chapter 8

Virtualization

VIRTUALIZTION IS THE USE of hardware and software to create the perception that one or more entities exist, although the entities, in actuality, are not physically present. Using virtualization, we can make one server appear to be many, a desktop computer appear to be running multiple operating systems simultaneously, a network connection appear to exist, or a vast amount of disk space or a vast number of drives to be available.

Learning Objectives

This chapter examines virtualization in detail. By the time you finish this chapter, you will be able to do the following:

- Define and describe virtualization.
- Discuss the history of virtualization.
- Describe various types of virtualization.
- List the pros and cons of virtualization.
- Identify applications that are well suited, as well as those that are not suited, for virtualization.
- Describe why companies should employ virtualization.

Understanding Virtualization

Virtualization uses hardware and software to create the illusion that two or more entities are present, when there is only one physical entity in existence. The most common forms of virtualization include the following:

- **Server virtualization**: Making one server appear as many. Each **virtual server** may run the same or different operating systems. Server virtualization provides greater CPU utilization, a smaller equipment footprint, less power consumption, and support for multiple operating systems.

- **Desktop virtualization**: This allows a user to switch between multiple operating systems on the same computer. (An operating system that resides within a virtualized environment is known as a **guest operating system**.) Some desktop virtualization techniques can provide an operating system environment on demand. Desktop virtualization provides support for multiple operating systems, which is very convenient for software developers, testers, and help desk support staff. In addition, desktop virtualization leads to ease of computer maintenance and reduces desktop IT staff administration.

- **Virtual networks**: These create the illusion that a user is connected directly to a company network and resources, although no such physical connection may exist. Virtual networks are sometimes called virtual private networks or VPNs. Using a virtual private network, users can connect to a network and access the network resources from any Internet-connected computer. Virtual networks also allow network administrators to segment a network, making different departments such as management, development, and sales appear to have their own separate networks.

- **Virtual storage**: This provides users (and applications) with access to scalable and redundant physical storage through the use of abstract, or logical, disk drives or file systems, or a database interface.

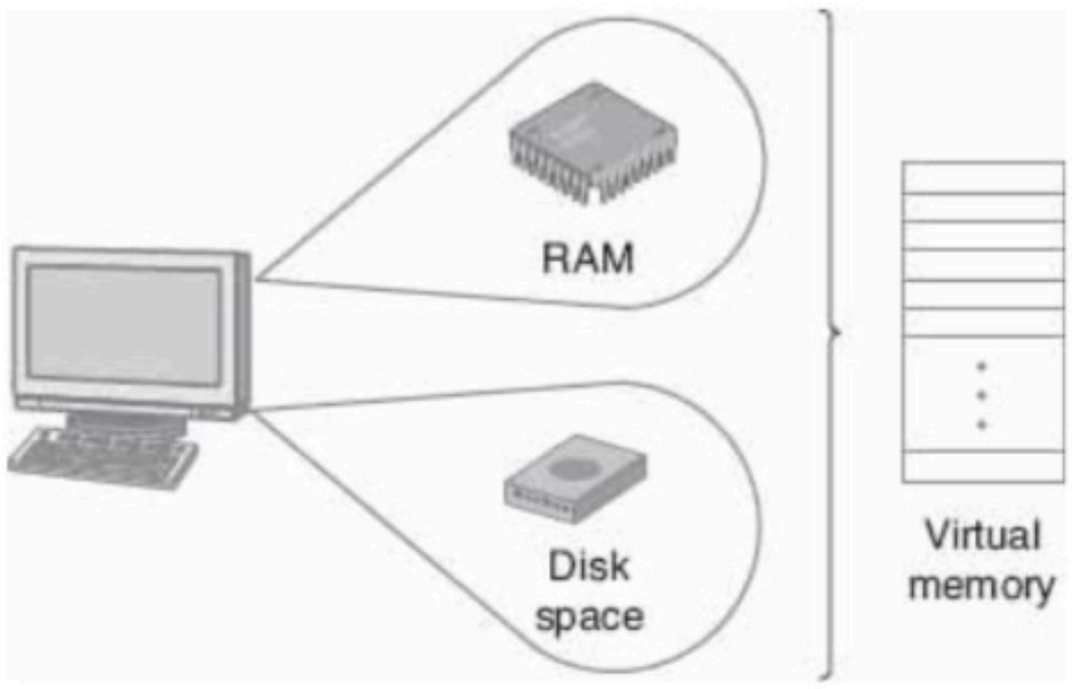

FIGURE 8-1 Virtual memory combines RAM with a page file on disk to create the illusion, to running programs, of the existence of a vast amount of RAM.

The History of Virtualization

Although virtualization has, over the past few years, become one of the hottest topics in computing, it's not a new idea. IBM, more than 30 years ago, had a

virtual operating system that allowed a mainframe computer to run multiple copies of the same or different operating systems. Further, most operating systems support virtual memory, which, as shown in **FIGURE 8-1**, combines random access memory (RAM) and a page file on disk to create the illusion that a process (a running program) has much more physical RAM than is present in the computer. Windows, Linux, Mac OS, and other operating systems all support virtual memory.

CASE 8-1 VIRTUAL MEMORY

Virtual memory is not physical memory (RAM). Instead, virtual memory combines RAM and space on a connected disk, called a page file, to create the illusion, to running programs, that a vast amount of RAM exists.

Before the CPU can execute a program, the program's instructions and data must reside within RAM. Virtual memory takes advantage of the fact that not all of the program's instructions or data must be in RAM at the same time. Rather, the CPU needs only the instructions and data with which it is currently working to reside in RAM.

A virtual memory operating system breaks a program's instruction and data into fixed-size chunks called pages. When the CPU needs specific instructions or data, the operating system loads the corresponding page from disk into RAM. When the CPU no longer needs a set of instructions or data, the operating system can move the pages from RAM back to disk. This process of moving pages between RAM and the page file on disk is called paging.

The advantages of virtual memory include the following:

- A running program (process) appears to have unlimited memory.
- The operating system can easily manage several different programs, running at the same time, and keep each program's data and instructions secure.
- The operating system can take advantage of disk storage, which is considerably less expensive than RAM.

The disadvantage of virtual memory is that the paging process (the process of moving instructions and data between RAM and disk) adds overhead, mostly because disk drives are much slower than RAM.

Exercise With computers supporting larger amounts of physical memory, some users argue that there are applications for which users should turn off virtual memory to improve performance. Discuss whether you agree.

Web Resources For additional information on virtual memory, see www.CloudBookContent.com/Chapter08/index.html.

Leveraging Blade Servers

For years, when user demands required additional servers, the IT department would add a physical server box within the data center, as shown in **FIGURE 8-2**.

Although the server box met user demands, each box consumed space within the data center and required considerable power.

FIGURE 8-2 Server computers originally required their own chassis, disk, power supply, and fan. Servers consumed considerable power, took up considerable space, and generated considerable heat within the data center.

CASE 8-2 GREEN COMPUTING INITIATIVE

Years ago many people made the claim that computers, e-mail, and computer networks would reduce the vast number of printed pages and that many forests would be spared. Unfortunately, the "less paper" thing never happened. Worse yet, with desktops, laptops, and handheld devices now touching all aspects of our lives 24/7, most devices never get powered off!

The result is that computer and device power usage is growing at exponential rates. Because of the impact that computers now play with respect to our environment, many green computing initiatives have emerged. Some general guidelines for green computing include the following:

- Power off devices when they are not in use.
- Power up energy-intensive devices, such as laser printers, only when needed.
- Use notebooks when possible instead of desktop computers.
- Use the computer's built-in power management features.
- Minimize unnecessary printing.
- Dispose of e-waste (devices, ink cartridges, monitors, and so on) in compliance with government regulations.

For more specifics on green computing, visit the Green Computing Initiative website hosted by the University of California, Berkeley, shown in **FIGURE 8-3**.

Exercise Discuss potential cost savings for a company supporting green computing initiatives.

Web Resources For additional information on green computing, see www.CloudBookContent.com/Chapter08/index.html.

FIGURE 8-3 The Green Computing Initiative details a variety of techniques and best practices.

As the server boxes were outgrowing many data centers, the blade server was born. In short, the blade server, as shown in **FIGURE 8-4**, is a scaled-down server

designed to consume less power and to fit within a rack with other blade servers, while still matching or exceeding the processing potential of chassis-based servers.

To share disk space, blade servers support network-attached storage (NAS) devices. Additional advantages of blade servers include the following:

- Consume less physical space (footprint)
- Consume less power
- Generate less heat and are easier to cool
- Easy to install and configure

Server Virtualization

Most servers today are either very busy, running at a high level of CPU utilization, or are idle a significant portion of the time, waiting for something to do. As you have learned, when a server becomes very busy, the IT staff may, as shown in **FIGURE 8-5**, introduce a load-balancing server and then add additional servers, as necessary, to handle the workload.

FIGURE 8-4 The blade server is designed to fit within a rack with other blade servers. This reduces the server's physical footprint, makes the server easier to cool, and reduces the server's power consumption.

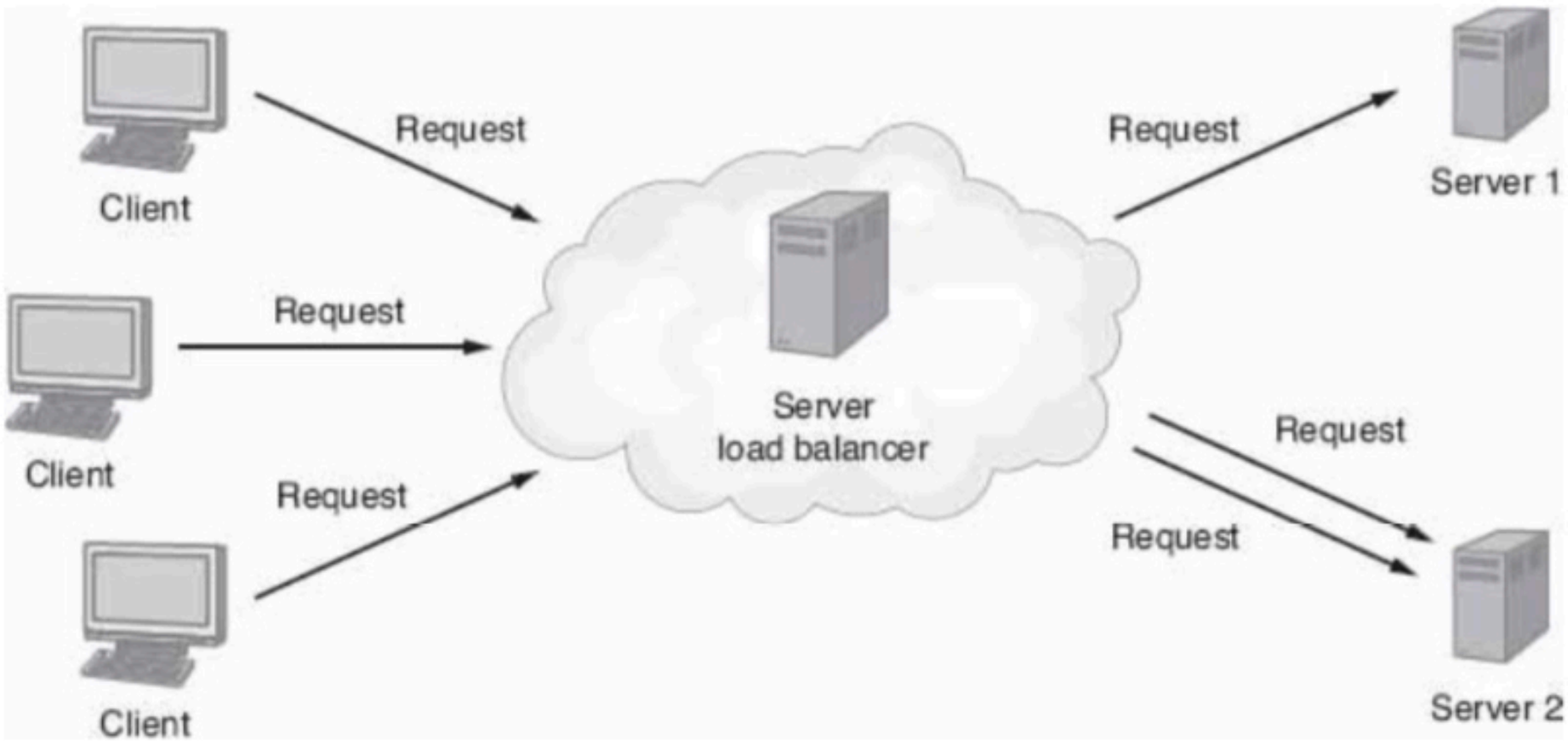

FIGURE 8-5 Using load balancing, the IT staff can supply the number of servers necessary to meet the server workload at a given time.

In contrast, when a server is idle, the server's potential processing power is being wasted. For a cloud-based platform as a service (PaaS) provider, such wasted processing time is a wasted revenue opportunity.

To reduce server idle time and to protect one client's server from another, PaaS providers use special software to divide the single physical server into multiple virtual servers. As shown in **FIGURE 8-6**, each virtual server may run a different operating system.

Improving CPU utilization is one reason to virtualize servers. Second, some companies (including PaaS providers) need to support multiple server operating systems. Fortunately, several tools exist to make it easy to virtualize most server operating systems.

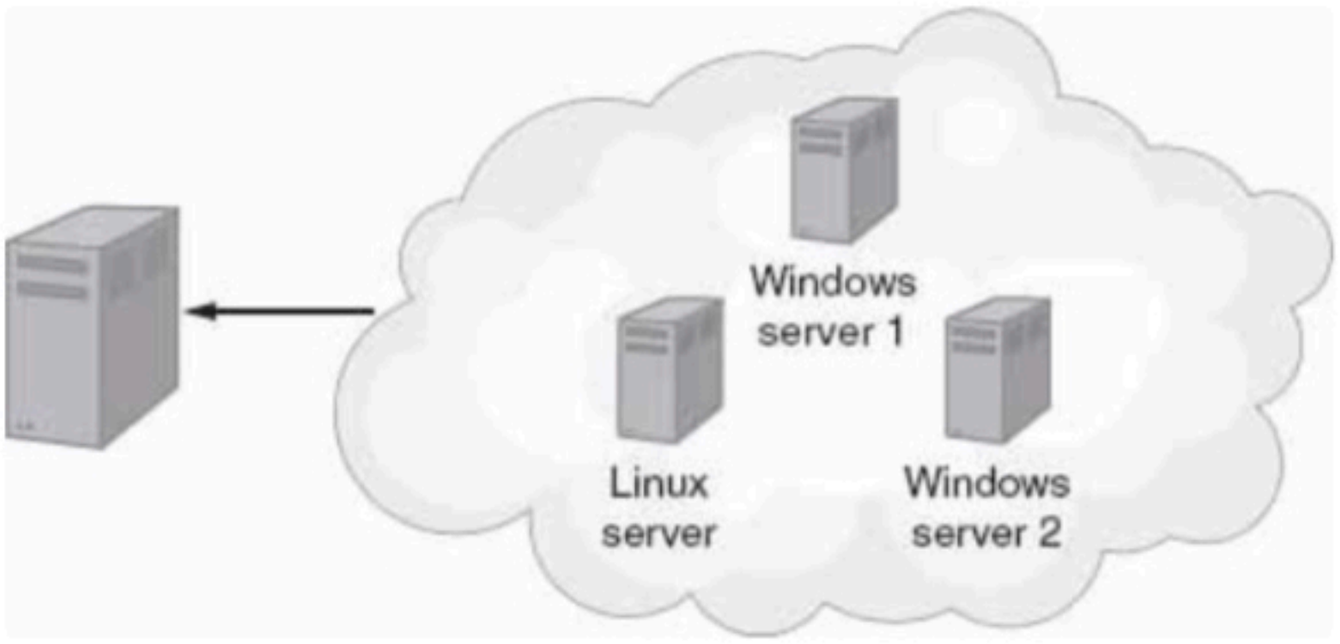

FIGURE 8-6 Through virtualization, a single physical server can be made to look like multiple separate servers, potentially running different operating systems.

CASE 8-3 MICROSOFT WINDOWS SERVER VIRTUALIZATION

Given Microsoft's aggressive approach to cloud computing, it makes sense that Microsoft would also aggressively pursue client and server virtualization. Microsoft servers now utilize an underlying technology the company refers to as Hyper-V to allow administrators to create virtual servers.

The advantages of Microsoft Hyper-V technology include the following:

- The ability to consolidate servers and increase CPU utilization
- Enhanced business continuity and disaster recovery
- Ease of deploying testing and support environments
- Enhanced support for Windows-based client virtualization
- Improved load balancing
- Ability to move live virtual machines from one physical server to another on the fly for load balancing and scalability

Exercise Assume your company primarily deploys .NET-based solutions. Periodically, however, your company releases a PHP or Perl solution running under Linux. Discuss the pros and cons of using Microsoft-based virtual servers.

Web Resources For additional information on Microsoft server virtualization, see www.CloudBookContent.com/Chapter08/index.html.

Within a virtual server, to support the execution of multiple operating systems, each operating system is actually installed on top of special software called the **hypervisor**. The hypervisor, in turn, essentially manages each operating system's execution and resource use.

CASE 8-4 VMWARE ESXI

VMware is one of the best-known providers of virtualization solutions. For companies that need to support multiple operating systems within a

virtual-server environment, VMware ESXi provides the solution. That said, ESXi is more than a simple server-virtualization tool. ESXi provides the following:

- Support for multiple operating systems
- Server consolidation
- Automated resource management to drive disaster recovery and service-level agreements
- Detail cost-reporting services
- Automated load balancing
- Centralized management and administration of virtual servers and the underlying machines

Exercise Assume your company must deploy virtual-server solutions for Windows and Linux. You anticipate that you will require only one physical server running the two virtual operating systems. Research and discuss the pros and cons as well as the costs of using VMware server virtualization.

Web Resources For additional information on VMware server virtualization, see www.CloudBookContent.com/Chapter08/index.html.

Desktop Virtualization

If you continue thinking in terms of the server-virtualization model, virtualizing the desktop means allowing the system to run multiple operating systems at the same time, as shown in **FIGURE 8-7**. The term for a desktop computer that runs two or more operating systems is a **virtual desktop**.

If you consider a software tester who must test multiple operating system platforms, or a help desk staff member who must answer calls from users running a variety of operating systems, you can understand how the ability to quickly switch between operating systems is very convenient and powerful.

The advantages of desktop virtualization of operating systems include the following:

- A single desktop computer can simultaneously run multiple operating systems.
- There is reduced need for duplicate hardware.

- Less power is consumed.

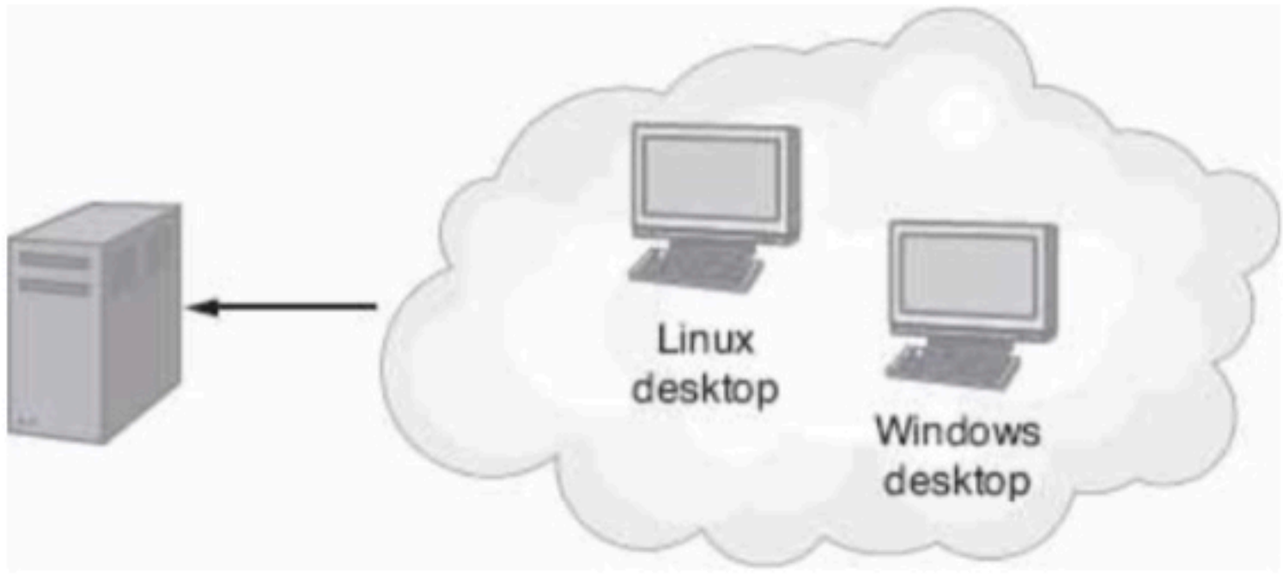

FIGURE 8-7 Desktop virtualization allows a desktop computer to run two or more operating systems at the same time and allows a user to quickly switch between the systems.

CASE 8-5 PARALLELS DESKTOP 4 WINDOWS AND LINUX

Parallels Desktop 4 for Windows and Linux lets users easily integrate and install multiple Windows- and Linux-based operating systems on the same desktop computer. Users can then quickly switch between operating systems as easily as clicking the mouse on the target operating system window. **FIGURE 8-8** shows Windows and Linux running on the same desktop computer using Parallels Desktop 4 for Windows and Linux.

Exercise Assume that your company has 10 programmers who write and test code for applications running on Windows and Linux, and they must also support applications running on these operating systems. Discuss the pros and cons as well as the costs of using Parallels Desktop 4 for Windows and Linux.

Web Resources For additional information on Parallels Desktop 4 for Windows and Linux, see www.CloudBookContent.com/Chapter08/index.html.

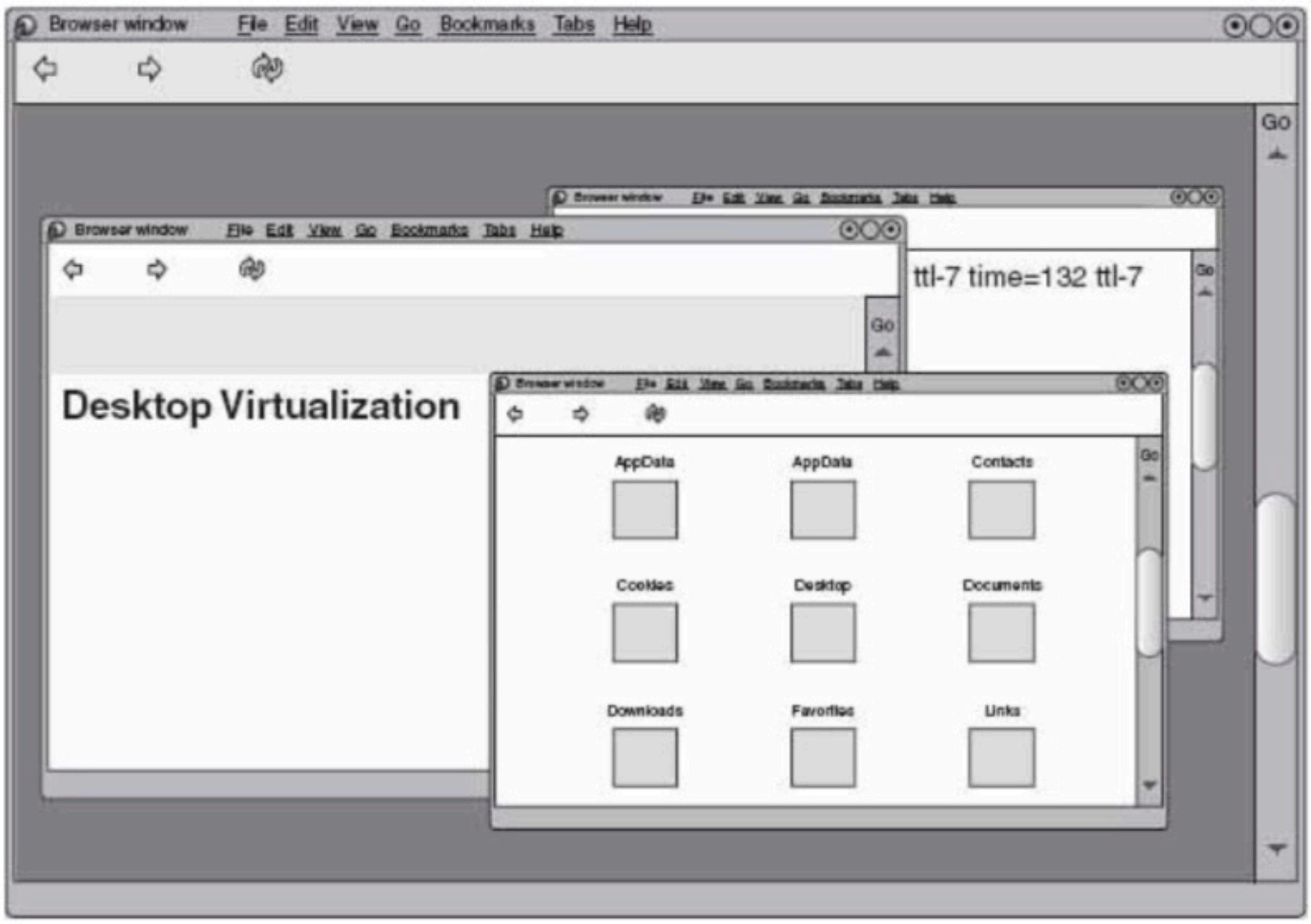

FIGURE 8-8 Using Parallels Desktop 4 for Windows and Linux to allow users to quickly switch between operating system environments.

The primary disadvantage of the virtual desktop is that the system incurs overhead due to the virtualization and will not be as fast as an identical standalone system running a single operating system.

Desktop Solutions on Demand

For years, desktop computer management went something like this:

- A new employee joins the company. The IT staff, in turn, prepares a computer with the needed software and delivers it to the new employee's desk.

- When it comes time to upgrade software, an IT support member carrying a CD-ROM disk would visit each desktop computer and take as long as needed to install the software. A high-tech data center, would then have a desktop administrator push the upgrade across the network either at night or early in the morning.

- When users encountered problems, the IT staff member would again show up at the user's desk to troubleshoot the problem, or the high-tech data center would have a help desk support team member remotely log in to the user's computer from across the network.

- Users who were frustrated with the IT staff and its processes would simply install software on their own systems, which the company may or may not own.

In any case, managing user desktop computers took time, money, and labor.

With faster computer networks, along with the migration to cloud-based solutions, the approach to desktop management is changing. Today many data centers are moving to on-demand delivery of desktop operating system environments. In this way, when a user logs in to a system, he or she receives access to his or her system customizations, assigned operating system, and needed applications.

CASE 8-6 MICROSOFT DESKTOP VIRTUALIZATION

Most desktop computers today run a Windows operating system and a Microsoft suite of applications (normally Office). To simplify the management of such desktop systems, Microsoft provides a suite of desktop virtualization tools:

- Microsoft Virtual Desktop Infrastructure (VDI) suite
- Microsoft Application Virtualization (App-V)
- Microsoft Enterprise Desktop Virtualization (MED-V)
- Microsoft Remote Desktop Services (RDS)
- Microsoft User State Virtualization (USV)
- Windows Thin computer

The advantages of the Microsoft desktop virtualization include the following:

- Simplified desktop management across the enterprise
- Access to user profiles and data from any computer
- Improved business continuity

- Improved management of software licenses
- Improved security and business compliance

Exercise Assume that your company has 1,000 desktops, for which your CIO wants to deliver an operating system and environment on demand. Discuss which Microsoft desktop virtualization tools you would require and the corresponding cost.

Web Resources For additional information on Microsoft desktop virtualization, see www.CloudBookContent.com/Chapter08/index.html.

As shown in **FIGURE 8-9**, in an on-demand operating system, software and user settings are pushed to a desktop across the network.

Because the operating system and applications reside within a centralized location within an on-demand environment, administrators can easily apply patches and software upgrades, which are transparently downloaded to the user's computer the next time he or she logs in. Further, the on-demand environment frees the user from ties to any one specific computer. A user can log in to the system from any network computer and receive his or her work environment.

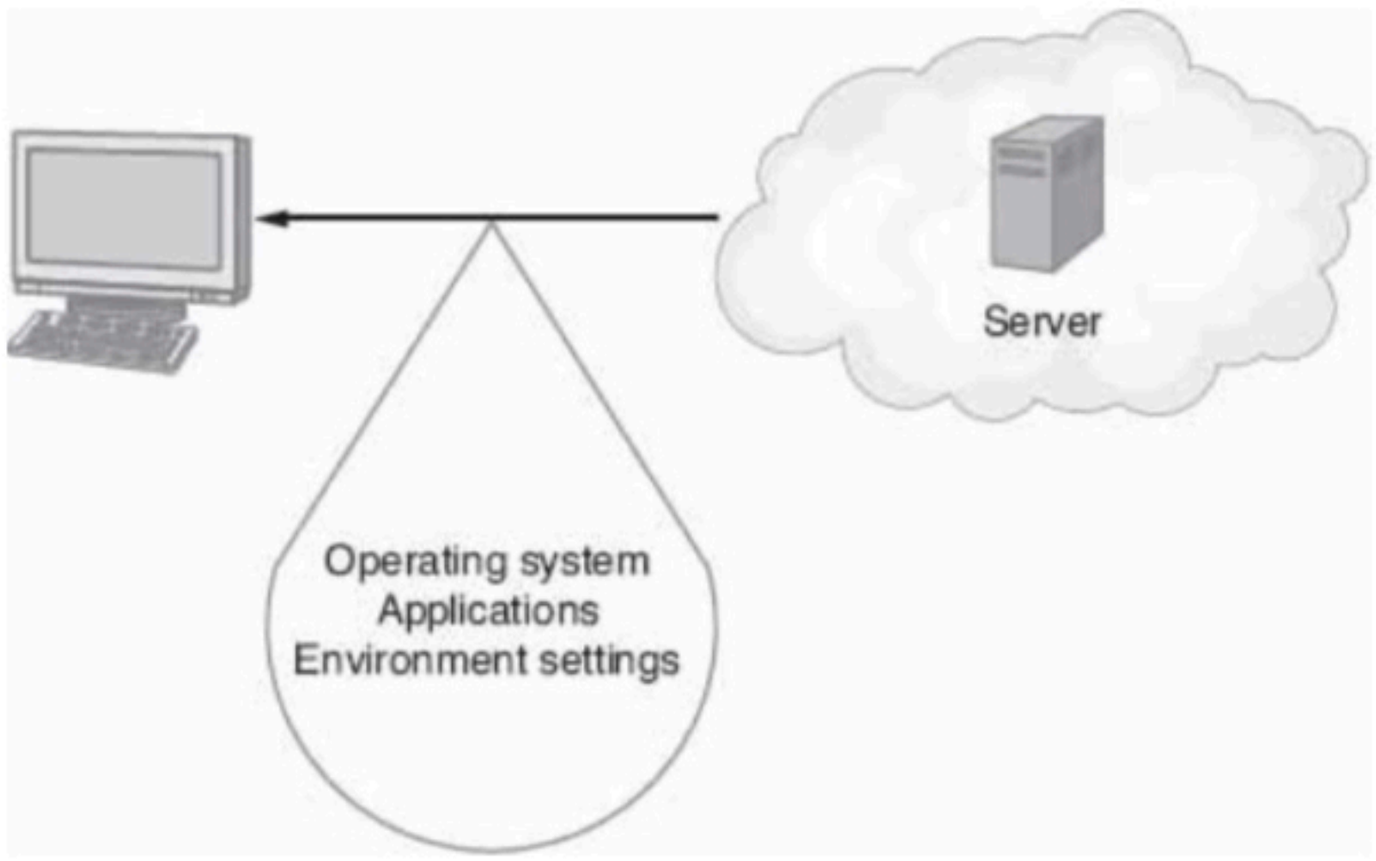

FIGURE 8-9 On-demand operating system environments deliver a user's operating system, environment customizations, and needed applications to any computer the user logs in to.

CASE 8-7 VMWARE VIEW

As one of the top leaders within the virtualization space, VMware offers View, a tool for providing virtual desktops on demand. Using View, system administrators can centralize the on-demand delivery of an operating system and user-assigned applications. The advantages of VMware View include the following:

- Simplified desktop operating system and application management
- Automated desktop provisioning (account generation)
- Virtual-desktop image management
- Support for a variety of client platforms

Exercise Discuss the pros and cons of using VMware, as opposed to Microsoft, to implement a company's desktop virtualization.

Web Resources For additional information on VMware View desktop virtualization, see www.CloudBookContent.com/Chapter08/index.html.

Virtual Networks

Networks allow users to share resources such as printers, storage devices, and applications. Most businesses utilize a local-area network (LAN) to connect users. Typically, LANs are just that—the cables or wireles devices that connect users are local to a specific office, building, or campus, as shown in **FIGURE 8-10**.

Often users who travel and users who work from remote locations must connect to the company's LAN in order to accomplish specific tasks. In such cases, the users can use special software to create a **virtual private network (VPN)** connection to the LAN. VPN software, as shown in **FIGURE 8-11**, uses a secure Internet connection to give the user the illusion that he or she is physically connected to the remote network from his or her current location.

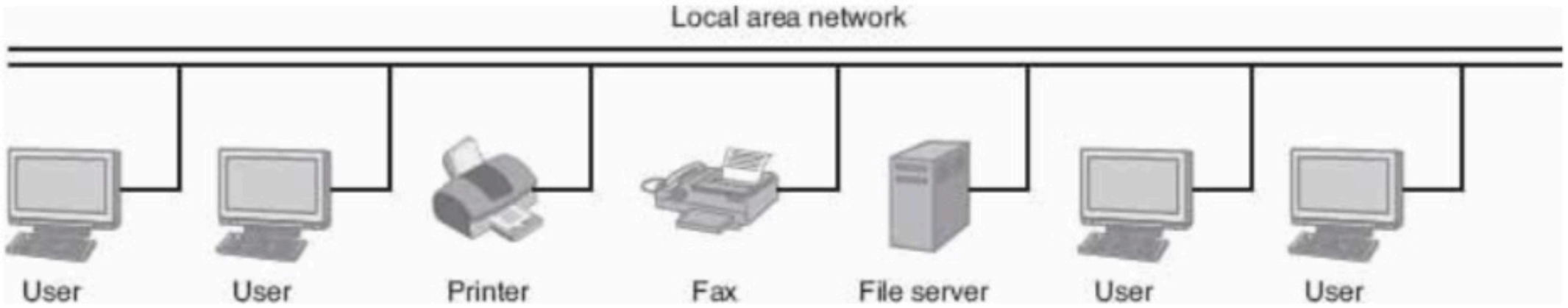

FIGURE 8-10 LANs are designed to allow users to share resources within a localized environment such as a home, business, office building, or small campus.

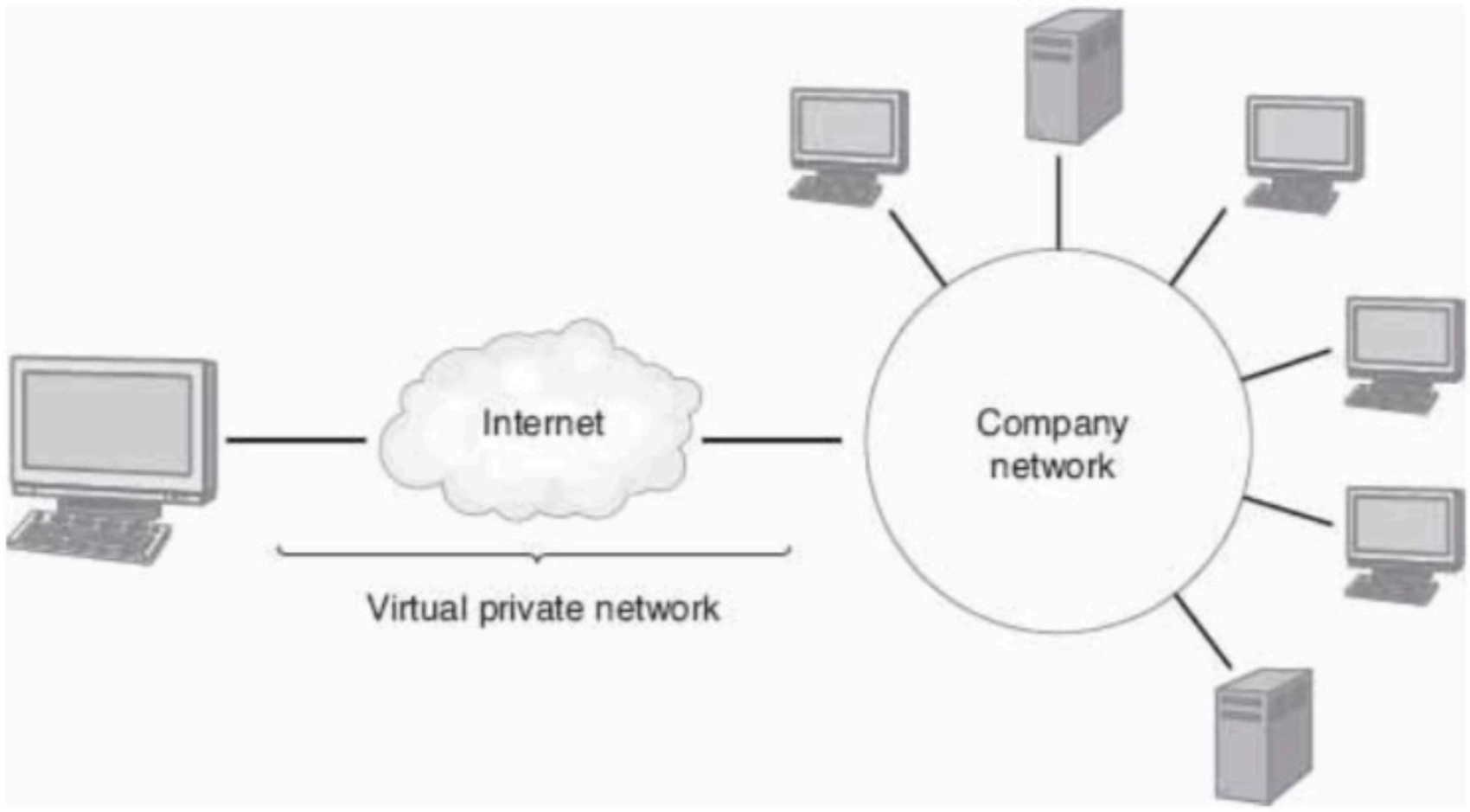

FIGURE 8-11 A VPN creates the illusion of a secure physical connection to a LAN using software and/or hardware to connect the user across the Internet.

When multiple employees work remotely, there may be times when the group needs to establish its own network in order collaborate securely and effectively. Rather than establish a physical network for the group, companies will configure a virtual local-area network (VLAN), which uses special routers to segment part of the physical network in such a way that the group appears to have its own private network.

CASE 8-8 WINDOWS VPN SUPPORT

Across the web, several companies, including Cisco, provide advanced VPN support. Should you need to get a VPN connection up and running quickly, however, Windows provides both client and server support. **FIGURE 8-12**, for example, shows the Windows Create VPN Connection dialog box that lets a client establish a VPN connection across the Internet. To create the connection, the user needs only to know the IP address or domain name of the remote VPN server.

Exercise Discuss the pros and cons of using VPN software provided with Windows as opposed to licensing or buying a solution from a network company such as Cisco.

Web Resources For additional information on Windows VPNs, see www.CloudBookContent.com/Chapter08/index.html.

FIGURE 8-12 Windows provides client and server support tools that users can use to establish a VPN connection.

In a similar way, for internal security purposes, companies may use virtual networks to create separate networking environments for sales, management, development, and support, as shown in **FIGURE 8-13**.

Again, many companies such as VMware and Cisco provide support for the creation, management, and security of VLANs.

Data Storage Virtualization

Chapter 6, *Data Storage in the Cloud*, discussed cloud-based data storage in detail. You learned that the advantages of cloud-based data storage include the following:

- Scalable disk storage space on demand
- The ability to pay as you go for the needed storage
- Behind-the-scenes backup and data replication
- Support for common operating systems
- Access from anywhere, anytime, and essentially any device
- Ease of document sharing

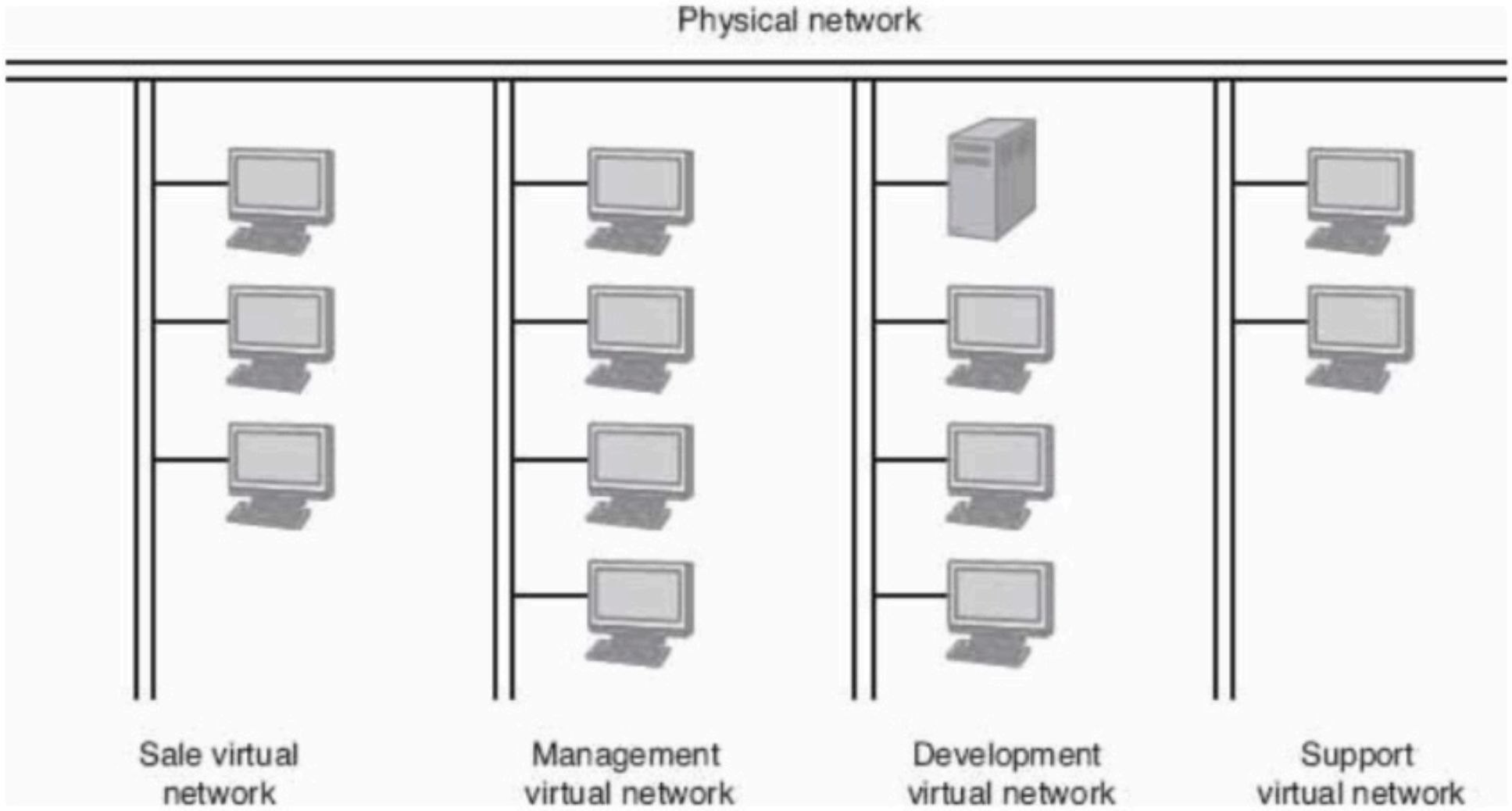

FIGURE 8-13 Virtual networks create the illusion of two or more stand-alone networks.

The primary disadvantages of cloud-based storage include the following:

- Some users are not comfortable with their data residing in the cloud.
- Cloud-based file access is slower than local file access due to network overhead.

Data storage virtualization essentially separates the physical data storage from the logical presentation that users (and applications) use to access the device. For example, computer users will often partition a large (physical) hard drive into two more logical drives (often drives C and D).

The process of making a device available to a user or application is called mounting the device. As you learned in Chapter 6, several cloud-based data storage providers allow users to mount the virtual storage so that the user can refer to the storage area using a familiar disk drive letter.

Again, as shown in **FIGURE 8-14**, the data storage virtualization hides the physical details of the actual storage device, which makes it very easy for administrators to scale the available storage space.

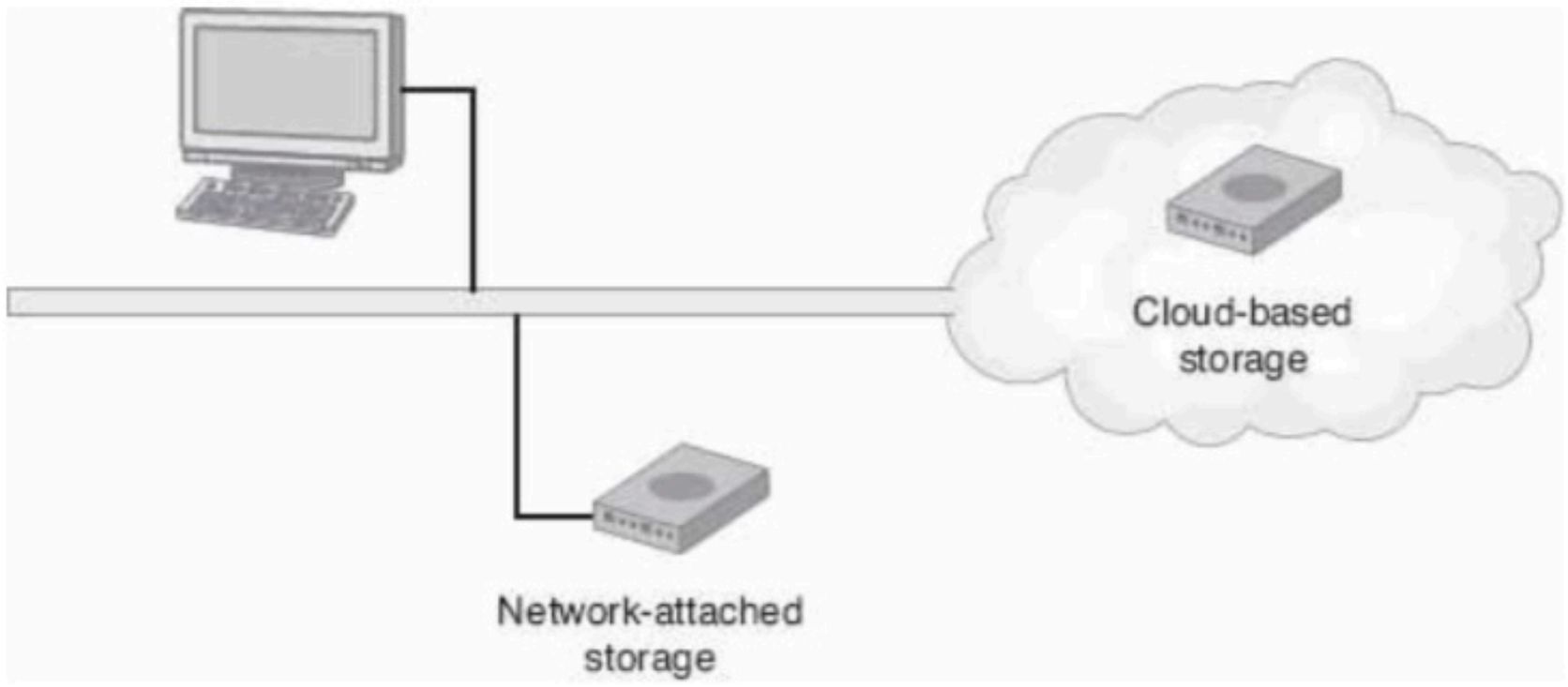

FIGURE 8-14 Data storage virtualization hides the physical storage device or devices from the logical presentation that users or applications use to access the space.

CASE 8-9 VMWARE STORAGE VMOTION

Despite the virtual nature of cloud-based storage, at some point, an administrator, somewhere, must manage the physical data-storage devices. The administrator may want to upgrade a device to a larger or faster drive, or, simply move data for load balancing. Unfortunately, to perform such upgrades, an administrator simply can't call "time out" and take the device off line.

VMware's Storage vMotion allows an administrator to move files from one virtual data store to another while the virtual disk is active for use! If a user updates a file on the source disk while the move is in progress, the Storage

vMotion software simply takes note and then later updates the file on the target disk.

Exercise Discuss application types for which a data storage device cannot be taken offline in order to perform system updates.

Web Resources For additional information on VMware Storage vMotion, see www.CloudBookContent.com/Chapter08/index.html.

Not All Applications Are Well Suited for Virtualization

Despite the performance utilization gains that most applications will experience within a virtual environment, some applications are not well suited for virtualization:

- **Applications with unique hardware requirements**: If an application requires a unique device or hardware device driver, the virtualization software may be unable to support the device.

- **Graphics-intensive applications**: If an application is graphics intensive, such as a 3-D modeling program, the virtual device drivers may slow down the I/O processing to an unacceptable level.

Why Virtualize?

Throughout this chapter, you have examined a variety of virtualization techniques. The following list summarizes a company's motivation to virtualize:

- Increased device utilization (particularly CPU utilization)
- Decreased device footprint
- Decreased power consumption
- Simplified operating system and application administration
- Ease of software provisioning and patch releases
- Device and storage scalability
- Increased user access to key resources
- Increased flexibility in supporting multiple operating system environments

- Improved use and management of software licenses
- Improved utilization reporting, which leads to improved capacity planning
- Improved disaster recovery and business continuity

The primary disadvantages of virtualization include the following:

- New staff or staff training may be required to understand the virtualization process.
- Not all applications are well suited for virtualization.
- The virtualization process adds slight overhead, which will make some applications run more slowly.

Chapter Summary

Virtualization is the use of hardware and software to create the perception that one or more entities exist, although the entities, in actuality, are not physically present. Using virtualization, we can make one server appear to be many, a desktop computer appear to being running multiple operating systems simultaneously, a network connection appear to exist, or a vast amount of disk space or a vast number of drives to be available.

Through the use of server virtualization, companies reduce their server footprint and power consumption, allow servers to support multiple operating systems, and drive server CPU utilization. Further, through the use of desktop virtualization, companies simplify operating system and application administration. If needed, a virtual desktop can also run two or more operating systems at the same time.

Virtualizing drives increases device utilization, simplifies device administration, and improves business continuity and disaster recovery.

Key Terms

Guest operating system

Hypervisor

Virtual desktop

Virtual private network (VPN)

Virtual server

CHAPTER REVIEW

1. Define and describe virtualization.

2. Defend the following statement: Virtualization is not a new concept within computer science.

3. Describe the various types of virtualization.

4. List the pros and cons of virtualization.

5. Discuss the attributes of applications that are *not* well suited for virtualization.

6. List reasons why companies should virtualize.

7. List the benefits of blade servers.

8. Define and describe the hypervisor.

9. Define and describe green computing.

10. Describe the concept of the desktop on demand, and include the benefits of such a system.