenten oder Werken in oder auf demselben Band eines Speicher- oder Verbreitungsmediums wird dann eine Aggregation genannt, wenn die Copyrights der Zusammenstellung nicht dazu verwendet werden, die Rechte der Benutzer, die für die einzelnen Werke gewährt werden, stärker zu beschränken als dies durch die Lizenzen der einzelnen Werke geschieht. Wenn das Werk in einer Aggregation vorhanden ist, so gilt diese Lizenz nicht für die anderen Werke dieser Aggregation, die keine Ableitung des Dokuments sind.

Wenn die Bestimmungen für die Umschlagtexte aus Ziffer 3 Anwendung finden und wenn das Dokument weniger als die Hälfte der gesamten Aggregation ausmacht, dann können die Umschlagtexte auf Seiten gesetzt werden, die das Dokument innerhalb der Aggregation umschließen, oder auf das elektronische Äquivalent eines Umschlages, wenn das Dokument in elektronischer Form vorliegt. Anderenfalls müssen sie auf gedruckten Umschlägen erscheinen, die das gesamte Werk umschließen.

## ÜBERSETZUNG

Übersetzungen werden als eine Art von Modifikationen betrachtet. Damit können Sie eine Übersetzung des Dokuments unter den Bestimmungen von Ziffer 4 verbreiten. Um die unveränderlichen Abschnitte durch eine Übersetzung zu ersetzen, benötigen Sie die spezielle Erlaubnis des Copyright-Inhabers. Sie können allerdings Übersetzungen von einigen oder allen unveränderlichen Abschnitten zu den Originalversionen der unveränderlichen Abschnitte hinzufügen. Sie können eine Übersetzung dieser Lizenz und allen Lizenzhinweisen im Dokument sowie allen Garantieausschlüssen hinzufügen, vorausgesetzt, dass Sie ebenso die originale englische Version dieser Lizenz und aller Hinweise und Ausschlüsse beifügen. Sollten die Übersetzung und die Originalversion dieser Lizenz oder eines Hinweises oder Ausschlusses voneinander abweichen, so hat die Originalversion Vorrang.

Wenn ein Abschnitt des Dokuments als “Danksagung”, “Widmungen” oder “History” überschrieben ist, so erfordert die Forderung (Ziffer 4), den Titel dieses Abschnitts zu erhalten, die Änderung des aktuellen Titels.

## ABSCHLUSSBESTIMMUNGEN

Sie dürfen dieses Dokument nicht kopieren, verändern, unterlizenzieren oder verteilen, mit der Ausnahme, dass Sie es ausdrücklich unter dieser Lizenz tun. Jedweder andere Versuch zu kopieren, zu modifizieren, weiterzulizenzieren oder -zuverbreiten, ist unzulässig und führt automatisch zum Entzug der durch diese Lizenz gewährten Rechte. Für Personen, die Kopien oder Rechte von Ihnen gemäß den Bestimmungen dieser Lizenz erhalten haben, wird die Lizenz jedoch nicht beendet, solange sie alle Bestimmungen einhalten.

## SPÄTERE ÜBERARBEITUNGEN DIESER LIZENZ

Die Free Software Foundation kann von Zeit zu Zeit neue, überarbeitete Versionen der Freien GNU-Dokumentationslizenz (GNU Free Documentation License) veröffentlichen. Solche neuen Versionen ähneln in den Grundzügen der aktuellen Version, können sich jedoch in Details bezüglich neuer Probleme davon unterscheiden. Siehe <http://www.gnu.org/copyleft/>.

Jede Version dieser Lizenz erhält eine eigene Versionsnummer. Wenn im Dokument angegeben wird, dass es dieser Lizenz in einer bestimmten Versionsnummer oder "jeder späteren Version" unterliegt, so haben Sie die Wahl, entweder den Bestimmungen der genannten Version zu folgen oder denen jeder beliebigen späteren Version, die von der Free Software Foundation veröffentlicht wurde. Wenn das Dokument keine Versionsnummer angibt, können Sie eine beliebige Version wählen, die je von der Free Software Foundation veröffentlicht wurde (jedoch keine Entwürfe).

## ANHANG: Wie Sie diese Lizenz für Ihre Dokumente verwenden können

Um diese Lizenz in einem Dokument zu verwenden, das sie selbst geschrieben haben, schließen Sie eine Kopie dieser Lizenz in Ihr Dokument mit ein und setzen Sie den folgenden Copyright- und Lizenzhinweis gleich hinter die Titelseite:

```
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".
```

Wenn Sie unveränderlichen Abschnitte, vordere und hintere Umschlagtexte haben, ersetzen Sie die Zeile: "Es gibt keine..... Umschlagtext" durch die folgende:

```
with the Invariant Sections being LIST THEIR TITLES, with the
Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.
```

Wenn Sie unveränderliche Abschnitte, aber keine Umschlagtexte oder irgendeine andere Kombination der drei Bereiche haben, mischen Sie die verschiedenen Alternativen, dass sie zu Ihren Anforderungen passen.

Wenn Ihr Dokument nichttriviale Codebeispiele enthält, empfehlen wir, diese Beispiele parallel unter einer freien Softwarelizenz Ihrer Wahl, beispielsweise der Allgemeinen öffentlichen GNU-Lizenz (GNU General Public License) zu lizenzieren, um ihren Gebrauch in freier Software zu erlauben.