NETWORKING

Hands-On Virtual Computing

Second Edition

Ted Simpson
Jason Novak

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Hands-On Virtual Computing,
Second Edition

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Introduction

The IT field is experiencing a dramatic change in computing models, moving from proprietary hardware-based infrastructures to software-defined data centers and cloud computing. The driving force behind this change is virtualization. To be in a position to take advantage of the new opportunities these changes will bring, you need to understand how virtualization of computer resources can be used to create IT environments that are flexible, scalable, and affordable. This book is the best way to start learning about virtualization as it combines theories and concepts with practical hands-on activities and projects that allow you to apply the concepts you are learning to real world scenarios. Currently there are two major commercial leaders in the virtualization products, VMware and Microsoft. This book is unique in that it presents products from both of these leaders so you can learn about and gain comparative experience with them.

This book will provide you with a working knowledge of the leading virtualization products, including Oracle VirtualBox, VMware Workstation, Microsoft Hyper-V, and VMware vSphere. In addition to learning how to install and use the products, you learn how to apply virtualization technology to create virtual data centers that use clusters for high availability, use management software to administer multiple host systems, implement a virtual desktop environment, and leverage cloud computing to build or extend the data center and provide disaster recovery services. By the time you finish reading this book and performing the activities you will have a solid base in virtualization concepts and products that you can use to build your IT career.

Intended Audience

Hands-On Virtual Computing, 2e, is intended for people who want to increase their employment opportunities in the IT field by learning how to configure and use virtualization software to meet a variety of computing needs. This book can be used in a college computer lab environment or with computer equipment you have in your home or office. The activities in this book have been planned and written carefully to allow you to use open-source and trial versions of virtualization and Windows software.

This Book Includes:

- Complete coverage of virtualization concepts, including abundant screen captures and diagrams to visually reinforce the text and hands-on activities
- Coverage of the features each major virtualization package offers
- Instructions on how to download free and trial versions of virtualization products, including Oracle VirtualBox, VMware Workstation, and Microsoft Hyper-V
- Step-by-step hands-on activities that walk you through installing, configuring, and using virtualization products for a variety of real-world tasks
- Extensive review and end-of-chapter materials that reinforce what you've learned
- Challenging activities and case projects that build on one another and require you to apply the concepts and technologies learned throughout the book
- Appendixes that expand on virtualization concepts and products, including the technology behind virtualization, using VMware Player and Hyper-V Server, disaster recovery, and high availability

Chapter Descriptions

The book starts with an overview of virtualization technology in Chapter 1 and then proceeds with chapters dedicated to the latest virtualization products including Oracle VirtualBox, VMware Workstation, Microsoft Hyper-V, and VMware vSphere. Chapters 2 and 3 cover workstation virtualization products and techniques that may be used by developers, students, and home users to run multiple operating systems on a single computer. Chapter 4 moves the reader from using virtualization in a workstation environment to the virtual data centers. The chapter includes a discussion of topics related to using virtualization in software defined data center environments including building virtual networks, implementing high-availability clusters, enhancing performance and security, and managing the virtual data center. Chapters 5–8 provide you with concepts and experience building virtual data centers using Microsoft Hyper-V and VMware vSphere. Chapters 9 and 10 focus on some of the newest IT challenges. Chapter 9 introduces you to implementing virtual desktop infrastructures using both VMware Horizon and Microsoft VDI. Chapter 10 provides a background in utilizing cloud computing environments with VMware vCloud and Microsoft Azure. The following list provides more detailed information on each of this book's chapters:

- **Chapter 1**, "Introduction to Virtual Computing," gives you an overview of how virtualization works and describes the different types of virtualization products as well as cloud computing models. This chapter introduces the virtualization products covered in this book, compares product features, and gives you instructions on downloading free versions of the software you use for subsequent chapter activities.

- **Chapter 2**, "Working with Oracle VM VirtualBox 5," provides detailed information and hands-on activities installing and working with the freely available Oracle VirtualBox. Topics include creating and configuring virtual machine environments, installing Windows Server 2016 as a guest OS, working with virtual hard disks, using the administrative console, and working with features such as snapshots.
- **Chapter 3**, "Working with VMware Workstation 12 Pro," provides detailed information and hands-on activities installing and working with VMware Workstation 12 Pro. Topics include creating and configuring virtual machine environments, installing Windows Server 2016 and Ubuntu Linux as guest OSs, working with virtual hard disks, using the administrative console, and working with VMware Workstation 12 Pro features, such as cloning virtual machines, using Snapshot Manager, file sharing, and enabling Unity view.
- **Chapter 4**, "Data Center Virtualization and Cloud Computing," is an overview of virtualization software and technologies that are used in data center and cloud-based environments. The chapter compares data center virtualization features available in both VMware and Hyper-V. The chapter builds a base of terminology and concepts that you will use in the remaining chapters.
- **Chapter 5**, "Working with Microsoft Hyper-V," covers Microsoft's virtualization product, Hyper-V, which is included with Windows Server 2016. You learn how to add the Hyper-V role to a host and how to use Hyper-V Manager to create and interact with virtual machines running Windows Server 2016, create checkpoints, manage virtual disks, and configure the virtual switches.
- **Chapter 6**, "Working with Virtual Machine Manager," covers using Microsoft System Center Virtual Machine Manager (VMM) 2016, which has advanced features for managing multiple Hyper-V and hosts. In this chapter you install VMM and its prerequisites. You then learn how to use VMM Administrator Console to create and deploy virtual machines across multiple hosts and manage a library of shared resources for generating new virtual machines easily.
- **Chapter 7**, "Working with VMware vSphere," introduces you to using VMware's data center virtualization product. The activities in this chapter focus on the freely available ESXi hypervisor and vSphere Windows client. Using these tools you will learn how to install ESXi hypervisors along with the Windows-based vSphere client, and then use these products to build a simple virtual data center environment for a fictitious company consisting of two ESXi hosts, shared storage, and virtual machines connected to the physical network using virtual network switches.
- **Chapter 8**, "Working with VMware vCenter Server," introduces using the licensed version of vSphere to manage a data center consisting of multiple ESXi hosts. In this chapter you will learn how to install vCenter server as a virtual machine as well as use the Web-based vCenter client to create objects and centrally manage the entire virtual data center. Topics include licensing, creating distributed switches, implementing iSCSI shared storage, cloning virtual machines, creating clusters, and moving virtual machines between hosts.
- **Chapter 9**, "Implementing a Virtual Desktop Infrastructure," provides students with a hands-on introduction to setting up a virtual desktop infrastructure. Virtual desktop infrastructure or VDI is one of the fastest growing applications of virtualization technology as it can reduce IT support costs and provide a solution that allows users to work from a variety of different devices and physical locations. This chapter covers the concepts and challenges of VDI

architectures and provides the student with hands-on experience implementing a simple Virtual Desktop Infrastructure using both VMware Horizon 7 and Microsoft VDI products.

- **Chapter 10**, "Introduction to Cloud Computing," introduces you to the way in which the cloud can be used to build and extend the virtual data center. Cloud-based services are becoming a major part of the IT environment and virtualization is the backbone supporting cloud computing, allowing resources and services to be provisioned as neededsaving time and costs. In this chapter we focus on the services offered through VMware vCloud Air and Microsoft Azure, as well as introduce the student to cloud environments based on OpenStack architecture. Hands-on activities in this chapter will allow you to experience vCloud Air by using VMware's lab environment as well as working directly with Microsoft Azure to build a cloud-based data center for a simulated application.
- **Appendix A**, "The Technology Behind Virtualization," explains how virtualization products use hardware and software to work behind the scenes, including how virtual machines emulate physical hardware. You learn about early virtualization methods as well as how virtualization works on today's x86 processors. You will also learn how hardware virtualization, which uses features built into modern processors, is improving virtualization performance.
- **Appendix B**, "Using VMware Workstation Player and Hyper-V Server 2016 Virtualization Products," explains installing and using the free VMware Player to run virtual machines and applications (called virtual appliances). Topics include installing VMware Player, running virtual machines and appliances, and performing basic configuration tasks, such as accessing CDs with ISO images. This appendix also includes a section that covers using Hyper-V Server 2016. Based on Server Core, this free, UI-less operating system can run virtual machines without a full version of Windows Server 2016. In this section you will learn how to install and configure Hyper-V Server using the command line and a simple text-based menu system.
- **Appendix C**, "Disaster Recovery and High Availability," provides an overview of disaster recovery services and high availability in virtualized data centers. This appendix also gives you an introduction to backup systems, including Microsoft Volume Shadow Copy Service (VSS), which allows backing up data while applications and files are open, and VMware's Virtual Data Protection (VDP) server. You also learn about using high-availability techniques used by VMware and Microsoft to keep virtual servers available continuously using host clusters.

Features

This book is unique in that it incorporates real world scenarios into hands-on activities using trial versions of the latest products. Combining hands-on activities with easy to read text allows students to build the skills necessary for a successful career in a computer industry that is increasingly focused around virtualization and the software defined data center. This book includes the following features to help you learn about the latest virtualization products and how to use them in a variety of IT settings:

- *Hands-on* activities—Nearly 100 hands-on activities and case projects give you practice in installing, configuring, managing, and operating virtualization software in a simulated organization. In addition, in the hands-on activities in Chapters 5–8, you use data center virtualization products for common IT tasks, such as networking, clustering, enhancing performance, and improving security. These activities give you a strong foundation for carrying out server virtualization tasks in the real world. In Chapter 9 you will perform activities that allow you to experience using both VMware's Horizon and Microsoft VDI products to implement a simple virtual desktop infrastructure. Cloud-based, on-demand services have become a major player in the IT infrastructure. In the activities in Chapter 10 you work with VMware vCloud labs and Microsoft Azure to learn how to create and manage virtual machines in the cloud.

- *Software*—The activities in each chapter are written to use free downloads or trial versions of virtualization software and include instructions on obtaining software from the VMware or Microsoft Web sites. Chapter activities are designed with a common theme of using Windows Server 2016 and Windows 10 in evaluation mode as the guest OS.
- *Product focus*—This book is designed to maximize your learning options and can be used in multiple courses. By showcasing both VMware and Microsoft virtualization and cloud services, students can compare the benefits and limitations of both environments.
- *Certifications*—This book provides you with the knowledge you need to pass the VMware Certified Associate 6–Data Center Virtualization Exam (VCA exam).
- *Class curriculum*—This textbook is designed to be used in a single Introduction to Virtualization class or may be applied to multiple classes that have a specific product focus. For example, if you want to learn only about VMware products, you can do the activities in Chapters 1–4, and then skip to Chapters 7–10. If you're working with only Microsoft products, you can do the activities in Chapters 1–6 before moving on to Chapters 9 and 10.
- *Chapter objectives*—Each chapter begins with a list of the concepts to be mastered. This list is a quick reference to the chapter's contents and a useful study aid.
- *Screen captures, illustrations, and tables*—Numerous screen captures and illustrations aid you in visualizing theories and concepts and seeing how to use tools and desktop features. In addition, tables are used often to provide details and comparisons of virtualization products and features.
- *Chapter summary*—Each chapter ends with a summary of the concepts introduced in the chapter. These summaries are a helpful way to recap and revisit the material covered in the chapter.
- *Key terms*—All terms in the chapter introduced with bold text are gathered together in the Key Terms list at the end of the chapter. This list gives you a way to check your understanding of all new terms.
- *Review questions*—The end-of-chapter assessment begins with review questions that reinforce the concepts and techniques covered in each chapter. Answering these questions helps ensure that you have mastered important topics.
- *Case projects*—Each chapter closes with one or more case projects designed to develop your critical and analytical skills in applying the virtualization concepts covered in that chapter.
- *Instructional flexibility*—This book has been written to meet a variety of instructional needs. The first chapters give students an overview of several virtualization products so that they can

make better decisions about selecting a product. This book can also be used for a course on using a specific product, such as Microsoft Hyper-V or VMware ESXi, for a variety of server IT tasks, including networking, clustering, enhancing performance and security, and managing servers. For more information on instructional options, download the instructor's guide and materials.

Text and Graphics Conventions

Additional information has been added to this book to help you better understand what's being discussed in the chapter. Icons throughout the text alert you to these additional materials:

Tips offer extra information on resources, problem-solving techniques, and time-saving shortcuts.

Notes present additional helpful materials related to the subject being discussed.

Each hands-on activity in this book is preceded by the Activity icon.

Case Project icons mark the end-of-chapter case projects, which are scenario-based assignments that ask you to apply what you've learned in the chapter.

Instructor's Resources

The following supplemental materials are available when this book is used in a classroom setting. All the supplements available with this book are provided to instructors for downloading at www.cengage.com/sso.

- *Instructor's manual*—The instructor's manual that accompanies this book includes additional material to assist in class preparation, including suggestions for classroom activities, discussion topics, and additional activities.
- *Solutions*—The instructor's resources include solutions to all end-of-chapter materials, including review questions, hands-on activities, and case projects.
- *PowerPoint presentations*—This book comes with Microsoft PowerPoint slides for each chapter. They're included as a teaching aid for classroom presentation, to make available to students on the network for chapter review, or to be printed for classroom distribution. Instructors, please feel free to add your own slides for additional topics you introduce to the class.

System Requirements

Hardware:

One computer per student to act as the host machine that meets the following minimum requirements:

- Windows 10 (VMware) or Windows Server 2016 (Hyper-V) installed
- 2.4 GHz or faster CPU with hardware virtualization
- 4 GB RAM (8 GB or more recommended to do VMware activities)
- 120 GB disk minimum (more disk space is recommended for VMware activities)
- DVD-ROM drive or bootable USB
- Network interface card connected to the classroom, lab, or school network

Software:

- Windows Server 2016 Standard or Enterprise Edition (students can download an evaluation copy through Microsoft's DreamSpark program at *www.dreamspark.com*; see Chapter 1 for more details)
- Windows 10: Any edition except Home Edition (you can download an evaluation virtual machine from the Microsoft Web site)

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chapter 1

Introduction to Virtual Computing

After reading this chapter and completing the exercises, you will be able to:

- Understand the advantages of virtualization
- Describe how virtual machines work
- Give an overview of features in virtualization software
- Identify the categories of virtualization software products and how they are used in today's IT environment
- Summarize features of virtualization products from Microsoft and VMware
- Describe Virtual Desktop Infrastructure (VDI) and application virtualization, and identify the products used in supporting VDI environments
- Describe cloud services and identify features in Microsoft Azure and VMware vCloud

Today's high-powered multi-core CPUs with gigabytes of memory are often underutilized. Virtual Computing is the process of empowering these high-powered computer systems to run multiple operating systems, reducing the number of physical computers needed in the data center. Not only does virtual computing save hardware and energy costs, it also offers other features for the data center such as rapid provisioning of new systems, load balancing, high availability, backup, and disaster recovery. These capabilities, along with the ability to adapt computing resources quickly to a variety of customer requirements, have made virtualization the backbone of most cloud computing services, affecting most if not all computer users and IT professionals.

In addition to its use in data centers, virtualization offers a number of benefits for workstation environments. Developers may use virtual machines to develop and test their applications on a variety of platforms. IT professionals often use virtual machines to pre-configure servers as well as deploy desktop environments quickly to many users. Users benefit from virtual machines by using them to run other operating systems and applications side by side that normally couldn't be installed on a single system. Additional features available through virtualization include suspending the system to continue work later or taking a snapshot so that you can return to a specific system point if you make a mistake.

In this book you will learn about the many capabilities of virtual computing, how it differs from traditional computing environments, and how to implement this technology using the most popular virtualization products from VMware, Microsoft, and Oracle. In this chapter, you're introduced to these virtualization software packages, how virtualization works, and how virtualization features can be applied in the IT world to enhance existing data center services and enable new cloud-based services.

Overview of Virtual Machines and Virtualization Software

In traditional computing, a physical computer supports a single operating system.

The operating system provides an environment for applications and manages the physical computer's hardware resources including the CPU, memory, disk, and I/O devices. During installation, the operating system is configured to the physical computer's hardware environment using a specialized kernel along with a variety of device drivers. This hardware dependency makes it very difficult to move an operating system from one computer to another without re-installing the operating system or using nearly identical hardware.

Virtual computing frees the operating system from its hardware dependency and provides hardware resource sharing that allows a physical computer to simultaneously run multiple operating system environments. Each of these virtualized computer environments is called a **virtual machine** or VM and can run its own operating system as though it were running on a dedicated computer.

Virtual computing technology shares hardware resources by placing a piece of software called the **hypervisor** (see Figure 1-1) between the physical computer hardware and the operating system environments. The hypervisor allows you to create an environment for each virtual machine containing its own virtual CPU, memory, hard disk, and network interface card. These virtual devices appear to the virtual machine's operating system like physical devices.

By sharing hardware resources, the hypervisor makes it possible to run multiple computer environments on a single computer. As illustrated in Figure 1-1, hypervisors can be classified as type-1 or type-2. **Type-1 hypervisors** are called **bare metal hypervisors** because they run directly on the hardware without the need of a host operating system. **Type-2 hypervisors** require a host operating system and are often used to run other operating system environments on desktop computers.

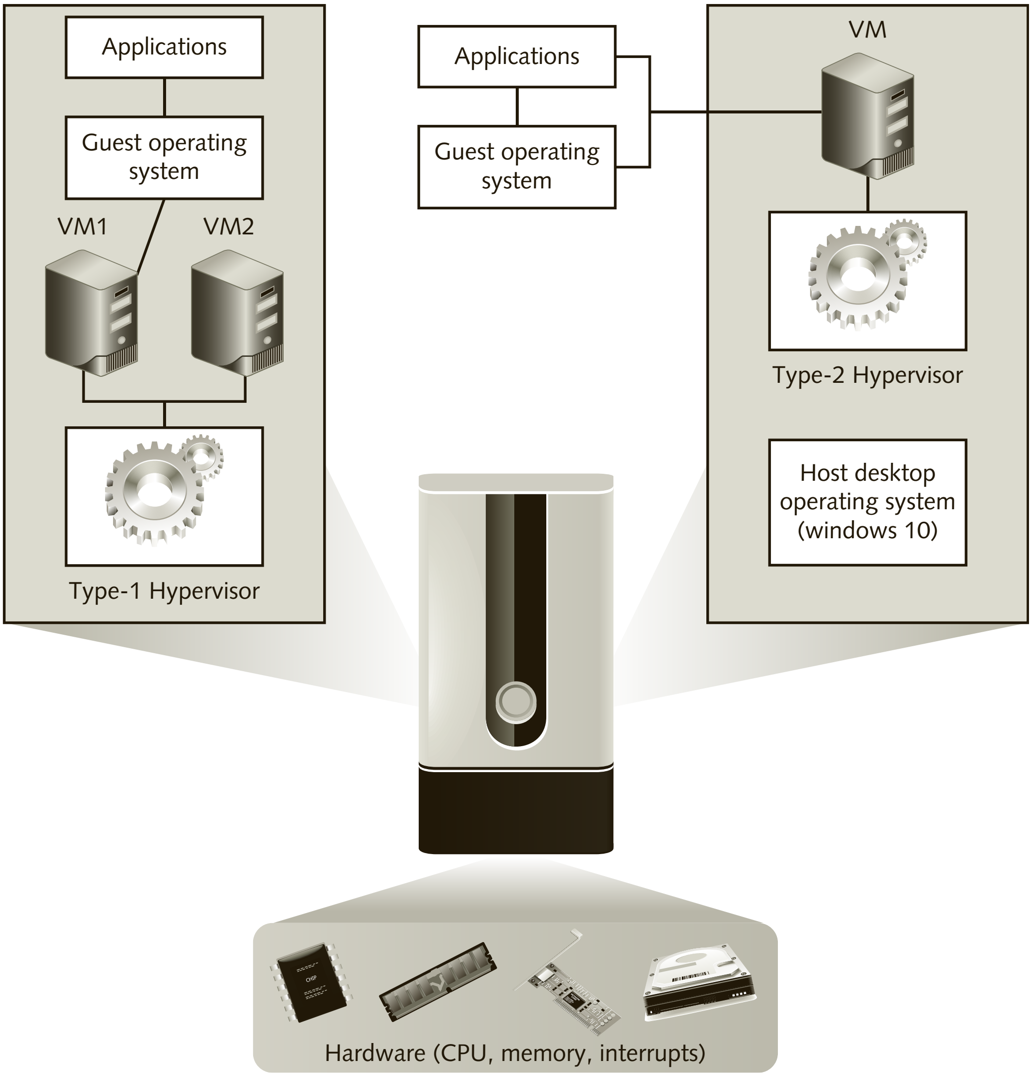

Figure 1-1 Hypervisor types

Running directly on the hardware without the overhead of a host operating system allows bare metal hypervisors to provide better performance and security, making them the choice of data centers to run virtual machines containing server operating systems. Bare metal hypervisors include products such as VMware vSphere, Microsoft's Hyper-V, and Xen hypervisor. You will work with VMware and Microsoft products in the later chapters.

Type-2 hypervisors require an operating system such as Windows, Linux, or Macintosh to manage the computer environment and are intended for use on personal workstations. The advantages of type-2 hypervisors are that they are easy to install and use, are not as hardware-specific as type-1 hypervisors, and allow you to use your normal desktop applications while still running virtual machines. Type-2 hypervisors include such products as VMware Workstation, VMware Workstation Player, and Oracle VirtualBox. You will learn how to work with these products in Chapters 2 and 3.

The computer running the hypervisor is referred to as the **host computer** since it hosts virtualized computers. When an OS is installed on a virtual machine, the virtual machine is referred to as a **guest system**, and the OS running on it is called a "guest OS."

A number of terms are used for a physical computer running a virtual machine, including "host computer," "desktop computer," and "local computer." For the purposes of this book, "host computer" is used to refer to the physical computer that is running the virtual machines.

Many of the concepts used in today's virtualization products date back to IBM mainframe computers of the 1970s. In 1998, VMware began developing and marketing commercial virtualization products for Intel x86 computers. Being first to the market and providing a number of advanced features allowed VMware to get the lion's share of the virtualization market. Today VMware still holds a large share of the virtualization market, but Microsoft and others are gaining ground.

According to a Nasdaq poll conducted in 2014, VMware held 21% of the market, but was declining due to competition from Microsoft and others.

Connectix, another company involved in early virtualization products for PCs, developed a type-2 virtualization product for running Windows applications on the Macintosh platform. Connectix ported its virtualization technology to the Windows platform in 2001 to create Virtual PC. In 2003, Microsoft purchased Virtual PC from Connectix and released it as Microsoft Virtual PC 2004. Windows 7 includes Microsoft Virtual PC 2007, an enhanced version of the original Virtual PC from Connectix. Microsoft's latest hypervisor, Hyper-V, ships with Professional versions of Windows 8 and later. If you want to run VMs on a home version of Windows 8 or later, you will need to install the virtualization software from another source.

A few companies including Oracle, Citrix, and Red Hat currently offer open source virtualization solutions based on the Xen hypervisor. Xen hypervisor is a bare metal hypervisor that began at the University of Cambridge as a research project in the late 1990s. The goal of the project was to create an efficient distributed computing platform. In 2002 the Xen hypervisor code was made open source, allowing anyone to use it and contribute to improving its features and capabilities. The XenSource organization was formed in 2004 to package and market the Xen hypervisor for commercial and educational use. A year later, Novell, Red Hat, and Sun Microsystems added the Xen hypervisor to their product offerings. In 2007, Citrix, a provider of cloud and virtual terminal services, acquired XenSource to complement their application delivery. In 2010, Oracle acquired Sun Microsystems and added a Xen hypervisor product they call Oracle VM Server to their product line. Another popular Xen-based hypervisor called KVM (Kernel-based Virtual Machine) is available through Red Hat, IBM, and other Linux distributions.

While a number of companies offer virtualization software packages, the products we cover in this book from VMware, Microsoft, and Oracle are the leading providers of commercial and open source virtualization products. The commercial products often require purchasing a license and have more advanced features, including technical support, than the free downloadable products. The free type-2 products such as VMware Workstation Player and Oracle's VirtualBox are suitable for home, small office, and school use and give users in these environments a way to enjoy the benefits of virtualization without a high cost. Most companies, including VMware, now offer their hypervisor as a free download. A license is required for technical support and advanced features or management consoles. For example, with VMware's vSphere 6, the vSphere Hypervisor (also referred to as ESXi server or host) is free, but you need to buy a license to obtain the vCenter Server used for employing advanced features and managing multiple hosts. In this chapter you will learn more about how virtualization software works, its features, and its hardware, software, and licensing requirements. In addition, you will learn about the categories of virtualization applications as well as what products are available to meet these types of applications.

How Virtualization Software Works with Virtual Machines

In traditional computer architectures, the operating system interacts directly with the installed hardware. It schedules processes to run on the CPU, allocates memory to applications, sends and receives data on network interfaces, and reads from and writes to attached storage devices. In comparison, an operating system installed in a guest virtual machine interacts with installed hardware through a thin layer of software called the virtualization layer or hypervisor. To support the operation of the guest virtual machines, the hypervisor must provide hardware resources dynamically to each virtual machine as needed. As illustrated in Figure 1-2, using the hypervisor, each virtual machine environment shares the computer's hardware resources, such as CPU, memory, disk, keyboard, video, and I/O ports, with the host computer and other virtual machines.

The hypervisor intercepts and processes requests coming from the guest operating systems and then returns the results back to the virtual machine. For example, the hypervisor uses one or more disk files on the host computer to emulate a hard drive for each virtual machine. When a guest OS requests a disk read, the hypervisor intercepts the request, accesses the data from the file representing that virtual machine's hard disk, and then returns the data to the virtual machine. The virtual machine is never aware of the actual hardware being used to store the data, as it appears to the guest OS that it is working with an actual hard drive. Sharing hardware resources allows virtual machines to operate with a high degree of

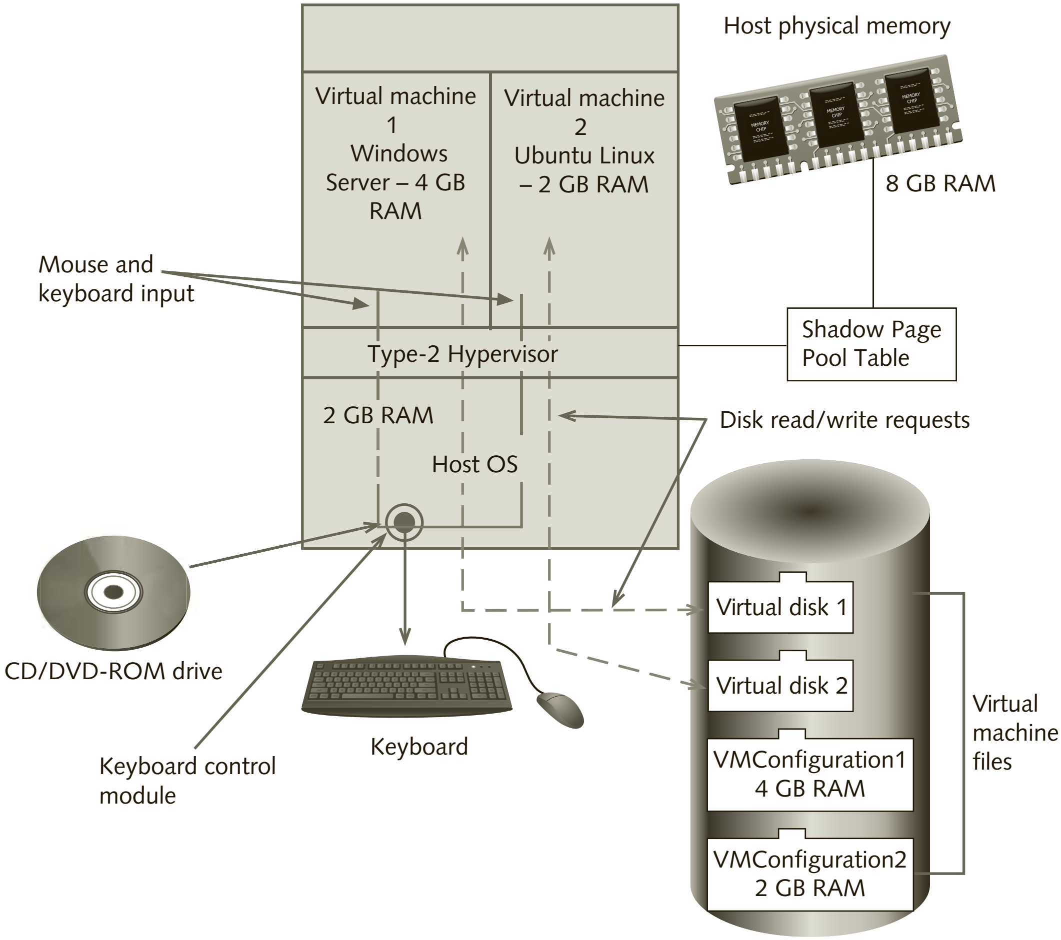

Figure 1-2 Virtualization software operation

independence from the underlying physical hardware, providing the ability for a virtual machine or its data to be moved from one physical host to another.

Type-1, or bare metal, hypervisors are more efficient than type-2 hypervisors because they access the hardware directly rather than going through the desktop operating system as shown in Figure 1-2.

When accessing the hardware, there is a slight difference between VMware hypervisors and Xen-based hypervisors such as Citrix Xen, Oracle VM Server, or KVM. Xen-based hypervisors use a special guest called Domain 0 that loads along with the hypervisor and is used to directly access the hardware. When a Xen-based guest makes a request for a hardware resource, such as doing a disk read, the Xen hypervisor sends the request to the Domain 0 guest. The Domain 0 guest then processes the request by directly accessing the disk system and returns the results to the Xen hypervisor. The hypervisor then sends the data to the guest operating system through its virtualized adapter. The downside to this process is that the Domain 0 guest may compete for resources with the other guest machines, slowing down performance. VMware on the other hand does all the hardware access inside the vSphere Hypervisor (or ESXi host), improving performance. Hyper-V works similarly to the Xen-based hypervisors in that it uses a special guest, called the parent partition, to manage hardware access. You will learn more working with Hyper-V in Chapters 5 and 6.

In addition to the hypervisor, Figure 1-2 illustrates each virtual machine having two main files on the host computer: a configuration file and a virtual disk file. The **configuration file** contains settings for virtual hardware, including the amount of physical RAM the virtual machine uses; the number of CPUs; the name, size, and location of the virtual disk file; CD/DVD-ROM settings; network configuration; port settings; and other configuration options. The hypervisor uses this information to configure the virtual machine when it is loaded. As with a physical hard drive, the **virtual disk file** contains a boot loader along with OS files and applications and data used with the virtual machine. This file will appear to the guest operating system as an entire disk drive or volume.

As shown in Figure 1-2, a virtual machine's disk system may be stored on the host computer as one or more separate files on the host computer's hard drive. Using a file to emulate a virtual machine's hard disk enables you to install and run multiple OS environments on a single host computer without creating multiple disk partitions on the physical hard drive. Virtual machine files can also be stored on shared storage or SAN drives allowing a virtual machine to be quickly moved from one host to another.

When you're running virtual machines, a section of the host computer's memory is reserved for each virtual machine, so the amount of physical memory the host computer has is a critical factor in how many virtual machines you can run simultaneously.

Peripheral devices, such as NICs and USB ports, can be shared by virtual machines and host computers. However, certain peripherals, including USB ports, the keyboard, and mouse, can be used by only one system at a time. With virtualization software, however, you can pass control of these peripherals to a virtual machine by using a menu or keystroke combination. The virtualization software covered in this book also includes optional tools that make transferring keyboard and mouse control as easy as clicking a virtual machine window or desktop. In later chapters, you learn how to install these tools for each virtualization product.

See Appendix A for a technical description of methods used by hypervisors to perform the virtualization process.

Hardware and Software Requirements for Virtualization

Host computer requirements depend on the type of virtualization software you are installing along with the memory requirements for the guest VMs you will be running. Type-1, or bare metal, hypervisors are installed directly on the host computer's hardware, which must match the hypervisor's requirements. Type-2 hypervisors install in the host computer's operating system requiring you to obtain a version of the virtualization software that is compatible with the operating system and version your computer is running. For example, VMware provides versions of its Workstation 12 package for the Windows, Macintosh, and Linux platforms. As shown in Table 1-1, over the years, Microsoft has offered a variety of type-2 hypervisors that ship with different versions of Windows.

Table 1-1 shown later in this chapter provides a list of type-2 hypervisors and what operating system they are available for.

Processor Requirements All modern computer systems since 2003 typically have 64-bit, multi-core processors that are required by most virtualization software. A multi-core processor is a single CPU chip that contains two or more actual processing units called cores. Each core is capable of independently processing instructions, enabling the CPU to run multiple programs at the same time. Multi-core CPUs are a great asset to virtual computing as the multiple cores allow the hypervisor to more efficiently share the CPU across a number of virtual machines. Many Intel processors have a feature called **hyperthreading**, which is used to create additional virtual cores that can be used by the hypervisor to improve the performance of virtual machines. In addition to multiple cores, most CPUs today have a number of features that support hardware virtualization.

Earlier hypervisors relied on software to share hardware resources among virtual machines. Both Intel and AMD now have built-in support for virtualization in their processors, improving the performance of virtualization software designed to work with these enhancements. **Hardware virtualization** helps solve performance issues by performing part of the virtualization process inside the processor chip. AMD calls this feature AMD Virtualization (AMD-V) and started including virtualization support with its Athlon 64 processors. Intel's version is called Intel Virtualization Technology (Intel VT). Depending on your computer, you may need to enable the AMD-V or VT-x support in the Host system's BIOS in order to install the hypervisor.

In addition to having a processor that supports hardware virtualization, your computer's BIOS must be able to enable virtualization. Before purchasing a computer, check to be sure the motherboard supports hardware virtualization.

Another concern when running multiple VMs on a single computer is the potential for malicious software running in one guest environment to access data or modify software running in another virtual machine. The NX/XD CPU feature, also referred to as **Data Execution Prevention**, helps isolate virtual machines by enabling the hypervisor to use a special flag (or bit) to mark certain areas of memory as non-executable. When this happens the processor will refuse to modify or execute any code that resides in the protected areas of memory. Any attempt to execute code from a page that is marked as "no execute" will result in a memory access violation. This feature adds a layer of security to virtual machines by preventing software in one VM from running or accessing information in another VM running on the same host. AMD first added the NX bit feature to their AMD64 processor line starting with the Opteron processor in 2003. Intel followed suit shortly thereafter by introducing the XD (eXecute Disable) bit with their Pentium 4 Prescott processor in 2004. Both the NX bit and the XD bit have the exact same functionality, just different names, so you will often see this CPU technology referred to as NX/XD. The NX/XD technology is standard on most processors, so almost every server built since 2006 should support it. Support for NX/XD is usually enabled or disabled in the server BIOS and is typically found under Processor options, labeled something like "Execute Disable Bit," "NX Technology," or "XD Support."

Memory Requirements The memory requirement of the host is based on the combined memory requirements of the guest systems that you plan to run concurrently. The host system must have enough memory to run the host operating system (if using a Type-2 hypervisor), the guest operating systems that run inside the virtual machines on the host system, and the applications that run on the host and in the guest operating systems. As shown previously in Figure 1-2, the hypervisor assigns physical memory (RAM) from the host computer to each virtual environment that's currently running. The amount of memory assigned to each VM is based on the amount specified in that VM's configuration file.

NOTE

You can change the amount of RAM a virtual machine uses in the administrative console.

When determining how much RAM is needed on the host running a type-2 hypervisor, you should start by allowing at least 1 to 2 GB of RAM for the host operating system and hypervisor and then add the memory requirements for each virtual machine environment that will be running concurrently.

NOTE

You can use memory overcommitment, also called overbooking as described below to assign virtual machines more memory than is available in the host computer, however, this can reduce performance.

For example, Figure 1-2 shows the amount of memory used to run two virtual machines on a Windows 10 host computer with 8 GB RAM. In this case we have allowed 2 GB of RAM for the Windows 10 host computer and hypervisor, the Windows Server guest is given 4 GB RAM, and Ubuntu Linux guest is given 2 GB RAM, for a total of 8 GB physical RAM required on the host computer. To determine the guest virtual machine requirements, you will need to check the guest operating system and application documentation for information on memory requirements for each of the virtual machines and then configure the virtual machine for the amount of memory needed. For example, to support Windows Aero graphics in a virtual machine, at least 3.25 GB of host system memory is required (2 GB of memory for the host computer, 1 GB for the Windows guest operating system, and 256 MB to the guest's graphics memory). Computer operating systems manage memory through the use of page tables. The hypervisor manages the real hardware page table for the entire host computer, but each guest operating system keeps its own page table of the memory it has allocated to its applications and services. To do this, the hypervisor places the guest's page mapping in the hardware table only when that guest is running. The hypervisor uses what is called a **shadow page table** to keep track of the memory pages allocated by each guest VM. Whenever a guest OS allocates a page of memory to its VM, that allocation is tracked by the hypervisor in the shadow page table. Often guest VMs do not need all the memory that is allocated to them. Because the hypervisor controls all the physical memory, it has the ability to make any unused memory pages in each guest available for other virtual machines or the host computer. A guest operating system that has been allocated extra memory may hold infrequently used pages of memory in its page table, making that memory inaccessible to other virtual machines. Hypervisors can use a technique called **ballooning** to cause the guest VM to release infrequently used memory pages. To implement ballooning, each VM has a special driver called a balloon driver inserted into its guest OS. When the hypervisor senses that a VM has allocated extra memory that is not used, the balloon driver for that VM is activated and it "inflates," taking up memory on that VM. This inflation process causes the guest OS running on that VM to release memory pages back to the disk pool. After the excessive memory pages are released, the hypervisor de-activates the balloon driver freeing up the extra memory pages. A byproduct of having the hypervisor's management of the physical is called **memory overcommitment** or overbooking. With memory overcommitment you can load more VMs on the host computer than the amount of physical memory. The downside to overcommitment is that it can hurt virtual machine performance when it becomes necessary to swap memory pages to the hard disk due to memory contention. To improve virtual machine performance or run more virtual machines concurrently, you can usually add RAM to the host computer to reduce memory contention.

As described earlier, the hypervisor uses a shadow page table to keep track of which memory pages are in use by each of the guest VMs. Managing this shadow page table requires software overhead and can slow down the virtual machines. Another way to improve virtual machine guest performance is by using a CPU that supports **Second Level Address Translation** (**SLAT**). SLAT, also known as nested paging, is a hardware-assisted virtualization technology that makes it possible to avoid the overhead associated with software-managed shadow page tables, improving virtual machine performance. Newer versions of data center virtualization products such as Hyper-V and VMware vSphere require CPUs that support SLAT. In Chapter 4 you will learn more about memory management and performance issues for data center environments.

Storage Requirements To determine the host computer's disk storage requirement, you need to add up the disk storage needed to install the virtualization software along with the storage needed for each virtual machine, plus any storage requirements needed to support the host computer's operating system and its applications. While memory requirements are based on the number of virtual machines that will be running concurrently, the disk storage requirements will need to include all virtual machines that may be loaded by the host computer. There are a number of storage options available depending on the virtualization software and host computer. Local disk storage includes all disk drives that are attached to the host computer using direct attachment interfaces such as PATA, SATA, and SCSI disk drives. Local disk storage is typically used for workstation virtualization products such as VMware Workstation and Oracle VirtualBox as well as environments where a virtual machine will always run on a certain host. In addition to local storage, data center virtualization products such as vSphere and Microsoft Hyper-V support shared network disk storage.

There are two major types of shared network storage: Network Attached Storage (NAS), and Storage Area Network (SAN). These storage systems will be covered in Chapter 4.

Networking and Peripherals Requirements If the virtual machines will need to access an outside network or the Internet, they can be configured to use the host computer's network interface(s). In data center applications the host computer may require multiple network interfaces to provide higher network speeds and to support more advanced virtualization features such as clustering and load balancing. The hypervisor can also share peripheral devices such as the keyboard, display, USB ports, and optical drives with the virtual machines. Only one VM can be using a specific peripheral device at one time. You will learn more about how the virtualization software shares peripheral devices and networking in later chapters.

Licensing Requirements

Virtualization software packages can either be open or licensed. Examples of open virtualization products that do not require licensing include Oracle VirtualBox, Windows Virtual PC (ships with certain version of Windows 7), Hyper-V with Windows 8 and Windows 10, and VMware Workstation Player. Data center virtualization products such as vSphere and Windows Hyper-V Server provide a free hypervisor, but require licensing for advanced features and management tools.

When you're using virtual machines, keeping licensing requirements in mind is important. From a licensing perspective, installing an OS or application on a virtual machine is usually the same as installing the product on a physical computer. For example, installing Windows 10 on a virtual machine requires activation within 30 days. If your Windows product key is already in use on another physical computer or virtual machine, you get an error message when you attempt to activate it and must purchase an additional license. Be aware that running multiple copies of the same virtual machine might violate the license agreement for software installed on the virtual system.

To make virtualization more economically feasible, Microsoft includes Hyper-V with Server 2008 or later, and has developed a new licensing system that allows network administrators to install multiple Windows Server virtual servers on a computer with a single license.

Virtualization Software Categories and Products

With the rapid increase in the use of virtual machines, hardware and software vendors are designing products to enhance virtual machine performance and capabilities. Based on their area of specialization, today's virtualization products can be classified as workstation, data center, or cloud based. In the following sections, you learn more about these types of virtualization as well as the virtualization products that support each type of virtualization.

Workstation Virtualization Products

Workstation virtualization products use type-2 hypervisors designed for creating virtual machines that run on top of an existing operating system such as Windows, Macintosh, or Linux. Workstation virtualization products have many benefits for use in home, office, education, software development, server administration, and help desk environments. Now that Apple is using the Intel processors in its Macintosh line of computers, it is possible to run Windows guest environments on the Apple Mac platform. The VMware Fusion product is an example of a virtualization package available for the Mac platform. The benefits of using virtual machines with workstation environments include the following:

- *Running user desktop environments*—Virtual machines can be used to provide the user desktop environment instead of relying on the host computer OS. In this model, virtualization software is used to run a virtual machine containing the user's OS and desktop environment settings. Because each user's virtual machine consists of just a few files, the IT Department can roll out new OS releases quickly and restore user environments by simply copying the necessary files to users' computers. In addition, a single computer can run more than one OS easily, allowing it to better meet the user's needs. Home users can also benefit from using virtual machines because each family member can have his or her own OS environment. In Chapters 2 and 3, you use Oracle VirtualBox and VMware Workstation to create and manage user desktops.
- *Running applications*—A **virtual appliance** is a software package that includes a virtual machine containing a preinstalled and configured application that's ready to use. Virtual appliances free you from installing specialized applications on your desktop computer's OS. In addition to keeping your desktop computer less cluttered, using virtual appliances makes it easier for you to move an application to another computer or run the application from different locations. Examples of virtual appliances include Web development systems, security analyzers, and database applications. You can learn more about virtual appliances by visiting *www.vmware.com/appliances*.
- *Software development*—Software developers can use virtual machines to test software by running the programs in different OS environments. Instead of needing multiple computers or having to restart a computer in a different OS, software developers can simply open a virtual machine running the OS they want and test their programs. In addition, some virtualization software can be linked to the developer's programming environment for easy debugging.
- *Configuration Workbench*—Workstation-based hypervisors can be used as a workbench to allow network administrators to install, configure, and test servers and applications prior to deploying them in the production environment.
- *Help desk support*—Virtual machines make supporting users easier for help desk personnel. A help desk agent can bring up the same OS a user is having trouble with to walk him or her through a problem. For example, a help desk agent running Windows 10 can open a Windows XP virtual machine to help a user running that OS.
- *Classroom training*—Training classes often involve using different OS environments. For example, the same classroom might be used for both Windows and Linux classes. By using virtual machines, students in a Windows 10 class can install and work with

that OS without interfering with the next class that needs to install and manage a Linux server.

Workstation virtualization software is designed to have more end-user features than data center virtualization products do, such as virtual USB ports, advanced snapshot management, and more user-friendly interfaces. As summarized in the preceding list, these features help support software development, testing, and user training. You will learn more about workstation virtualization features and benefits in "Comparing and Downloading Virtualization Products" later in this chapter.

You have a variety of workstation virtualization products to choose from, including free products from Microsoft and VMware. The products listed in Table 1-1 are designed to run on desktop OSs.

Table 1-1 Workstation virtualization products and requirements

Product Vendor	Product	Supported Host OS	Description
VMware (www.vmware.com)	VMware Workstation	Windows 7 and later Linux	Free download Requires license within 30 days Contains advanced features not available in other free products
	VMware Workstation Player	Windows XP and later Linux	Free and Paid versions available Runs existing VMs Limited features Often used to run virtual appliances
	VMware Fusion 7	Mac OS X 10.8 or later	Free download Requires license within 30 days
Microsoft	Hyper-V (client)	Windows 8 Professional or later	Ships with Windows, but needs to be activated using Control Panel
Oracle	VirtualBox	Windows 7 or later	Free products with good features and support

Although workstation virtualization products can be used to run server OSs, they don't have the performance or management features organizations need to host multiple virtual servers on a single computer. For these reasons, if you're planning to virtualize a server environment, you should consider one of the data center virtualization products described in the following section.

Virtualization in the Data Center

Like workstation virtualization products, server virtualization products emulate a physical computer's hardware. The major difference between data center and workstation virtualization is in the product's specialization. Data center virtualization products are specialized to improve performance, management, and reliability so that several servers can run on a single system. The major benefits of virtual servers are reduced hardware and power costs, server clustering, load balancing, and improved fault tolerance. You learn more about server clusters, load balancing, and fault tolerance in Chapter 4.

As servers have become more economical, many departments have become accustomed to having their own servers to run applications, which increases hardware and operating costs. In addition to separate departmental servers, today it is a recommended practice to dedicate servers to applications rather than running multiple applications on a single server. For example, a separate server is used for email, another for database, and another for file and print sharing. The accumulation of many specialized and departmental servers creates what's called **server sprawl** (see Figure 1-3).

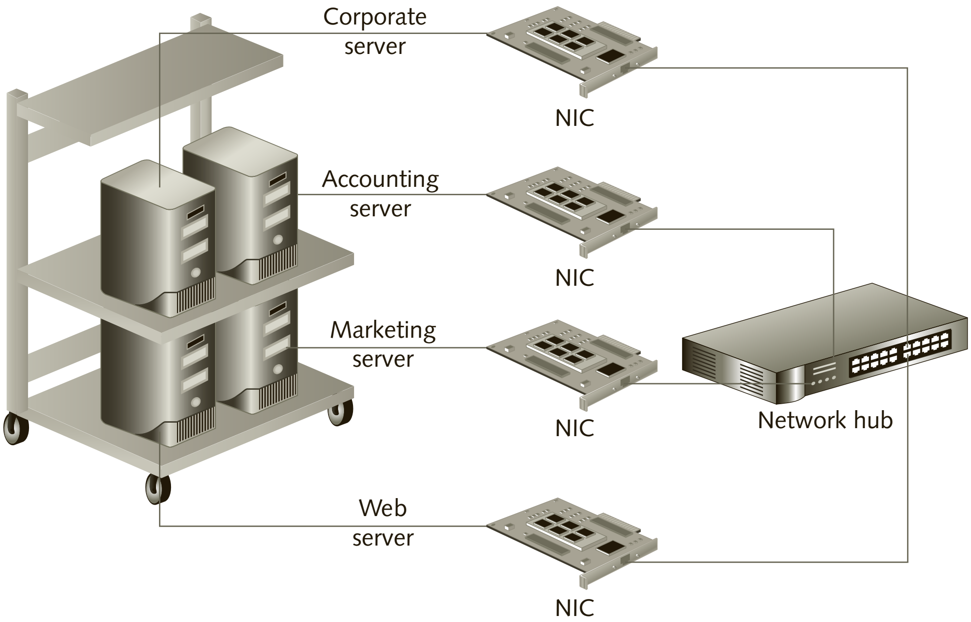

Figure 1-3 Server sprawl

Because of the speed and capacity of today's computers, using servers in this specialized fashion means they're running at only 5% to 40% utilization. Server sprawl increases costs of computer hardware and maintenance and increases power consumption. With current increases in energy costs, power consumption has become an important budgeting consideration. To help reduce hardware and power costs, almost 60% of IT organizations now use server virtualization products to consolidate multiple servers into a single high-performance system, as shown in Figure 1-4.

As mentioned earlier, a benefit of server virtualization is being able to create specialized servers to run different services, such as domain controllers, email servers, and database servers. Before virtualization, dedicating a server to each specialized service wasn't economical because it increased server sprawl and licensing costs. Virtual servers solve this problem because you can run multiple specialized virtual servers on a single computer. In addition, if a physical computer fails or gets bogged down, the virtual servers running on it can be started on another physical computer to ensure continued access during system recovery.

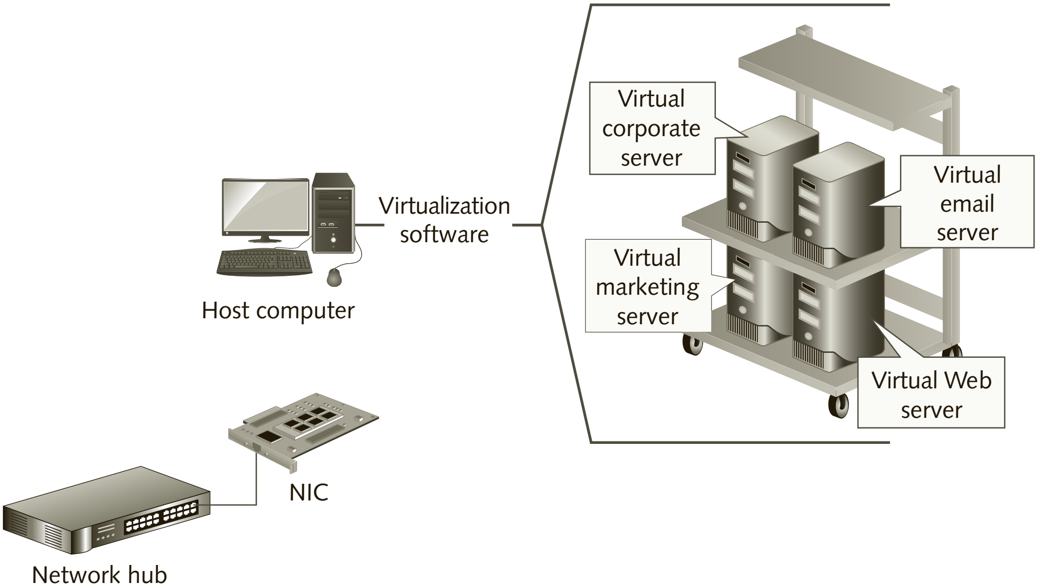

Figure 1-4 Using virtualization to consolidate several servers onto a single host

Being able to move virtual servers between physical computers helps balance server load and improve performance. In addition, reducing the number of services running on a physical server by moving each one to a separate virtual machine simplifies server configuration, improves performance, and enhances security. Keep in mind that you might need to distribute virtual servers over several physical machines to avoid overtaxing a single system when your servers are working at full load.

In addition to using a type-1 bare metal hypervisor, server virtualization products gain performance advantages over workstation virtualization products by eliminating certain features, such as advanced snapshot management, and some workstation device support. Server virtualization products also include administrative consoles for managing and configuring virtual servers remotely across networks, including the Internet. Table 1-2 lists the most common server virtualization products at the time of this book's writing.

Table 1-2 Data center virtualization products and requirements

Product	CPU Requirement	Memory Requirement	Disk
VMware vSphere	2 GHz Dual-core CPU that supports Data Execution Prevention and Hardware Virtualization	4 GB RAM	4 GB
Microsoft Hyper-V	1.5 GHz 64-bit processor that supports Data Execution Prevention and Hardware Virtualization	1 GB RAM	32 GB

Microsoft's newest product, Hyper-V, is built into all 64-bit versions of Windows Server 2008 and later. With 64-bit OSs, you can have more than 4 GB of RAM, which is useful for running multiple virtual machines simultaneously. As of this writing, Hyper-V is the only product to require a 64-bit processor with hardware virtualization support. Although including parts of the virtualization process in the processor chip can improve performance, it requires support from the host OS and the virtualization software. Current server products, such as Windows Server 2016, work directly with processor-based virtualization, which reduces software overhead.

Virtual Desktop Infrastructure

As computer technology and user needs have changed, new processing methods have been developed to better facilitate these capabilities. Early computer systems used batch processing to process a single batch of data (often contained on punch cards or magnetic tape), producing a report and updating files. Users submitted data to the data center and then waited until the next day to get their results on printed reports.

With the advent of more powerful computers and data terminals, time sharing allowed many users to share the processing power of one mainframe computer and interactively enter data, make requests, and get instant results on their terminal screens. Microcomputers allowed users to run programs on their own personal computers, accessing shared data from a file server. Personal computers that run their own operating system and applications are known as **thick clients**. The problem with thick clients is the amount of time and support that is required to update the client hardware and software, fix software problems, and ensure security and accessibility. In addition, thick clients limit the number and type of devices and locations available to the user.

Today mobility and support costs are becoming major issues in supporting user applications on thick clients. Virtual Desktop Infrastructure (VDI) helps solve this problem by running user desktops on virtual machines in the data center as shown in Figure 1-5.

A **virtual desktop** is a virtual machine that is running a desktop operating system such as Windows or Linux. In order to host the virtual desktops, the VDI infrastructure shown in Figure 1-5 requires several hardware and software components.

1. First you need host computers that have sufficient memory and storage space to support the number of virtual machines that will be running at any one time.
2. Second, you need a data center virtualization package that includes a bare metal hypervisor for each server and a management console such as the VMware vSphere and vCenter server.
3. Third, you need to create a virtual machine, called a VM image, for each user's desktop. VMware Horizon includes a software component called VMware Composer that can be used to simplify the process of creating and provisioning virtual machines for each desktop. To save disk space, virtual desktops that share a similar environment can be **linked clones**. The parent VM contains the desktop OS and all shared storage, whereas the linked clones contain only the changes that are unique for the user's desktop. You will learn more about the linked clone feature in the next section.
4. Fourth, users need a way to connect their client device to the virtual desktop. This is accomplished by having a small software package called a **thin client** on the user's device. The thin client connects to the user's virtual desktop through a connection broker. Connections can be made on the local network or across the Internet. The

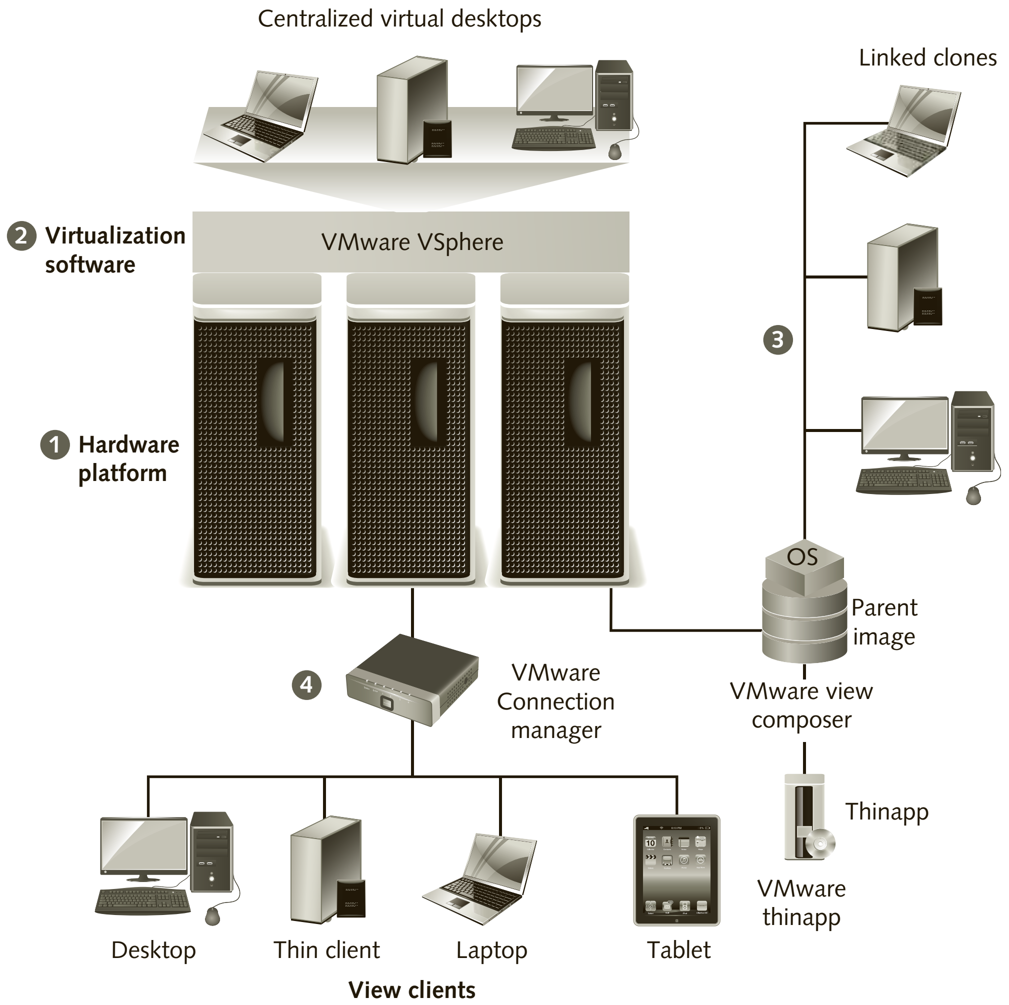

Figure 1-5 Virtual desktop infrastructure

connection broker requires the user's name and password to verify access to a virtual machine. Thin clients can run on a number of devices including desktop computers, notebooks, and tablets providing users with a variety of mobility options. The VMware Horizon product includes both a thin client and connection broker called the Connection Server.

Today, VDI has become a major player in IT data centers with a number of major companies offering VDI products (see Table 1-3). VDI allows the IT staff to host all user desktop environments on virtual machines running on powerful data center hosts or servers. IT staff can quickly deploy new virtual desktop environments or update existing environments at the data center using administrative software tools as compared to going out to the user's office or having the user bring their computer into the data center for maintenance.

In Chapter 9 you will learn more about VMware and Microsoft virtualization products that are used to support the VDI infrastructure. While there are a number of other desktop infrastructure products identified in Table 1-3, in this book we will focus on working with VMware Horizon View and Microsoft Virtual Desktop Infrastructure products and comparing their features to the other products from Microsoft, Oracle, and Citrix.

Table 1-3 Virtual Desktop Infrastructure products

Company/Product	Description	Requirements
VMware/Horizon and View	VMware View provides remote desktop capabilities to users using VMware's virtualization technology. A client desktop operating system and applications run within a virtual environment on a host using the vSphere Hypervisor (ESXi).	VMware Horizon software components (see above)
Microsoft Enterprise Desktop Virtualization (MED-V)	Enables the deployment and management of Windows Virtual PC images throughout an enterprise using Hyper-V.	Windows Server 2012 or later with R2 VDI RDS Cal License required for each user or client
Oracle/Virtual Desktop Infrastructure	Provides access to virtualized desktop environments hosted in the data center using the Oracle Virtual Desktop Infrastructure.	8 GB RAM to run 6 virtual desktops Linux or Solaris OS for the host computer and VirtualBox for the hypervisor Oracle Virtual Desktop Infrastructure
Citrix/XenDesktop and FlexCast	XenDesktop uses the FlexCast system to build a Virtual Desktop Infrastructure that can deliver desktop environments to users across a variety of devices.	XenServer Hyper-V vSphere

Application Virtualization

Application virtualization is a desktop virtualization technology that is used to run applications without affecting the desktop operating system environment. Application virtualization is different from workstation or server virtualization in that it doesn't create a separate virtual hardware environment. Instead, it abstracts the file system and Registry for the virtualized application. Allowing each application to have its own Registry and file system means you can run multiple versions of the same software on the desktop system. For example, you could install the latest version of Microsoft Office but still keep your original version active to maintain productivity while you're learning the new version.

Application virtualization products enable you to run virtual applications the same way you run standard applications on your desktop. The difference is that virtual applications leave no footprint in the host computer's Registry or file system. You can install and run these applications without causing conflicts with other applications or worrying that a new beta application might corrupt the Registry, making it difficult to remove.

Application virtualization has become an important part of VDI environments because it provides an efficient method to deliver and manage applications to a variety of user and desktops. Application virtualization products include VMware ThinApp, Microsoft App-V, and Altiris Software Virtualization Solution (SVS). These products isolate applications from their underlying operating system to eliminate application conflicts and streamline application deployment and mobility. ThinApp is a key component of VMware's Horizon line of virtual desktop products. App-V virtualizes all aspects of an application and offers advanced features, such as streaming application deployment and prepackaged virtualized applications. However, it requires Microsoft Active Directory, limiting its use to large Windows networks. SVS doesn't include all the network features of App-V but has the advantage of being more suitable to stand-alone desktop environments. The disadvantage is that it doesn't virtualize application functions, such as system and COM calls. However, it's adequate for most end-user application needs because it virtualizes the most important application objects, including the Registry and file system. With the success of these products, you can expect to see application virtualization play a bigger role in the future.

Activity 1-1: Creating a VMware Account and View Product Categories

Time Required: 10 minutes

Objective: Create a VMware account you can use for later activities and Case Projects.

Description: In this activity you will create a VMware account that you can use to obtain trial copies of products as well as free educational classes.

1. If necessary, log on to your host computer.
2. Open a Web browser and go to http://www.vmware.com.
3. Point to Login, click **My VMware**, and then click the **Register** link in the Log In frame.
4. Enter your email address and a password in the Login Information section.
5. Enter your name and business information in the Tell Us About Yourself frame.
6. Fill in the Language and Company information frames.
7. Click to put a check in the "I agree to the terms and conditions outlined in the My VMware Terms of Use Agreement" check box.
8. If you do not want to receive email, click to remove the check from the Yes check box.
9. Click the **Continue** button. After correctly entering the data, you should receive a confirmation that asks you to check your email for your registration.
10. After a few minutes check your email for a message from The VMware Team. Open the message and record your Customer Number below:

11. Click the **Activate Now** link in the email, then enter your password and click **Continue** to activate your account.
12. You should now see a window showing any current evaluations you have selected. Click the **Start New Eval** button to view the Evaluate VMware Products page.
13. Notice the various categories of virtualization products available for evaluation. You will be working with some of these products in later chapters.

14. Point to Login, then click **My VMware** to return to your account page.
15. Point to your name located in the upper right section of the page and notice your customer number is displayed. Click the **Logout** link from the pull down menu to log off.
16. Close your browser and log off the computer.

Cloud Environments

In the 1960s the cloud symbol started to be used on network diagrams to represent the complex telephone switching network used to connect devices across a long distance. Since that time, the cloud has become synonymous with data and network services hosted by servers connected through the Internet as illustrated in Figure 1-6.

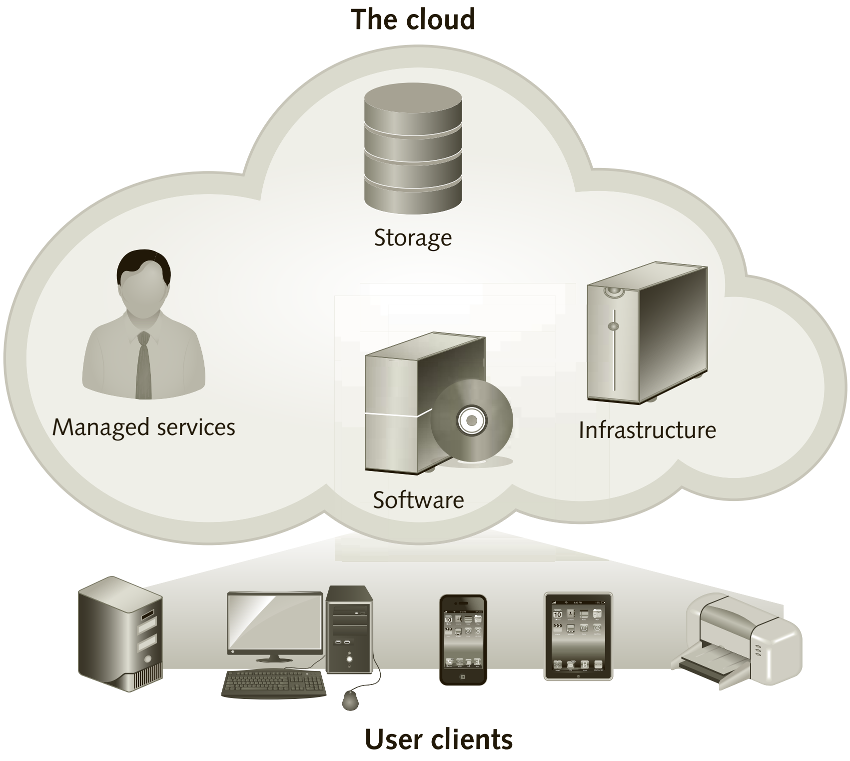

Figure 1-6 Cloud computing

Cloud services are classified depending upon the type of service as shown in Figure 1-7.

At the bottom of the stack, Infrastructure as a Service (IaaS) is the most basic cloud service offering computers and servers (typically virtual machines) along with other resources such as virtual switches, storage, firewalls, and other virtualized devices. IaaS allows a company to configure their own network operating environment using their software licenses and applications without the need to purchase and maintain all the hardware in their data center.

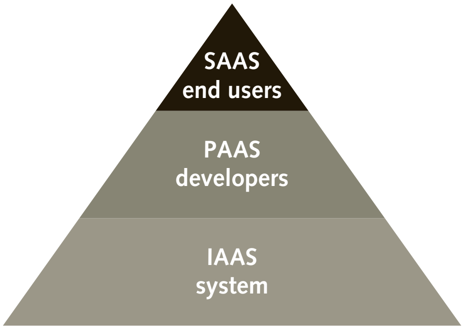

Figure 1-7 Cloud computing services

This is a very attractive option to small firms that cannot afford to invest in an expensive data center and staff. IaaS cloud services allow a company to grow by only paying for the hardware services they need.

Platform as a Service (PaaS) provides the hardware infrastructure along with the operating system software needed to run or develop the client's applications. For example, a small software development company can rent a PaaS cloud environment that includes software development tools and operating system software needed to develop and test their applications without the high cost of a software license. Like with IaaS, the client only pays for what they are using.

Software as a Service (SaaS) is perhaps the most common cloud service as it allows users to run software packages without the cost and hassle of installing the software on a device. SaaS not only saves cost and support time, it also allows users to access the applications and data they need using different devices. You may be able to do your word processing tasks from your desktop computer in the office, or use your tablet to access the software and data while on the road. In Chapter 10 you will learn how to use virtual machines to create a SaaS environment.

Virtualization technology is the backbone of cloud services. For example, when setting up a cloud service, you specify the amount of resources such as memory, CPU, and storage space needed. Rather than provision actual hardware for your account, the cloud provider will create a virtual machine that meets the requirements of your service. The cloud provider can then use load balancing and high availability to ensure that the service meets the required user access needs. As the organization's needs grow, the virtual server's storage space and processing power can be scaled to meet the new requirements. Without virtualization, cloud services have to be tied to physical equipment, making them very expensive and inflexible.

As shown in Figure 1-8, clouds can be classified as Public, Private, or Hybrid.

Public clouds can be configured to offer the services described previously to anyone connected to the Internet with a valid account. There are a number of major public cloud providers including Amazon Web Services, VMware vCloud, and Microsoft Azure. You will learn more about what services these companies provide in Chapter 10. Private clouds are hosted by the company that provides the private cloud service using virtual machines and

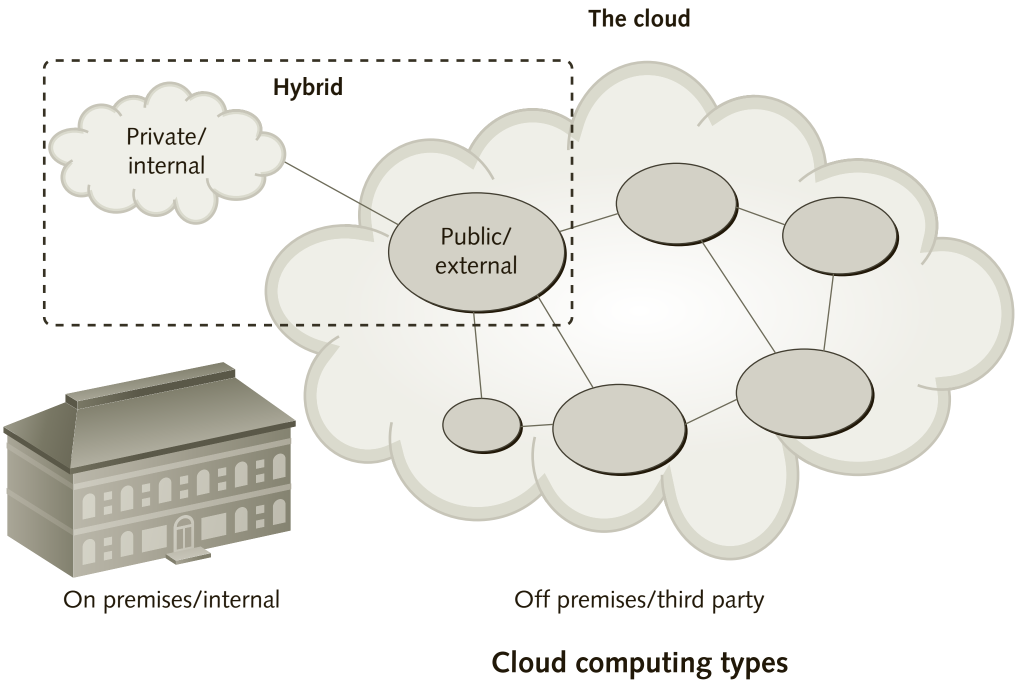

Figure 1-8 Cloud computing types

applications they maintain in their own data centers. Companies such as VMware and Microsoft offer services that can help you build private cloud services. In addition to proprietary solutions from VMware and Microsoft, OpenStack offers an open source solution that is becoming a standard for implementing private clouds. NASA worked with the Rackspace company to develop the OpenStack cloud standard and open source software in 2010. Since that time Rackspace has been a major champion of the OpenStack and provides both public cloud services along with a suite of OpenStack software companies can install to host their own private clouds. In Chapter 10, you will learn how to use these products to set up a simple private cloud environment to create and extend virtual data centers. One possible problem with hosting private cloud services is load balancing. During certain busy times the company's data center can get overloaded, slowing down the service. For example, if a company hosts an online shopping service, the data center servers could get bogged down during Black Friday. This is where a hybrid cloud service provider becomes important. Using a hybrid cloud service along with load balancing allows an organization to configure their data center so that it can off-load certain cloud services to a public cloud server during busy times. Renting the public cloud service for these exceptions is much less expensive than purchasing the additional hardware for the data center. In the following activities you will learn more about Microsoft Azure, and VMware vCloud by setting up accounts and viewing information.

Activity 1-2: Creating a Microsoft Live Account and Viewing Microsoft Azure Product Features

Time Required: 10 minutes

Objective: Create a Microsoft Live account that you can use for later activities and then view Microsoft Azure product features.

Description: In this activity you will create or access your Windows Live account and then view and record information about Microsoft Azure features. You may then use your Windows Live account to obtain a trial subscription to the Microsoft Azure service and use it to work with virtual machines and virtual networks. If necessary, log on to your host computer, open a Web browser.

1. If you already have a Microsoft Live account that you will be using for this class, go to http://live.com, enter your email address and password, and click the **Sign in** button. You may now skip to step 6.
2. If you do not have a Microsoft Live account, go to http://signup.live.com to display the Create an account page.
3. Enter the requested information and click the **Create account** button.
4. You will need to respond to an email message sent to the address you specified in step 4 to activate your account.
5. Enter the URL: http://azure.microsoft.com/en-us/pricing/free-trial/.
6. Click the **Products** link and record the popular solutions listed.
7. Click the **Virtual Machines** solution and record the features listed.
8. Log off of your Windows Live account and close the browser window.

Virtualization Features to Look for in Products

In addition to supporting multiple OSs on a single computer, virtualization software packages include many features for sharing hardware and managing virtual computer environments. You can choose from a variety of virtualization software products that offer many benefits to IT Departments, computer users, and educational environments. The following sections give you an overview of the features and capabilities found in many virtualization packages. You will get a chance to experience these features by working with various virtualization packages throughout this book.

Hardware Virtualization Features

As mentioned earlier, the hypervisor provides guest virtual machines with access to hardware devices on your computer by capturing requests for hardware devices that the virtual machine issues and redirecting them to the physical hardware. Because of this, an OS running on a virtual machine sees devices as though they were physical hardware. The system configuration information that defines memory, I/O ports, and storage devices for a virtual machine is kept in a configuration file, as shown previously in Figure 1-2, and you can view or change this information in the management consoles. The following sections describe the hardware configuration options and features that are available with the virtualization software covered in this book. You learn more details about these hardware features and how they relate to specific products in later chapters.

Motherboard and Processor Support Features The hypervisor software provides a virtual motherboard and chipset along with one or more virtual processors (vCPUs) based on the same processor model on the host computer. The hypervisor also provides emulated firmware and a CMOS for each virtual machine. You can use virtual firmware to change the virtual machine's CMOS settings, including the boot device selection. The latest hypervisors such as VMware Workstation 12, vSphere 6, and Hyper-V provide support for either the traditional BIOS or the new UEFI firmware.

In the mid-1990s, Intel developed the Extensible Firmware Interface (EFI) as an improvement to the original Basic Input Output System (BIOS) used in earlier systems. In 2005, Intel contributed the EFI standard to the Unified EFI Forum, which now manages this new standard known as UEFI.

If you are working with a recent release of the guest OS such as Windows 10 or Windows Server 2016, you may wish to use the virtual UEFI firmware as it provides more flexibility, security, and support. You will learn how to select and use both BIOS and EFI firmware in later chapters.

The CPU is the heart of any computer or virtual machine. As described earlier in this chapter, today most CPUs are designed to support virtualization. When selecting a virtualization package you need to consider how it supports virtualization. Most hypervisors support multiple virtual CPUs (vCPUs) for the guest virtual machines. Configuring multiple processors in a guest VM can help increase speed for certain VMs provided the host computer has multiple CPU cores available. However, if the host is running multiple VMs and applications, assigning extra vCPUs to guest VMs can actually decrease the guest VM performance. For example, if a guest VM has been configured with two vCPUs, the hypervisor will need to have two physical CPU cores available in order to perform the work. Waiting for the two physical CPU cores to be available at the same time can actually slow up the guest VM on a host that has limited number of physical cores. The general rule is to start with your VM using less hardware resources and then increase the number as needed. In addition to the number of vCPUs, you should check to see if the hypervisor supports both Intel and AMD hardware virtualization and Data Execution Prevention features as described earlier in the Processor Requirements section of this chapter.

Host computers that have CPUs with more cores are often preferred for running virtual machines.

Memory Support Features In addition to the CPU, memory plays a major role in virtual machine performance. In a simple world, the amount of memory in the host computer should equal the memory assigned to each concurrently running VM plus the amount needed for the host computer and hypervisor. However, there are a number of other memory management features that affect virtual machine performance. In this chapter you learned about several features including Second Level Address Translation (SLAT), ballooning, and overcommitment. When comparing virtualization products, be sure you are aware of what memory technologies they support. In addition to supporting SLAT, ballooning, and overcommitment technologies, data center virtualization products may also include support for page sharing and page compression. You will learn more about these advanced memory support features in Chapter 4.

Administrative and User Consoles

Virtualization packages include management software that you can use to create and remove virtual machines, configure virtual machine settings, manage virtual storage and network devices, start and stop virtual machines, and many other tasks, such as using templates to easily deploy multiple virtual machines rather than installing software on each virtual machine separately. Management software typically includes both administrative and user consoles. User consoles provide a window to the desktop of the OS running on the virtual machine so that users can interact with the OS and applications.

The administrative console provides an interface for creating, configuring, and managing virtual machine environments. While GUI consoles are typically the preferred environment for administrative consoles, many virtualization products use a combination of GUI and Web-based consoles for both user and administrative purposes. The advantage of Web-based consoles is that they make it easier to manage multiple virtual machines across a network or the Internet without additional software. The disadvantage of Web-based consoles is that they are slower, have lower resolution than GUI consoles, and are more cumbersome for testing systems and switching between virtual machines rapidly. The Microsoft Hyper-V GUI console uses a Microsoft Management Console (MMC) window for interacting with and managing virtual machines. Figure 1-9 shows an example of the Hyper-V MMC running on a host computer to provide user and administrative consoles.

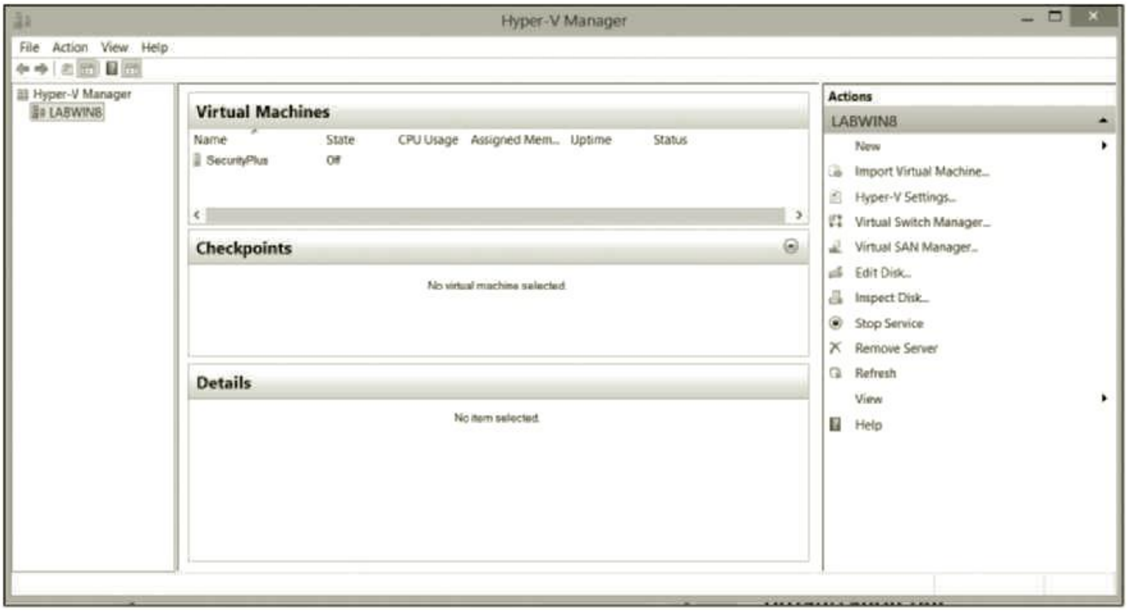

Figure 1-9 Hyper-V administrative console

Source: VMware

You will learn more about working with Hyper-V Manager in Chapter 5. In addition to a Web-based console, VMware vSphere uses the vCenter Server GUI console to manage multiple vSphere hosts or the vSphere Client GUI to work with individual vSphere Hypervisors (also called ESXi hosts). You will work with vSphere and vCenter consoles in Chapters 7 and 8.

COM and LPT Ports You can use the administrative console to configure a virtual machine to use standard COM and LPT ports by bridging them to the host computer's ports or routing their output to a file on the host computer. For example, if you're developing an application that sends output to a COM port, you can capture the virtual COM port's output to a file on the host computer. You could open that file with an editor program later and analyze the contents to make sure the application is working correctly.

USB Ports Universal Serial Bus (USB) has become the standard interface for many peripheral devices, including printers and removable storage media. Connecting a guest VM to the host computer's USB port often requires a few extra steps to enable and then capture the USB device. As of this writing, Hyper-V does not include native support for USB devices, but requires the addition of a product such as USB Redirector to connect a Hyper-V VM to a host computer's USB port. You will learn how to connect USB devices to specific virtualization products in later chapters.

USB support isn't considered as important with server virtualization because most USB devices are designed for use on desktop OSs.

CD/DVD Devices on a Virtual Machine A virtual machine can be configured to have virtual CD/DVD devices that can be linked to the host computer's physical CD/DVD-ROM drive, allowing the virtual machine's OS to use this type of media in the host computer's drive. In addition, a virtual machine's CD/DVD device can be redirected to an ISO image file. **ISO image files** use the ISO 9660 CD format to store a disc's contents in a single file on the host computer's hard drive or a network share. You can create ISO image files with a third-party tool, such as WinISO (www.winiso.com) or MagicISO (www.magiciso .com).

After creating an ISO image file, you can use the administrative console to point a virtual machine's CD/DVD device to the ISO image file rather than the physical CD/DVD-ROM drive, as shown with VMware Workstation in Figure 1-10. Using an ISO image file offers many advantages in both business and classroom settings. For example, an instructor can place an ISO image file on the classroom server for students instead of making copies of a CD/DVD for every student.

Figure 1-10 Setting a virtual optical drive to point to an ISO image file

Source: VMware

Disk Support Features

With virtualization software, a virtual machine typically uses a specially formatted file, called a disk image file, on the host computer as though it were an entire drive. As illustrated in Figure 1-11, using the hypervisor, the guest operating system will see the disk image file (VM2.VMDK) through Windows Server 2016 SCSI controller as though it was a standard SCSI disk drive.

There are a variety of disk image file formats in use by virtualization packages. Table 1-4 contains a list of the disk image file formats used by the virtualization products covered in this book.

Table 1-4 Disk image file formats

Disk File Format	Virtualization Platforms
Virtual Disk Image (VDI)	Native to Oracle VirtualBox
Virtual Machine Disk (VMDK)	Native to VMware
Virtual Hard Disk (VHD)	Native to Microsoft Virtual PC
Virtual Hard Disk Extended (VHDX) (Enhanced version of VHD to support advanced features of data center virtualization)	Native to Hyper-V running on Server 2008 and later

In addition to the primary disk drive, you can use the administrative console to create additional virtual disks for a virtual machine. As when adding drives to a physical system, the virtual machine must be shut down to add a virtual disk. Because the virtual disk file format

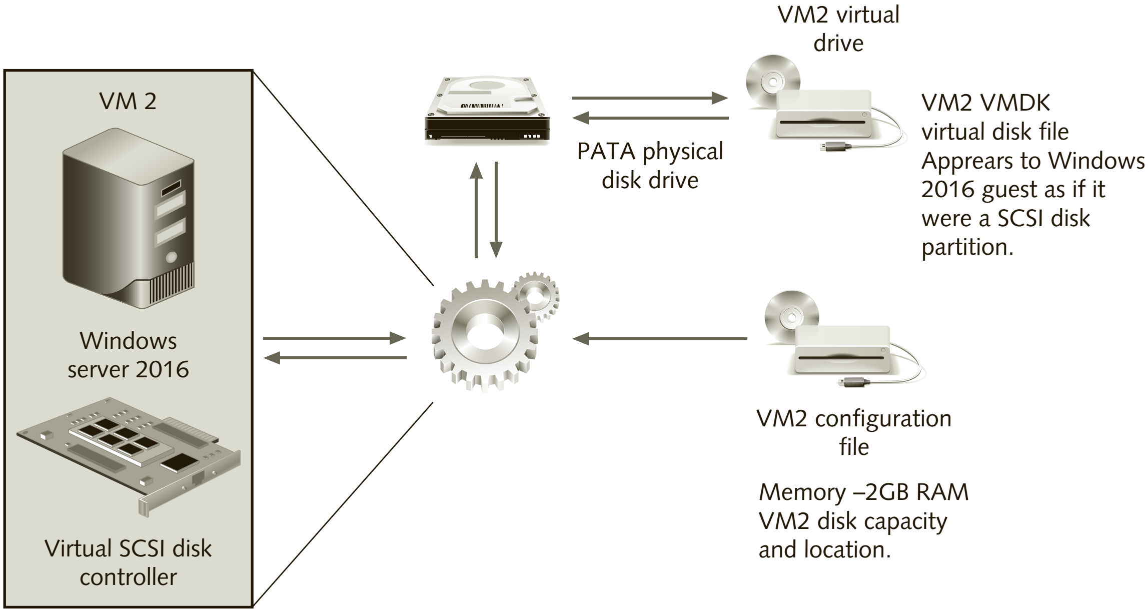

Figure 1-11 Virtual disk configuration

depends on the product used to create it, moving a virtual disk between different brands of virtual machines can be difficult. For example, a virtual machine in Microsoft Hyper-V cannot directly access a virtual disk file created by VMware. To help solve this problem, most virtualization products include an option for importing a virtual disk file from another virtual machine format.

When using workstation virtualization products, the disk image file is usually stored on a local IDE disk drive such as SATA or PATA. Data center virtualization products, such as VMware vSphere and Microsoft Hyper-V, also support storing virtual machine files on shared network drives such as a **Storage Area Network (SAN)** or **Network Attached Storage (NAS)**. In NAS, the storage device acts as a file server, allowing access to files and folders on the network based on name. The problem with NAS devices is they typically have slower access times than local hard drives and are designed to run on slower Ethernet networks. In a SAN, the storage devices are attached to a dedicated high speed network and accessed by blocks in much the same way that disks are accessed on a local file system. The most common form of SAN is an iSCSI network in which SCSI commands are transmitted across a standard TCP/IP network environment. The iSCSI SAN looks up the data by data cluster by block or cluster number and then returns the data across the network to the iSCSI controller running on the host computer. SAN systems can run at speeds similar to local hard drives, operate across high-speed networks, and often provide a more fault-tolerant storage system than NAS systems.

Using NAS or SAN shared storage allows the virtual machine to be moved quickly between host computers for high availability and load balancing. Figure 1-12 shows an example of NAS storage providing shared folders to two different host computers. In this example the virtual server VM2 is currently running on host computer 1 and accessing its virtual hard

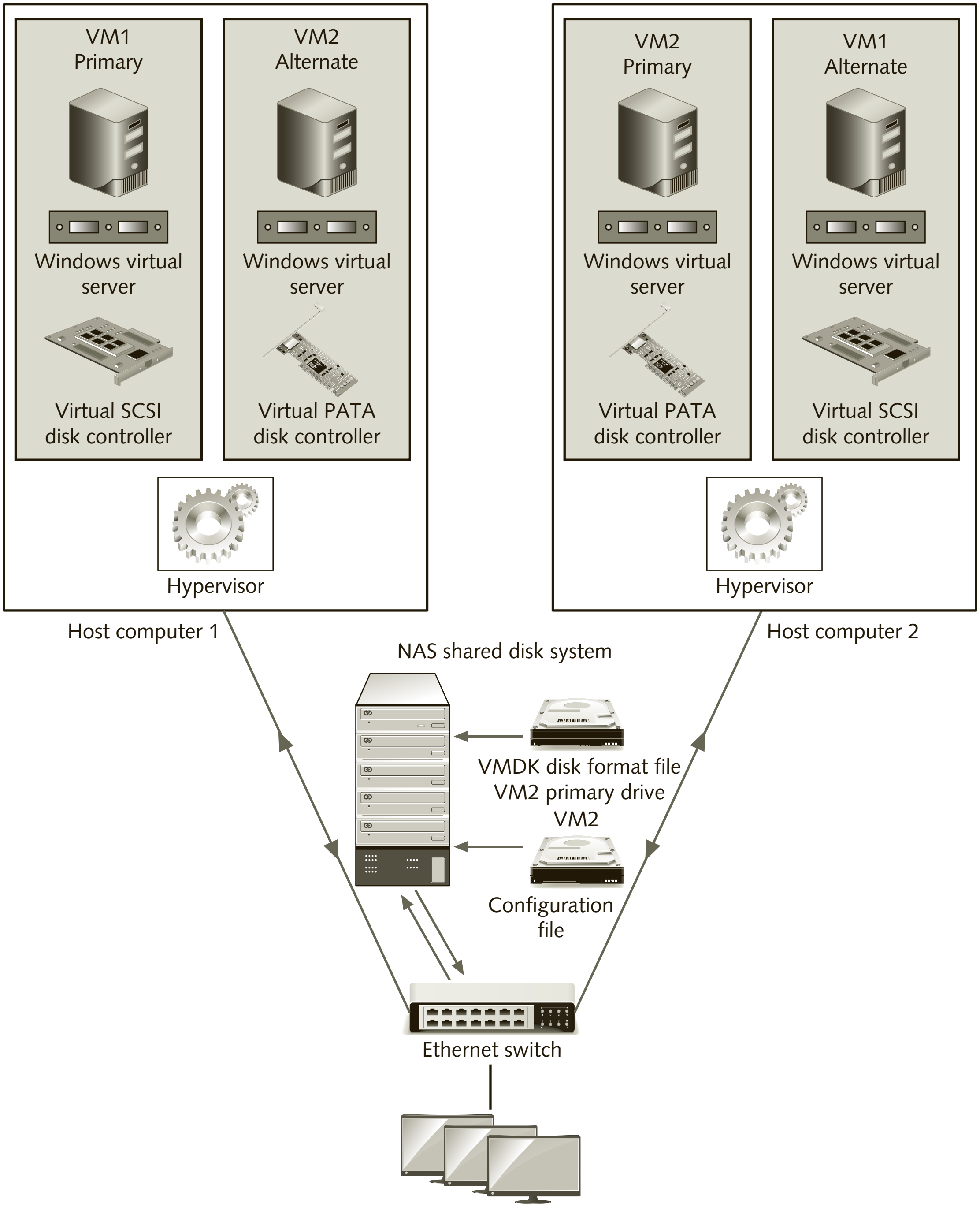

Figure 1-12 NAS system

disk storage, located on the NAS shared disk system, using a virtual SCSI disk controller. If host computer 1 fails, host computer 2 can also run the VM2 virtual machine by using the shared VM2 configuration file to load the VM2 guest. Once loaded, the VM2 guest can continue operations using its SCSI controller to access the primary drive located on the shared disk file just like it did when running on host computer 1. You will learn more about how NAS and SAN systems are used with data center virtualization systems in later chapters.

Virtual Disk Types When you create a virtual machine, you specify the type of virtual disk and the amount of disk space (fixed or dynamic) to reserve for it on the host computer. When you specify a **fixed-size virtual disk** type, the virtualization software creates a file on the host computer that takes up exactly the amount of disk space required for the virtual disk. For example, if you specify a 4 GB fixed-size virtual disk, the virtualization software creates a 4 GB file on the host computer to store the virtual disk data.

When you're using **dynamic virtual disk** types, the virtual disk file on the host computer takes up only the space the virtual disk is actually using. For example, if you select a 4 GB dynamic virtual disk and the virtual disk uses only 1.5 GB, the virtual disk file on the host computer occupies only 1.5 GB. As the amount of virtual disk space used increases, more space is allocated on the host computer's hard drive. Although fixed-size virtual disks provide better performance, they use more of the host computer's hard drive than a dynamic disk does. Because fixed-size disks provide better performance, they are often the default in server virtualization products; dynamic disks are more appropriate for workstation virtualization.

In addition to specifying the virtual disk's type and size, most virtualization products allow you to select either a SCSI or an IDE controller for the guest OS to use when accessing the virtual disk. IDE is the most common disk controller for workstation environments, whereas SCSI controllers are popular with virtual servers because they support a wider range of devices and can provide increased performance.

Saving the Virtual Machine State

An important feature in virtualization software is being able to save a virtual machine's current settings and disk contents so that you can return to this saved state later. Restoring a virtual machine to a saved state is useful in development and education environments because you can experiment with software options by performing a process several times from the same starting point. The virtualization products covered in this book include options for saving a virtual machine's state, although the methods vary depending on the vendor.

Virtualization products often offer two ways to save a virtual machine state: non-persistent disks and snapshots (also known as checkpoints in Hyper-V). With nonpersistent disks, changes made to a virtual machine are used only in the current session. When you power off the virtual machine, the disk is returned to its initial state. Nonpersistent disks are useful when you don't want your virtual machine to be affected by an activity such as testing new software or when you want to protect your system while browsing the Internet. With snapshots, you can return a virtual machine to a specific point if you have problems. For example, if you're installing new software or making a change to the system configuration, take a snapshot first. If something goes wrong, you can return your virtual machine to that point and try again. VMware Workstation includes a Snapshot Manager feature for keeping track of snapshots in a tree structure. You will get a chance to work with VMware Snapshot Manager in Chapter 3.

Early Microsoft virtualization products use undo disks to save machine states. When using an undo disk, all changes are kept in a separate file on the host computer until you shut down the virtual machine, at which time you're given a choice to apply the changes, continue to keep the changes separate, or delete all changes. Deleting all changes effectively returns the virtual machine to its original state. Hyper-V uses a snapshot management system similar to VMware Workstation called checkpoints. Checkpoints enable you to keep multiple states of a virtual machine and then return to any saved state when necessary.

Parenting and Cloning

Virtual machine parenting, which enables you to have a master (parent) copy of a virtual machine that can be distributed to other users, is closely related to snapshots and undo disks. In VMware, the virtual machine created from the parent is called a linked clone. Users don't change the parent virtual machine's settings because all changes are written to a separate virtual disk file for the clone. Parenting can be useful in educational settings. For example, an instructor can create a parent machine for each chapter of a course. Students can then create a virtual machine clone for a chapter's Case Projectsby using the parent virtual machine as the source (see Figure 1-13). Using linked clones to share a standard VM environment is also very important to implementing a VDI environment. Without linked clones, storing virtual machines for 100s of users could take a tremendous amount of disk space. Using linked clones, only a limited number of parent VMs can be shared by many users while keeping the changes and settings that are unique for each user in the small linked clone files. You will learn how to work with linked clones to support VDI in later chapters.

Similar to clones, templates are an important virtualization feature to rapidly deploy fully configured virtual machines. The main difference between a template and a clone is that the clone is a running VM and the template is not. Templates are molds that contain a preconfigured, preloaded VM that can be used to "stamp" out copies of a commonly used server or virtual desktop. Virtualization software that support templates have a check box filter on a virtual machine that allows the administrator flag the VM as a template. Virtual machines that are flagged as templates cannot be run, but they can be used to create new VMs with all the features included in the template. If you need to change the template's configuration you first remove the template flag, launch the virtual machine, make any changes to the software or hardware configuration, and then reflag the machine as a template. You will learn how to work with templates to create virtual machines in later chapters.

Moving Virtual Machines

An important advantage of using virtual machines is the ability to move a virtual machine to another host, even if that host is using a different hardware and a different operating system.

If using the same hypervisor, moving a virtual machine can be as simple as copying the virtual machine files from one host computer to the other. Moving VMs between different hypervisor brands requires using a compatible file format. If you plan to move virtual

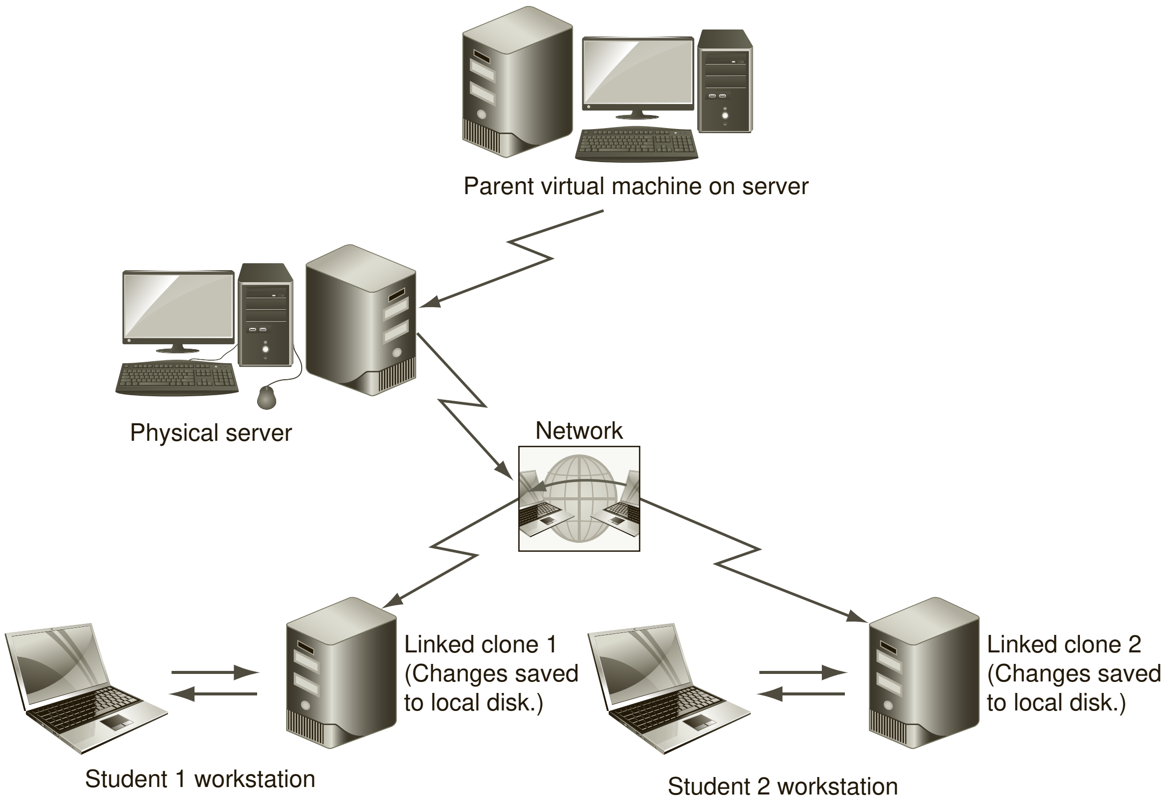

Figure 1-13 Linking clones of virtual machines with VMware

machines between hosts you should be sure the virtualization software you choose supports exporting and importing VMs by using the **Open Virtualization Format (OVF)**. OVF is a standard created by industry-wide vendors in various areas of virtualization for the purpose of copying or moving virtual machines between different platforms. For example, you could install, configure, and test a Windows mail server on a workbench using Oracle VM VirtualBox. After developing your Windows mail server using VirtualBox, you can use the export function to create a set of OVF files. You next use vSphere's option to import OVF files to place the virtual machine on your vSphere Hypervisor (ESXi). The OVF format is also often used to distribute virtual appliances. After developing the virtual appliance you can export the corresponding VM to a set of OVF files. The files can then be encapsulated into an archive and distributed with an OVF extension. Once the mail server is properly configured, you could use the export and import features to move the virtual machine containing the server, and any application software, to a host running VMware vSphere. Once running on the vSphere hypervisor (ESXi) you could assign additional hardware resources to the virtual machine such as more memory, storage, and even an additional vCPU.

The ability to move virtual machines between hosts can also be a major factor in providing high availability. VMware was the first virtualization company to support live migration of a running VM from one host to another using a process they called vMotion. Live migration of a VM requires that both hosts have the same CPU and hypervisor version. Another high availability process pioneered by VMware allows a VM to be automatically restarted on another host in the event the primary host crashes or is brought down for maintenance. High availability and live migration are now features that are available on both Xen and Hyper-V platforms. When selecting a server virtualization platform it is important to assess your high availability needs and select a virtualization platform that best supports them. You will learn more about implementing high availability and live migration in later chapters.

Network Support

With virtualization software, a virtual machine can have one or more simulated network adapters (NICs), depending on the virtualization product. As shown in Figure 1-14, a virtual network adapter can be configured in a number of ways, including bridged, local, or shared (NAT). You can think of each network mode as being a separate switch (or hub) to which you can connect the virtual machine's NIC.

When a virtual machine is in **local mode** (called "**host-only mode**" in VMware), its emulated NIC is plugged into a virtual switch that includes the host computer and other virtual machines running in local mode on the host computer. For example, in Figure 1-14, virtual machine VM2 and the host computer communicate by using a common IP address scheme on the local switch. If another virtual machine, such as VM1 or VM3, is configured to use the local switch, it can also communicate with VM2 and the host computer.

In Figure 1-14, VM1 uses **bridged mode** through its attachment to the bridged switch. Because the bridged switch includes the host computer's physical NIC, VM1 can use the network's IP address scheme to communicate with all devices on the local network and access other networks, including the Internet, as though it were a separate computer attached to the local network. You can use the administrative console to change a virtual network adapter's connection to any switch, even while the virtual machine is running.

Because communicating directly on the virtual network can cause network problems when you're running test servers or if virtual machines are configured incorrectly, bridged mode is often discouraged in testing environments. In addition, local mode doesn't allow connections to outside networks, such as the Internet. **Shared (NAT) mode**, however, allows access to outside networks yet isolates the virtual machine, preventing it from sending and receiving packets across the physical network. This mode uses a virtual switch running **Network Address Translation (NAT)** to convert packets coming from the virtual machine to use the host computer's IP address. The result is that all network traffic coming from the virtual machine seems as though it's originating from the host computer. The virtualization software on the host computer acts like a router, taking requests from outside networks and passing them to the virtual network, using the IP address assigned to the physical NIC. When a virtual machine is connected to a shared (NAT) switch, the Dynamic Host Configuration Protocol (DHCP) service running on the host computer automatically assigns the virtual machine a private IP address and gateway configuration to send packets to the host computer.

Data center virtualization products such as vSphere and Hyper-V Server allow you to create virtual switches for a variety of purposes. A virtual switch works like a physical switch except that it can have an almost limitless number of ports. You will learn more

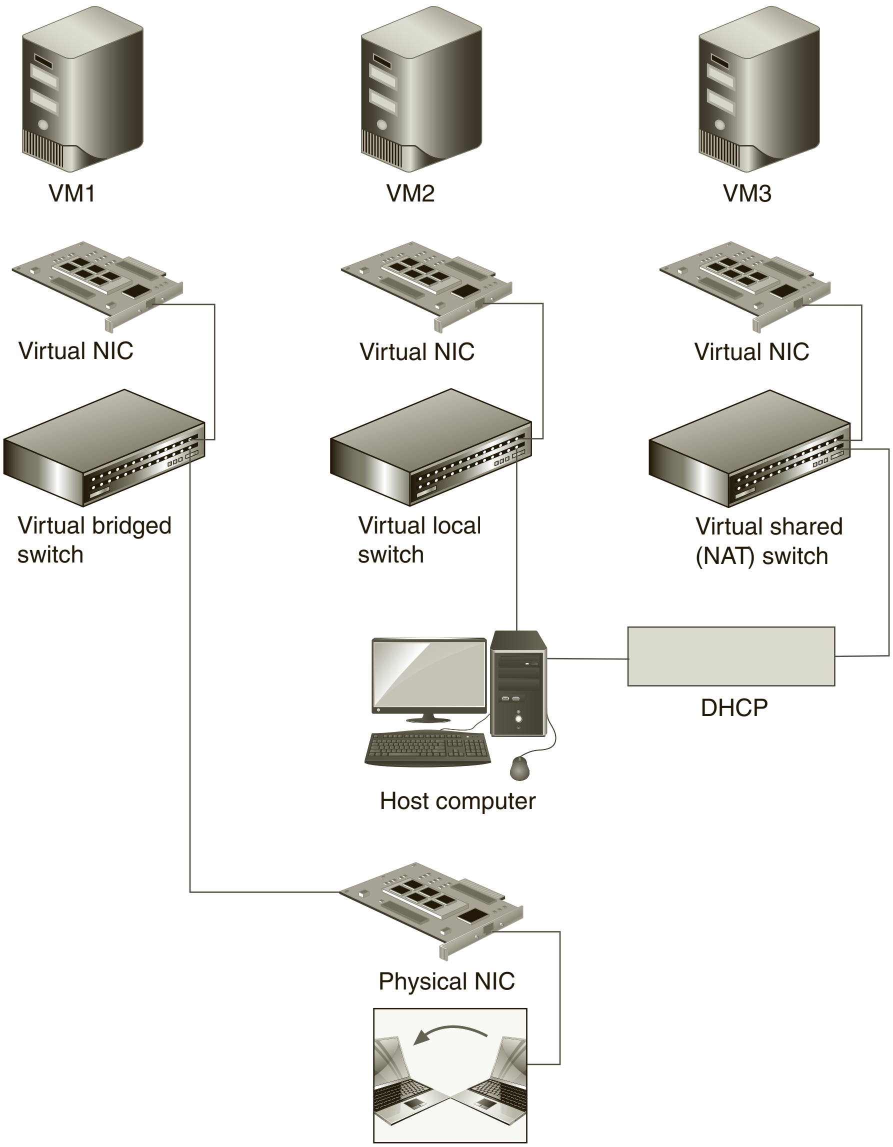

Figure 1-14 Virtual network adapter options

about creating and managing virtual adapters and switches for data center virtualization in Chapter 4.

Migration Tools

Most virtualization packages offer migration tools for importing virtual machine files from other sources and creating a virtual machine environment based on a physical computer. Being able to create virtual machines from physical computers has many benefits, including