CHAPTER 5

IT Infrastructure and Emerging Technologies

LEARNING OBJECTIVES

After reading this chapter, you will be able to answer the following questions:

5-1 What is IT infrastructure, and what are the stages and drivers of IT infrastructure evolution?

5-2 What are the components of IT infrastructure?

5-3 What are the current trends in computer hardware platforms?

5-4 What are the current computer software platforms and trends?

5-5 What are the challenges of managing IT infrastructure and management solutions?

5-6 How will MIS help my career?

CHAPTER CASES

PeroxyChem's Cloud Computing Formula for Success

Is Business Ready for Wearable Computers?

Look to the Cloud

Is BYOD Good for Business?

VIDEO CASES

Rockwell Automation Fuels the Oil and Gas Industry with the Internet of Things (IoT)

ESPN.com: The Future of Sports Coverage in the Cloud

Netflix: Building a Business in the Cloud

MyLab MIS

Discussion Questions: 5-6, 5-7, 5-8; **Hands-on MIS Projects:** 5-9, 5-10, 5-11, 5-12;
Writing Assignments: 5-18, 5-19; **eText with Conceptual Animations**

PeroxyChem's Cloud Computing Formula for Success

PeroxyChem is a leading global supplier of hydrogen peroxide and related substances for electronics, paper production, and household medical products. The company is headquartered in Philadelphia, Pennsylvania and has about 500 employees; generates over $400 million in revenue; and operates research, sales, and manufacturing facilities in North America, Europe, and Asia.

In February 2014 PeroxyChem was divested from its parent company and had just one year to take over management of its business systems. It would have to create its own IT infrastructure and IT department, all while keeping day-to-day business systems and operations running smoothly. As part of a large corporation, PeroxyChem had not been responsible for maintaining and managing its own IT systems but suddenly had to become self-sufficient. The company was understandably reluctant at that point to take on the cost or risk of procuring its own hardware, setting up a data center on premises, and maintaining a large in-house IT department, nor did it have the in-house expertise to do so.

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According to PeroxyChem CIO Jim Curley, management didn't want to change any of its applications, but it did want to transition to a cloud infrastructure where the computer hardware and software for running a firm's systems are available as on-demand services in remote computing centers accessed via the Internet. The goal was for PeroxyChem IT personnel to spend only 40 percent of their time on operational tasks to keep the company running and 60 percent on strategic projects designed to grow the business. PeroxyChem also lacked the time and resources to hire and train new personnel to run day-to-day operations.

PeroxyChem worked with IBM to migrate its existing systems to IBM's SoftLayer cloud computing infrastructure. This is a managed cloud infrastructure in which IBM, as a trusted and experienced third party, manages the organization's cloud computing activities, freeing the organization to focus on its core competencies. IBM also helped implement enterprise and business intelligence applications from SAP, configuring the systems to meet PeroxyChem's business requirements. The new infrastructure was rigorously tested and was able to go live in four and a half months with no disruptions to PeroxyChem's existing IT operations.

PeroxyChem can run and extend its enterprise business systems with a lean in-house team. The managed IBM Cloud hosting solution has made it possible for PeroxyChem's IT staff to spend less time on routine maintenance and more time on leveraging its core competencies and developing innovative products for specialty industries such as food safety and electronics.

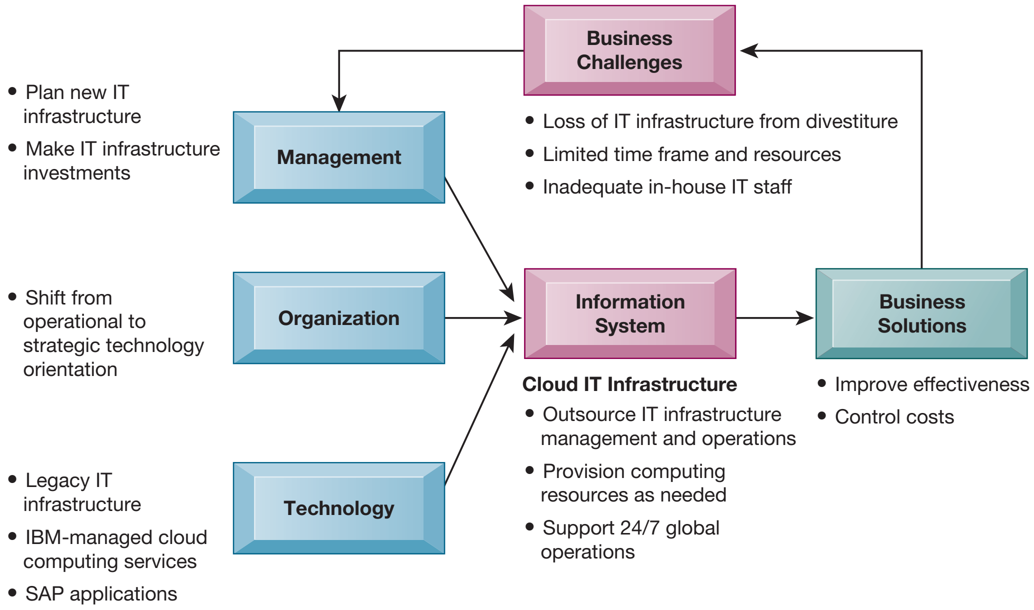
Using a cloud infrastructure has reduced costs and risk by avoiding large up-front capital investment for new hardware, software, and a data center, as well as the expense of maintaining a large in-house IT team. The infrastructure is scalable and can expand computing capacity if the company grows or has peaking workloads, or reduce computing resources (and expenses) if the company has fewer users or less computing work. The company can easily add more users without purchasing additional computing, storage, and networking resources of its own. PeroxyChem's cloud infrastructure is operational around the clock, making it easier to for this global company to do business.

Sources: David Slovensky, "PeroxyChem Builds a Whole New IT Infrastructure in Less Than Five Months," www.ibm.com, January 17, 2017; "PeroxyChem LLC." www.03-ibm.com, accessed February 20, 2018; Ken Murphy, "PeroxyChem Starts a Cloud Reaction," *SAP Insider Profiles*, December 12, 2016; and www.peroxychem.com, accessed February 20, 2018.

The experience of PeroxyChem illustrates the importance of information technology infrastructure in running a business today. The right technology at the right price will improve organizational performance. After divestiture from its parent corporation, PeroxyChem was left to manage its own information systems. The company would have been overwhelmed with setting up its own IT department and learning how to run its own systems, with no time for developing systems to support its strategy and future growth. PeroxyChem would be prevented from operating as efficiently and effectively as it could have.

The chapter-opening case diagram calls attention to important points raised by this case and this chapter. Divestiture left PeroxyChem with limited resources and a short time frame to set up and run its essential business information systems and data center. Using cloud computing for its IT infrastructure enabled PeroxyChem to quickly delegate the operation and management of its IT systems to outside specialists, to maintain a very small in-house IT staff, and to use that staff to support innovation rather than day-to-day operations. The company pays for only the computing capacity it actually uses on an as-needed basis, and did not have to make extensive and costly up-front IT investments.

Here are some questions to think about: What were the business benefits for PeroxyChem of using a cloud computing infrastructure? What role did divestiture play in PeroxyChem's choice of a solution?



5-1 What is IT infrastructure, and what are the stages and drivers of IT infrastructure evolution?

In Chapter 1, we defined *information technology (IT) infrastructure* as the shared technology resources that provide the platform for the firm's specific information system applications. An IT infrastructure includes investment in hardware, software, and services—such as consulting, education, and training—that are shared across the entire firm or across entire business units in the firm. A firm's IT infrastructure provides the foundation for serving customers, working with vendors, and managing internal firm business processes (see Figure 5.1).

Supplying firms worldwide with IT infrastructure (hardware, software, networking, and IT services) in 2018 was estimated to be a $3.7 trillion industry (Gartner, 2018). Investments in infrastructure account for between 25 and 50 percent of information technology expenditures in large firms, led by financial services firms where IT investment is well over half of all capital investment.

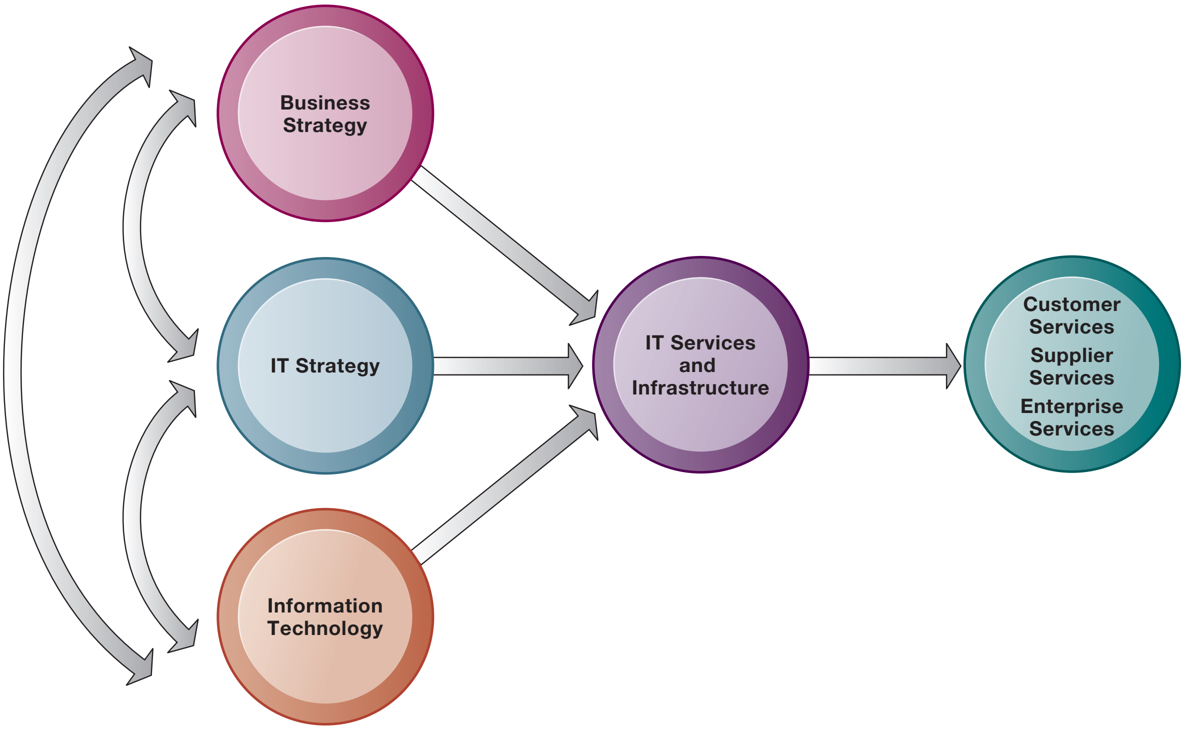
Defining IT Infrastructure

An IT infrastructure consists of a set of physical devices and software applications that are required to operate the entire enterprise. But IT infrastructure also includes a set of firmwide services budgeted by management and composed of both human and technical capabilities. These services include the following:

- Computing platforms used to provide computing services that connect employees, customers, and suppliers into a coherent digital environment, including large mainframes, midrange computers, desktop and laptop computers, and mobile handheld and remote cloud computing services

FIGURE 5.1 CONNECTION BETWEEN THE FIRM, IT INFRASTRUCTURE, AND BUSINESS CAPABILITIES

The services a firm is capable of providing to its customers, suppliers, and employees are a direct function of its IT infrastructure. Ideally, this infrastructure should support the firm's business and information systems strategy. New information technologies have a powerful impact on business and IT strategies as well as the services that can be provided to customers.



- Telecommunications services that provide data, voice, and video connectivity to employees, customers, and suppliers
- Data management services that store and manage corporate data and provide capabilities for analyzing the data
- Application software services, including online software services, that provide enterprise-wide capabilities such as enterprise resource planning, customer relationship management, supply chain management, and knowledge management systems that are shared by all business units
- Physical facilities management services that develop and manage the physical installations required for computing, telecommunications, and data management services
- IT management services that plan and develop the infrastructure, coordinate with the business units for IT services, manage accounting for the IT expenditure, and provide project management services
- IT standards services that provide the firm and its business units with policies that determine which information technology will be used, when, and how
- IT education services that provide training in system use to employees and offer managers training in how to plan for and manage IT investments

- IT research and development services that provide the firm with research on potential future IT projects and investments that could help the firm differentiate itself in the marketplace

This "service platform" perspective makes it easier to understand the business value provided by infrastructure investments. For instance, the real business value of a fully loaded personal computer operating at 3.5 gigahertz that costs about $1,000 and a high-speed Internet connection is hard to understand without knowing who will use it and how it will be used. When we look at the services provided by these tools, however, their value becomes more apparent: The new PC makes it possible for a high-cost employee making $100,000 a year to connect to all the company's major systems and the public Internet. The high-speed Internet service saves this employee about an hour per day in reduced wait time for Internet information. Without this PC and Internet connection, the value of this one employee to the firm might be cut in half.

Evolution of IT Infrastructure

The IT infrastructure in organizations today is an outgrowth of more than 50 years of evolution in computing platforms. There have been five stages in this evolution, each representing a different configuration of computing power and infrastructure elements (see Figure 5.2). The five eras are general-purpose mainframe and minicomputer computing, personal computers, client/server networks, enterprise computing, and cloud and mobile computing.

Technologies that characterize one era may also be used in another time period for other purposes. For example, some companies still run traditional mainframe systems or use mainframe computers as servers supporting large websites and corporate enterprise applications.

General-Purpose Mainframe and Minicomputer Era (1959 to Present)

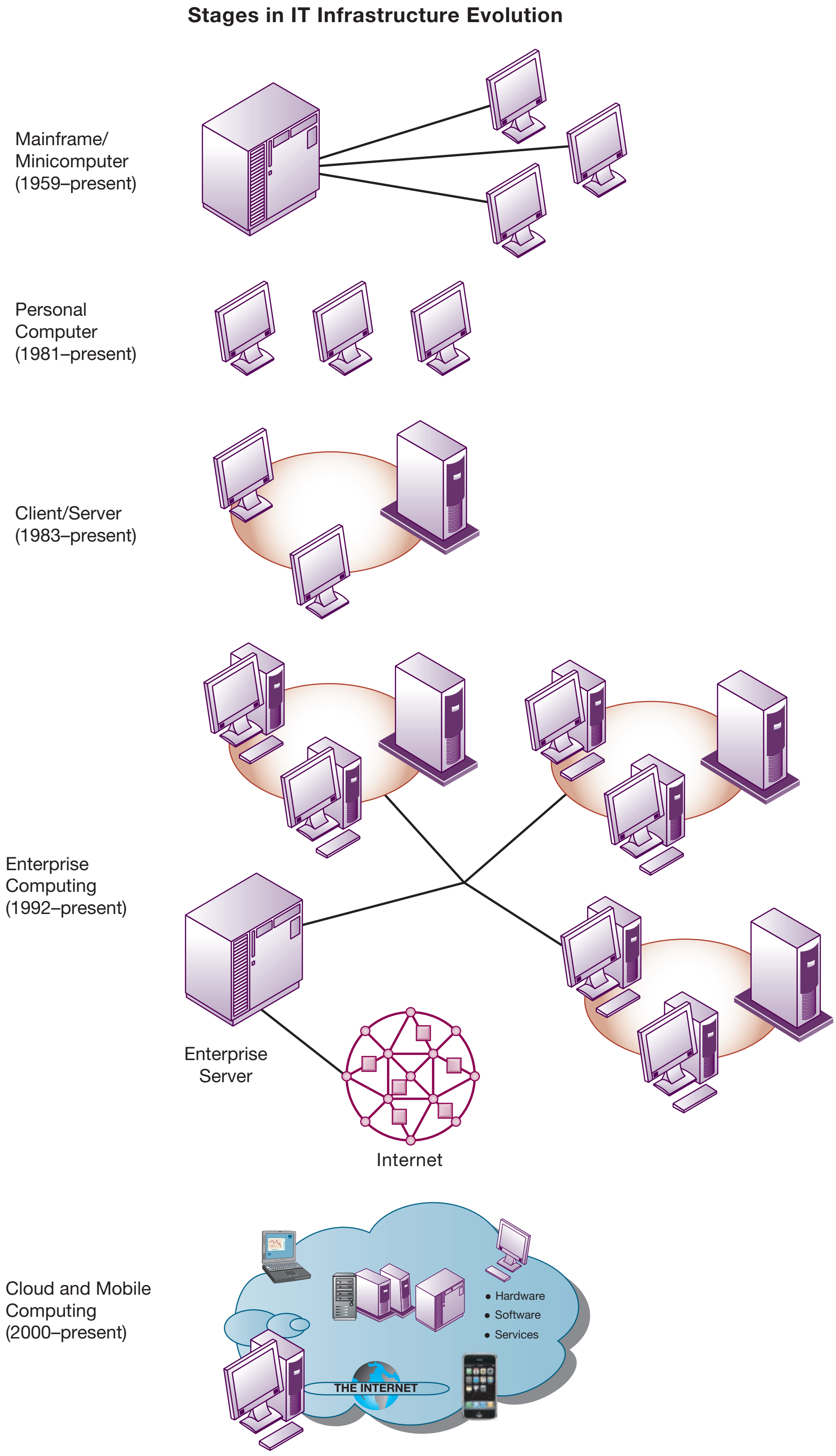
The introduction of the IBM 1401 and 7090 transistorized machines in 1959 marked the beginning of widespread commercial use of **mainframe** computers. In 1965, the mainframe computer truly came into its own with the introduction of the IBM 360 series. The 360 was the first commercial computer that could provide time sharing, multitasking, and virtual memory in more advanced models. IBM has dominated mainframe computing from this point on. Mainframe computers became powerful enough to support thousands of online remote terminals connected to the centralized mainframe using proprietary communication protocols and proprietary data lines.

The mainframe era was a period of highly centralized computing under the control of professional programmers and systems operators (usually in a corporate data center), with most elements of infrastructure provided by a single vendor, the manufacturer of the hardware and the software.

This pattern began to change with the introduction of **minicomputers**, produced by Digital Equipment Corporation (DEC) in 1965. DEC minicomputers (PDP-11 and later the VAX machines) offered powerful machines at far lower prices than IBM mainframes, making possible decentralized computing, customized to the specific needs of individual departments or business units rather than time sharing on a single huge mainframe. In recent years, the minicomputer has evolved into a midrange computer or midrange server and is part of a network.

FIGURE 5.2 **ERAS IN IT INFRASTRUCTURE EVOLUTION**

Illustrated here are the typical computing configurations characterizing each of the five eras of IT infrastructure evolution.



Personal Computer Era (1981 to Present)

Although the first truly personal computers (PCs) appeared in the 1970s (the Xerox Alto, the MITS Altair 8800, and the Apple I and II, to name a few), these machines had only limited distribution to computer enthusiasts. The appearance of the IBM PC in 1981 is usually considered the beginning of the PC era because this machine was the first to be widely adopted by businesses. At first using the DOS operating system, a text-based command language, and later the Microsoft Windows operating system, the **Wintel PC** computer (Windows operating system software on a computer with an Intel microprocessor) became the standard desktop personal computer. Worldwide PC sales have declined because of the popularity of tablets and smartphones, but the PC is still a popular tool for business. Approximately 88 percent of desktop PCs are thought to run a version of Windows, and about 8 percent run a version of MacOS. Wintel dominance as a computing platform is receding as iPhone and Android device sales increase.

Proliferation of PCs in the 1980s and early 1990s launched a spate of personal desktop productivity software tools—word processors, spreadsheets, electronic presentation software, and small data management programs—that were very valuable to both home and corporate users. These PCs were stand-alone systems until PC operating system software in the 1990s made it possible to link them into networks.

Client/Server Era (1983 to Present)

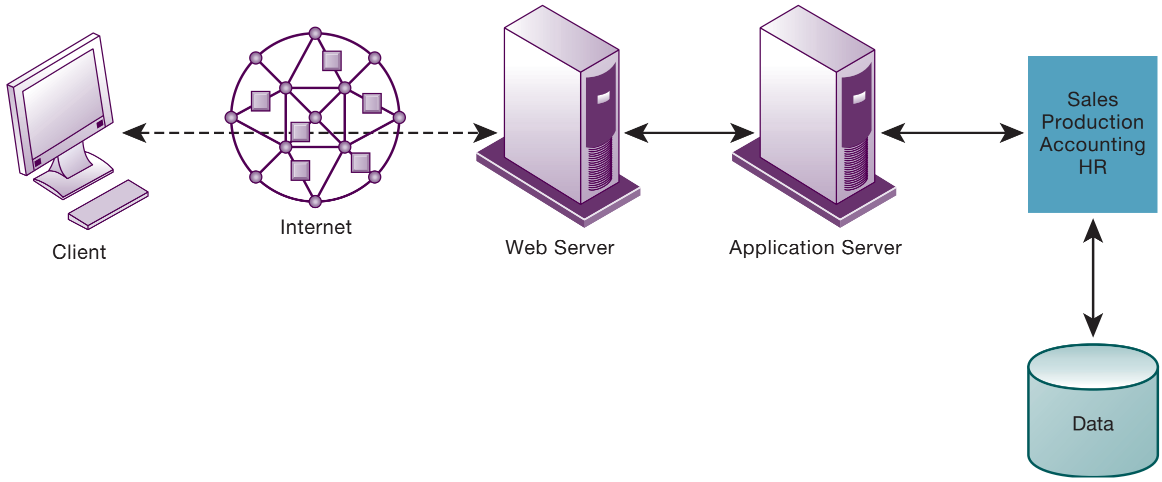
In **client/server computing**, desktop or laptop computers called **clients** are networked to powerful **server** computers that provide the client computers with a variety of services and capabilities. Computer processing work is split between these two types of machines. The client is the user point of entry, whereas the server typically processes and stores shared data, serves up web pages, or manages network activities. The term *server* refers to both the software application and the physical computer on which the network software runs. The server could be a mainframe, but today, server computers typically are more powerful versions of personal computers, based on inexpensive chips and often using multiple processors in a single computer box or in server racks.

The simplest client/server network consists of a client computer networked to a server computer, with processing split between the two types of machines. This is called a *two-tiered client/server architecture*. Whereas simple client/server networks can be found in small businesses, most corporations have more complex, **multitiered client/server architectures** (often called *N-tier client/server architectures*) in which the work of the entire network is balanced over several different levels of servers, depending on the kind of service being requested (see Figure 5.3).

For instance, at the first level, a **web server** will serve a web page to a client in response to a request for service. Web server software is responsible for locating and managing stored web pages. If the client requests access to a corporate system (a product list or price information, for instance), the request is passed along to an **application server**. Application server software handles all application operations between a user and an organization's back-end business systems. The application server may reside on the same computer as the web server or on its own dedicated computer. Chapters 6 and 7 provide more detail on other pieces of software that are used in multitiered client/server architectures for e-commerce and e-business.

FIGURE 5.3 A MULTITIERED (N-TIER) CLIENT/SERVER NETWORK

In a multitiered client/server network, client requests for service are handled by different levels of servers.



Client/server computing enables businesses to distribute computing work across a series of smaller, inexpensive machines that cost much less than centralized mainframe systems. The result is an explosion in computing power and applications throughout the firm.

Novell NetWare was the leading technology for client/server networking at the beginning of the client/server era. Today, Microsoft is the market leader with its **Windows** operating systems (Windows Server, Windows 10, Windows 8, and Windows 7).

Enterprise Computing Era (1992 to Present)

In the early 1990s, firms turned to networking standards and software tools that could integrate disparate networks and applications throughout the firm into an enterprise-wide infrastructure. As the Internet developed into a trusted communications environment after 1995, business firms began seriously using the *Transmission Control Protocol/Internet Protocol (TCP/IP)* networking standard to tie their disparate networks together. We discuss TCP/IP in detail in Chapter 7.

The resulting IT infrastructure links different pieces of computer hardware and smaller networks into an enterprise-wide network so that information can flow freely across the organization and between the firm and other organizations. It can link different types of computer hardware, including mainframes, servers, PCs, and mobile devices, and it includes public infrastructures such as the telephone system, the Internet, and public network services. The enterprise infrastructure also requires software to link disparate applications and enable data to flow freely among different parts of the business, such as enterprise applications (see Chapters 2 and 9) and web services (discussed in Section 5-4).

Cloud and Mobile Computing Era (2000 to Present)

The growing bandwidth power of the Internet has pushed the client/server model one step further, toward what is called the "cloud computing model." **Cloud computing** refers to a model of computing that provides access to a shared pool of computing resources (computers, storage, applications, and services) over the network, often the Internet. These "clouds" of computing resources can be accessed on an as-needed basis from any connected device and location.

Cloud computing bas become the fastest-growing form of computing, with worldwide public cloud spending to reach $411 billion by 2020. Cisco Systems predicts that 94 percent of all computer workloads will run in some type of cloud environment by 2021 (Gartner, 2017; Cisco 2018).

Thousands or even hundreds of thousands of computers are located in cloud data centers, where they can be accessed by desktop computers, laptop computers, tablets, entertainment centers, smartphones, and other client machines linked to the Internet. Amazon, Google, IBM, and Microsoft operate huge, scalable cloud computing centers that provide computing power, data storage, application development tools, and high-speed Internet connections to firms that want to maintain their IT infrastructures remotely. Firms such as Google, Microsoft, SAP, Oracle, and Salesforce.com sell software applications as services delivered over the Internet.

We discuss cloud and mobile computing in more detail in Section 5-3. The Learning Tracks include a table titled "Comparing Stages in IT Infrastructure Evolution," which compares each era on the infrastructure dimensions introduced.

Technology Drivers of Infrastructure Evolution

The changes in IT infrastructure we have just described have resulted from developments in computer processing, memory chips, storage devices, networking hardware and software, and software design that have exponentially increased computing power while exponentially reducing costs. Let's look at the most important developments.

Moore's Law and Microprocessing Power

In 1965, Gordon Moore, the director of Fairchild Semiconductor's Research and Development Laboratories, wrote in *Electronics* magazine that since the first microprocessor chip was introduced in 1959, the number of components on a chip with the smallest manufacturing costs per component (generally transistors) had doubled each year. This assertion became the foundation of **Moore's Law**. Moore later reduced the rate of growth to a doubling every two years.

There are at least three variations of Moore's Law, none of which Moore ever stated: (1) the power of microprocessors doubles every 18 months, (2) computing power doubles every 18 months, and (3) the price of computing falls by half every 18 months.

Figure 5.4 illustrates the relationship between number of transistors on a microprocessor and millions of instructions per second (MIPS), a common measure of processor power. Figure 5.5 shows the exponential decline in the cost of transistors and rise in computing power. For instance, in 2018, you could buy an Intel i7 processor chip with 2.5 billion transistors for about one ten-millionth of a dollar per transistor.

Exponential growth in the number of transistors and the power of processors coupled with an exponential decline in computing costs may not be able to continue much longer. In the last five years, the cost improvement rate has fallen to single digits from 30 percent annual reductions. Chip manufacturers continue to miniaturize components. Today's transistors are 14 nanometers in size, and should no longer be compared to the size of a human hair (80 thousand nanometers) but rather to the size of a virus (400 nanometers). Within the next five years or so, chip makers may reach the physical limits

FIGURE 5.4 MOORE'S LAW AND MICROPROCESSOR PERFORMANCE

Packing 5 billion transistors into a tiny microprocessor has exponentially increased processing power. Processing power has increased to more than 250,000 MIPS (about 2.6 billion instructions per second).

Source: Authors' estimate.

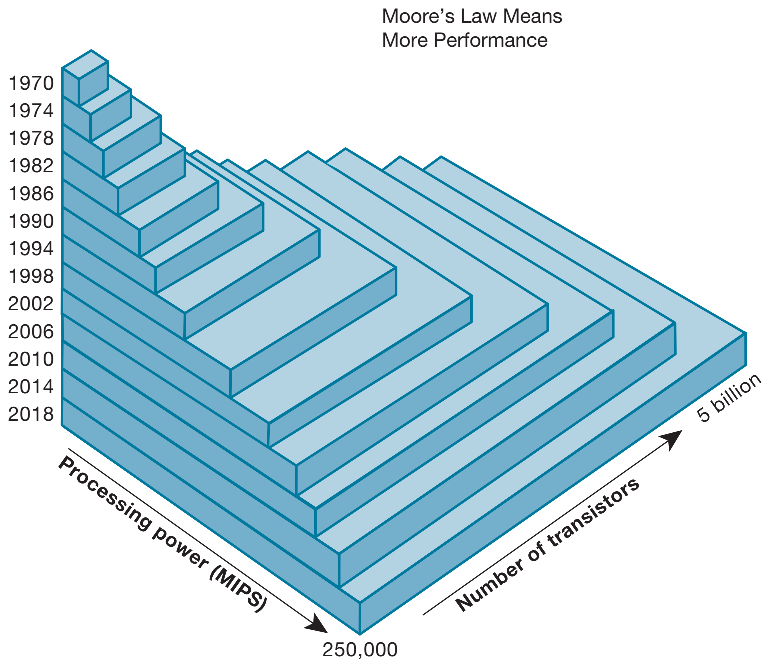
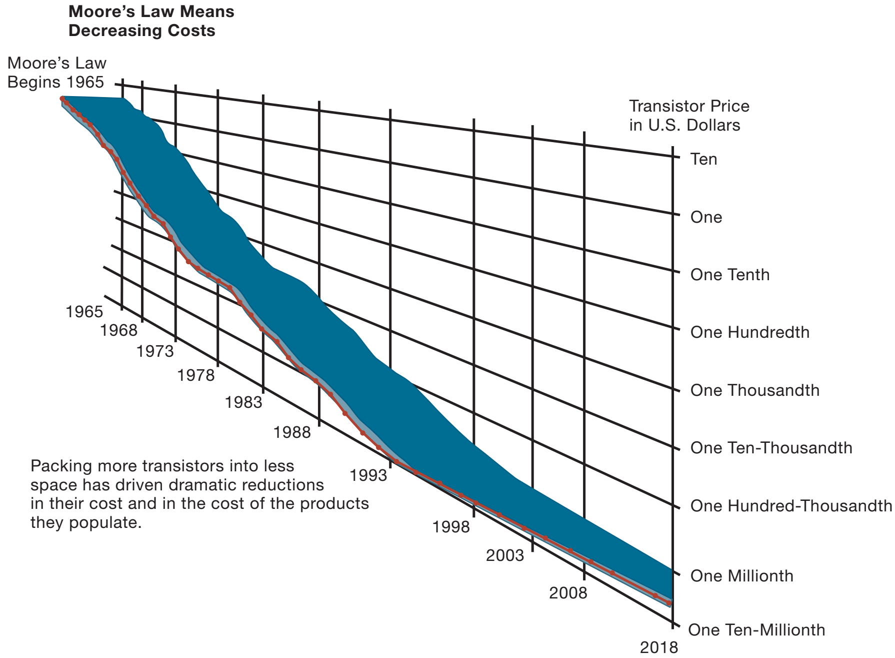
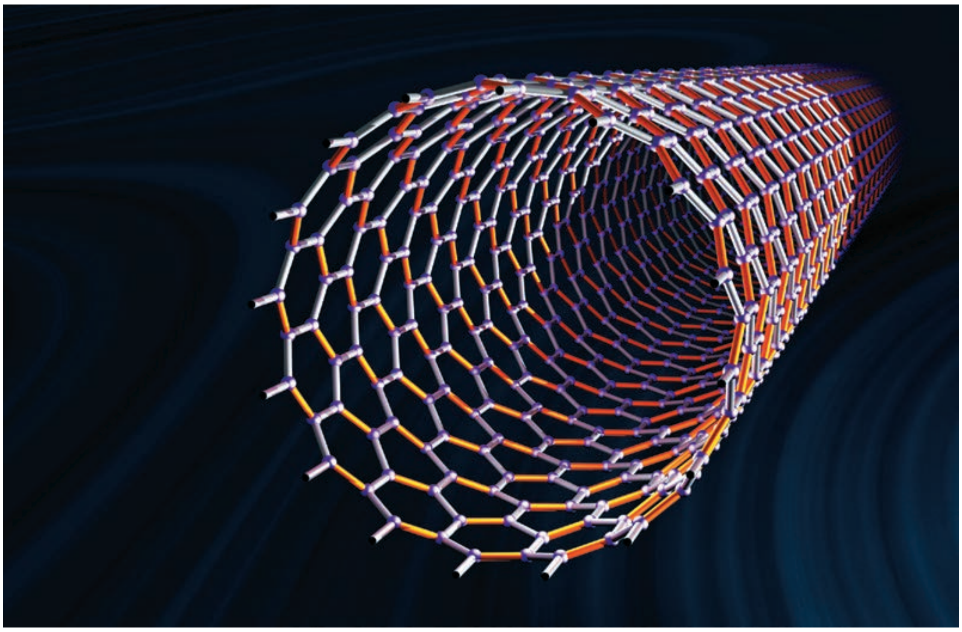


FIGURE 5.5 FALLING COST OF CHIPS

Changes in production technology, and very-large-scale production runs, have driven dramatic declines in the cost of chips, and the products that use them.

Source: Authors' estimate.





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Nanotubes are tiny tubes about 10,000 times thinner than a human hair. They consist of rolled-up sheets of carbon hexagons, have potential use as minuscule wires or in ultrasmall electronic devices, and are very powerful conductors of electrical current.

of semiconductor size. At that point they may need to use alternatives to fashioning chips from silicon or find other ways to make computers more powerful.

Chip manufacturers can shrink the size of transistors down to the width of several atoms by using nanotechnology. **Nanotechnology** uses individual atoms and molecules to create computer chips and other devices that are thousands of times smaller than current technologies permit. Chip manufacturers are trying to develop a manufacturing process to produce nanotube processors economically. Stanford University scientists have built a nanotube computer.

The Law of Mass Digital Storage

A second technology driver of IT infrastructure change is the Law of Mass Digital Storage. The amount of digital information is roughly doubling every year (Lyman and Varian, 2003). Fortunately, the cost of storing digital information is falling at an exponential rate of 100 percent a year. Figure 5.6 shows that the number of megabytes that can be stored on magnetic media for $1 from 1950 to the present roughly doubled every 15 months. In 2018, a 1 terabyte hard disk drive sells at retail for about $50.

Metcalfe's Law and Network Economics

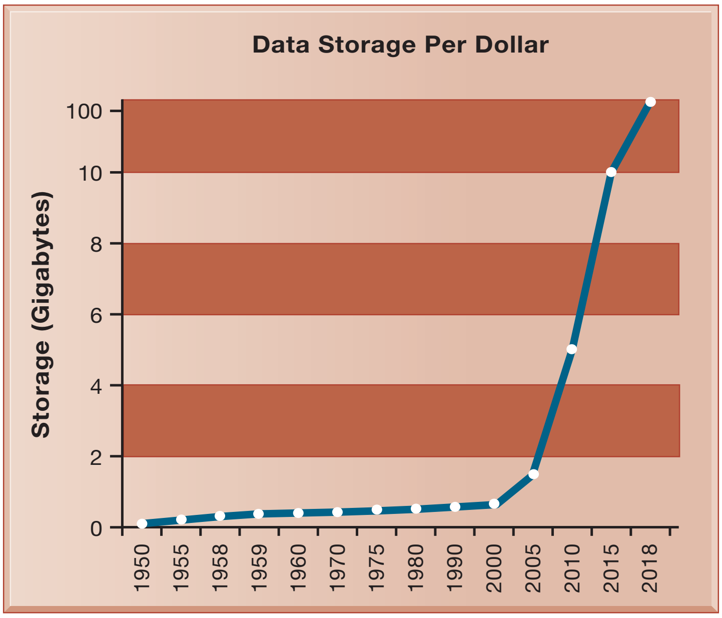
Moore's Law and the Law of Mass Digital Storage help us understand why computing resources are now so readily available. But why do people want more computing and storage power? The economics of networks and the growth of the Internet provide some answers.

Robert Metcalfe—inventor of Ethernet local area network technology—claimed in 1970 that the value or power of a network grows exponentially as a function of the number of network members. Metcalfe and others point to the *increasing returns to scale* that network members receive as more and more people join the network. As the number of members in a network grows

FIGURE 5.6 THE AMOUNT OF STORAGE PER DOLLAR RISES EXPONENTIALLY, 1950–2018

Cloud storage services like Google Drive provide 100 gigabytes of storage for $1.99 per month.

Source: Authors' estimates.



linearly, the value of the entire system grows exponentially and continues to grow as members increase. Demand for information technology has been driven by the social and business value of digital networks, which rapidly multiply the number of actual and potential links among network members.

Declining Communications Costs and the Internet

A fourth technology driver transforming IT infrastructure is the rapid decline in the costs of communication and the exponential growth in the size of the Internet. Today there are 4.2 billion Internet users worldwide (Internetworldstats.com, 2018). Figure 5.7 illustrates the exponentially declining cost of communication both over the Internet and over telephone networks (which increasingly are based on the Internet). As communication costs fall toward a very small number and approach zero, utilization of communication and computing facilities explode. In 2018, one megabit of Internet access costs about $2.60. In 2000, the cost was over $300 if available. In this same time frame, average household Internet speeds have risen from .2 Mbps to 18 Mbps.

To take advantage of the business value associated with the Internet, firms must greatly expand their Internet connections, including wireless connectivity, and greatly expand the power of their client/server networks, desktop clients, and mobile computing devices. There is every reason to believe these trends will continue.

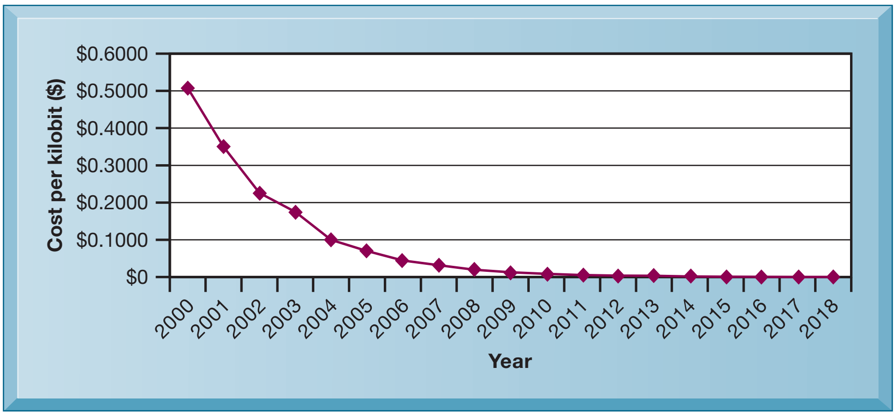
Standards and Network Effects

Today's enterprise infrastructure and Internet computing would be impossible—both now and in the future—without agreements among manufacturers and

FIGURE 5.7 EXPONENTIAL DECLINES IN INTERNET COMMUNICATIONS COSTS ($/MBPS)

The cost of communication over the Internet and over telephone networks has declined exponentially, fueling the explosive growth of communication and computing worldwide.

Sources: 2007–2018: "Average Internet Connection Speed in the United States from 2007 to 2017 (in Mbps), by Quarter" Statista, 2018; 2006 Home Broadband Adoption 2006 BY John B. Horrigan PEW Research 2007; Internet speeds: How Fast Does Internet Speed grow?By Xah Lee. Date: 2006-12-30. Last updated: 2017-01-22,http://xahlee.info/comp/bandwidth.html



widespread consumer acceptance of **technology standards**. Technology standards are specifications that establish the compatibility of products and the ability to communicate in a network.

Technology standards unleash powerful economies of scale and result in price declines as manufacturers focus on the products built to a single standard. Without these economies of scale, computing of any sort would be far more expensive than is currently the case. Table 5.1 describes important standards that have shaped IT infrastructure.

In the 1990s, corporations started moving toward standard computing and communications platforms. The Wintel PC with the Windows operating system and Microsoft Office desktop productivity applications became the standard desktop and mobile client computing platform. (It now shares the spotlight with other standards, such as Apple's iOS and Macintosh operating systems and the Android operating system.) Widespread adoption of Unix-Linux as the enterprise server operating system of choice made possible the replacement of proprietary and expensive mainframe infrastructures. In networking, the Ethernet standard enabled PCs to connect together in small local area networks (LANs; see Chapter 7), and the TCP/IP standard enabled these LANs to be connected into firmwide networks, and ultimately, to the Internet.

5-2 What are the components of IT infrastructure?

IT infrastructure today is composed of seven major components. Figure 5.8 illustrates these infrastructure components and the major vendors within each component category. These components constitute investments that must be coordinated with one another to provide the firm with a coherent infrastructure.

TABLE 5.1 SOME IMPORTANT STANDARDS IN COMPUTING

STANDARD	SIGNIFICANCE
American Standard Code for Information Interchange (ASCII) (1958)	Made it possible for computer machines from different manufacturers to exchange data; later used as the universal language linking input and output devices such as keyboards and mice to computers. Adopted by the American National Standards Institute in 1963.
Common Business Oriented Language (COBOL) (1959)	An easy-to-use software language that greatly expanded the ability of programmers to write business-related programs and reduced the cost of software. Sponsored by the Defense Department in 1959.
Unix (1969–1975)	A powerful multitasking, multiuser, portable operating system initially developed at Bell Labs (1969) and later released for use by others (1975). It operates on a wide variety of computers from different manufacturers. Adopted by Sun, IBM, HP, and others in the 1980s, it became the most widely used enterprise-level operating system.
Ethernet (1973)	A network standard for connecting desktop computers into local area networks that enabled the widespread adoption of client/server computing and local area networks and further stimulated the adoption of personal computers.
Transmission Control Protocol/Internet Protocol (TCP/IP) (1974)	Suite of communications protocols and a common addressing scheme that enables millions of computers to connect together in one giant global network (the Internet). Later, it was used as the default networking protocol suite for local area networks and intranets. Developed in the early 1970s for the U.S. Department of Defense.
IBM/Microsoft/Intel Personal Computer (1981)	The standard Wintel design for personal desktop computing based on standard Intel processors and other standard devices, Microsoft DOS, and later Windows software. The emergence of this standard, low-cost product laid the foundation for a 25-year period of explosive growth in computing throughout all organizations around the globe. Today, more than 1 billion PCs power business and government activities every day.
World Wide Web (1989–1993)	Standards for storing, retrieving, formatting, and displaying information as a worldwide web of electronic pages incorporating text, graphics, audio, and video enables creation of a global repository of billions of web pages.

In the past, technology vendors supplying these components offered purchasing firms a mixture of incompatible, proprietary, partial solutions that could not work with other vendor products. Increasingly, vendor firms have been forced to cooperate in strategic partnerships with one another in order to keep their customers. For instance, a hardware and services provider such as IBM cooperates with all the major enterprise software providers, has strategic relationships with system integrators, and promises to work with whichever data management products its client firms wish to use (even though it sells its own database management software called DB2).

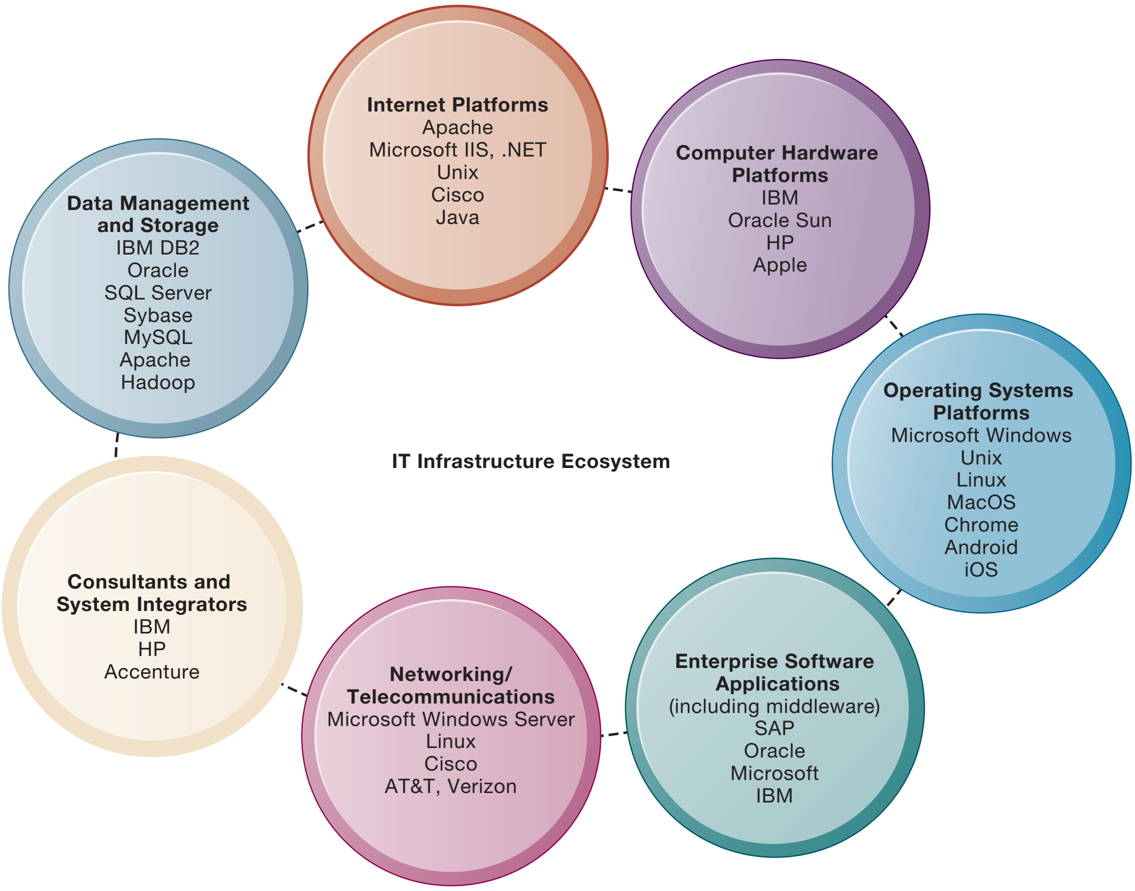
Another big change is that companies are moving more of their IT infrastructure to the cloud or to outside services, owning and managing much less on their premises. Firms' IT infrastructure will increasingly be an amalgam of components and services that are partially owned, partially rented or licensed, partially located on site, and partially supplied by external vendors or cloud services.

Computer Hardware Platforms

Firms worldwide are expected to spend $704 billion on computer hardware devices in 2018, including mainframes, servers, PCs, tablets, and smartphones. All these devices constitute the computer hardware platform for corporate (and personal) computing worldwide.

FIGURE 5.8 THE IT INFRASTRUCTURE ECOSYSTEM

There are seven major components that must be coordinated to provide the firm with a coherent IT infrastructure. Listed here are major technologies and suppliers for each component.



Most business computing has taken place using microprocessor chips manufactured or designed by Intel Corporation and, to a lesser extent, AMD Corporation. Intel and AMD processors are often referred to as "i86" processors because the original IBM PCs used an Intel 8086 processor and all the Intel (and AMD) chips that followed are downward compatible with this processor. (For instance, you should be able to run a software application designed 10 years ago on a new PC you bought yesterday.)

The computer platform changed dramatically with the introduction of mobile computing devices, from the iPod in 2001 to the iPhone in 2007 and the iPad in 2010. Worldwide, 2 billion people use smartphones. You can think of these devices as a second computer hardware platform, one that is consumer device–driven.

Mobile devices are not required to perform as many tasks as computers in the first computer hardware platform, so they consume less power, and generate less heat. Processors for mobile devices are manufactured by a wide range of firms, including Apple, Samsung, and Qualcomm, using an architecture designed by ARM Holdings.

Mainframes have not disappeared. They continue to be used to reliably and securely handle huge volumes of transactions, for analyzing very large quantities of data, and for handling large workloads in cloud computing centers. The mainframe is still the digital workhorse for banking and telecommunications networks that are often running software programs that are older and require a specific hardware platform. However, the number of providers has dwindled to one: IBM. IBM has also repurposed its mainframe systems so they can be used as giant servers for enterprise networks and corporate websites. A single IBM mainframe can run thousands of instances of Linux or Windows Server software and is capable of replacing thousands of smaller servers (see the discussion of virtualization in Section 5-3).

Operating System Platforms

The leading operating systems for corporate servers are Microsoft Windows Server, **Unix**, and **Linux**, an inexpensive and robust open source relative of Unix. Microsoft Windows Server is capable of providing enterprise-wide operating system and network services and appeals to organizations seeking Windows-based IT infrastructures. Unix and Linux are scalable, reliable, and much less expensive than mainframe operating systems. They can also run on many different types of processors. The major providers of Unix operating systems are IBM, HP, and Oracle-Sun, each with slightly different and partially incompatible versions.

Nearly 90 percent of PCs use some form of the Microsoft Windows **operating system** for managing the resources and activities of the computer. However, there is now a much greater variety of client operating systems than in the past, with new operating systems for computing on handheld mobile digital devices or cloud-connected computers.

Google's **Chrome OS** provides a lightweight operating system for cloud computing using a web-connected computer. Programs are not stored on the user's computer but are used over the Internet and accessed through the Chrome web browser. User data reside on servers across the Internet. **Android** is an open source operating system for mobile devices such as smartphones and tablet computers, developed by the Open Handset Alliance led by Google. It has become the most popular smartphone platform worldwide, competing with iOS, Apple's mobile operating system for the iPhone, iPad, and iPod Touch. Conventional client operating system software is designed around the mouse and keyboard but increasingly is becoming more natural and intuitive by using touch technology. **iOS**, the operating system for the phenomenally popular Apple iPad and iPhone, features a **multitouch** interface, where users employ one or more fingers to manipulate objects on a screen without a mouse or keyboard. Microsoft's **Windows 10** and Windows 8, which run on tablets as well as PCs, have multitouch capabilities, as do many Android devices.

Enterprise Software Applications

Firms worldwide are expected to spend about $389 billion in 2018 on software for enterprise applications that are treated as components of IT infrastructure. We introduced the various types of enterprise applications in Chapter 2, and Chapter 9 provides a more detailed discussion of each.

The largest providers of enterprise application software are SAP and Oracle. Also included in this category is middleware software supplied by vendors such as IBM and Oracle for achieving firmwide integration by linking the firm's existing application systems. Microsoft is attempting to move into the lower ends of this market by focusing on small and medium-sized businesses.

Data Management and Storage

Enterprise database management software is responsible for organizing and managing the firm's data so that they can be efficiently accessed and used. Chapter 6 describes this software in detail. The leading database software providers are IBM (DB2), Oracle, Microsoft (SQL Server), and SAP Sybase (Adaptive Server Enterprise). MySQL is a Linux open source relational database product now owned by Oracle Corporation, and Apache Hadoop is an open source software framework for managing very large data sets (see Chapter 6).

Networking/Telecommunications Platforms

Companies worldwide are expected to spend $1.43 trillion for telecommunications services in 2018 (Gartner, Inc., 2018). Windows Server is predominantly used as a local area network operating system, followed by Linux and Unix. Large, enterprise-wide area networks use some variant of Unix. Most local area networks, as well as wide area enterprise networks, use the TCP/IP protocol suite as a standard (see Chapter 7).

Cisco and Juniper Networks are leading networking hardware providers. Telecommunications platforms are typically provided by telecommunications/telephone services companies that offer voice and data connectivity, wide area networking, wireless services, and Internet access. Leading telecommunications service vendors include AT&T and Verizon. This market is exploding with new providers of cellular wireless, high-speed Internet, and Internet telephone services.

Internet Platforms

Internet platforms include hardware, software, and management services to support a firm's website, including web hosting services, routers, and cabling or wireless equipment. A **web hosting service** maintains a large web server, or series of servers, and provides fee-paying subscribers with space to maintain their websites.

The Internet revolution created a veritable explosion in server computers, with many firms collecting thousands of small servers to run their Internet operations. There has been a steady push to reduce the number of server computers by increasing the size and power of each and by using software tools that make it possible to run more applications on a single server. Use of standalone server computers is decreasing as organizations transition to cloud computing services. The Internet hardware server market has become increasingly concentrated in the hands of IBM, Dell, Oracle, and HP, as prices have fallen dramatically.

The major web software application development tools and suites are supplied by Microsoft (Microsoft Visual Studio and the Microsoft .NET development platform), Oracle-Sun, and a host of independent software developers, including Adobe. Chapter 7 describes the components of the firm's Internet platform in greater detail.

Consulting and System Integration Services

Today, even a large firm does not have the staff, the skills, the budget, or the necessary experience to deploy and maintain its entire IT infrastructure. Implementing a new infrastructure requires (as noted in Chapters 13 and 14) significant changes in business processes and procedures, training and education, and software integration. Leading consulting firms providing this expertise include Accenture, IBM Services, HP, Infosys, and Wipro.

Software integration means ensuring the new infrastructure works with the firm's older, so-called legacy systems and ensuring the new elements of the infrastructure work with one another. **Legacy systems** are generally older transaction processing systems created for mainframe computers that continue to be used to avoid the high cost of replacing or redesigning them. Replacing these systems is cost prohibitive and generally not necessary if these older systems can be integrated into a contemporary infrastructure.

5-3 What are the current trends in computer hardware platforms?

The exploding power of computer hardware and networking technology has dramatically changed how businesses organize their computing power, putting more of this power on networks and mobile handheld devices and obtaining more of their computing capabilities in the form of services. We look at eight hardware trends: the mobile digital platform, consumerization of IT and BYOD, quantum computing, virtualization, cloud computing, edge computing, green computing, and high-performance/power-saving processors.

The Mobile Digital Platform

Chapter 1 pointed out that new mobile digital computing platforms have emerged as alternatives to PCs and larger computers. The iPhone and Android smartphones have taken on many functions of PCs, including transmitting data, surfing the web, transmitting e-mail and instant messages, displaying digital content, and exchanging data with internal corporate systems. The new mobile platform also includes small, lightweight netbooks optimized for wireless communication and Internet access, **tablet computers** such as the iPad, and digital e-book readers such as Amazon's Kindle with some web access capabilities.

Smartphones and tablets are becoming the primary means of accessing the Internet and are increasingly used for business computing as well as for consumer applications. For example, senior executives at General Motors are using smartphone applications that drill down into vehicle sales information, financial performance, manufacturing metrics, and project management status.

Wearable computing devices are a recent addition to the mobile digital platform. These include smartwatches, smart glasses, smart ID badges, and activity trackers. Wearable computing technology has many business uses, and it is changing the way firms work, as described in the Interactive Session on Technology.

Consumerization of IT and BYOD

The popularity, ease of use, and rich array of useful applications for smartphones and tablet computers have created a groundswell of interest in allowing employees to use their personal mobile devices in the workplace, a phenomenon

INTERACTIVE SESSION TECHNOLOGY

Is Business Ready for Wearable Computers?

Wearable computing is starting to take off. Smartwatches, smart glasses, smart ID badges, and activity trackers promise to change how we go about each day and the way we do our jobs. According to Gartner Inc., sales of wearables will increase from 275 million units in 2016 to 477 million units by 2020. Although smartwatches such as the Apple Watch and fitness trackers have been successful consumer products, business uses for wearables appear to be advancing more rapidly. A report from research firm Tractica projects that worldwide sales for enterprise wearables will increase exponentially to 66.4 million units by 2021.

Doctors and nurses are using smart eyewear for hands-free access to patients' medical records. Oil rig workers sport smart helmets to connect with land-based experts, who can view their work remotely and communicate instructions. Warehouse managers are able to capture real-time performance data using a smartwatch to better manage distribution and fulfillment operations. Wearable computing devices improve productivity by delivering information to workers without requiring them to interrupt their tasks, which in turn empowers employees to make more-informed decisions more quickly.

Wearable devices are helping businesses learn more about employees and the everyday workplace than ever before. New insights and information can be uncovered as IoT sensor data is correlated to actual human behavior. Information on task duration and the proximity of one device or employee to another, when combined with demographic data, can shed light on previously unidentified workflow inefficiencies. Technologically sophisticated firms will understand things they never could before about workers and customers; what they do every day, how healthy they are, where they go, and even how well they feel. This obviously has implications for protecting individual privacy, raising potential employee (and customer) fears that businesses are collecting sensitive data about them. Businesses will need to tread carefully.

Global logistics company DHL worked with Ricoh, the imaging and electronics company, and Ubimax, a wearable computing services and solutions company, to implement "vision picking" in its warehouse operations. Location graphics are displayed on smart glasses guiding staffers through the warehouse to both speed the process of finding items and reduce errors. The company says the technology delivered a 25 percent increase in efficiency. Vision picking gives workers locational information about the items they need to retrieve and allows them to automatically scan retrieved items. Future enhancements will enable the system to plot optimal routes through the warehouse, provide pictures of items to be retrieved (a key aid in case an item has been misplaced on the warehouse shelves), and instruct workers on loading carts and pallets more efficiently.

Google has developed Glass Enterprise Edition smart glasses for business use, with its development partners creating applications for specific industries such as manufacturing and healthcare. Glass Enterprise Edition is being touted as a tool for easing workflows by removing distractions that prevent employees from remaining engaged and focused on tasks. More than 50 businesses including Dignity Health, The Boeing Company, and Volkswagen have been using Glass to complete their work more rapidly and efficiently.

Duke Energy has been piloting the use of smart glasses, and sees multiple uses for them. According to Aleksandar Vukojevic, technology development manager for Duke Energy's Emerging Technologies Office, smart glasses can enable employees working in the field to access training or instructional videos to help with equipment repairs or upgrades. The glasses also allow remote management, enabling managers to capture what a line or transformer worker sees, annotate images and video with instructions, and send them back out to workers in the field. Duke also tried out the smart glasses in its warehouses for stock inventory. As a worker looks at an item code, it's automatically recorded against an existing database.

There are some challenges. Locking down data that's accessed with smart glasses is essential, as with any other mobile device used in the enterprise. Today's smart glasses haven't been designed with security in mind. The sensors in the smart glasses are also not as accurate as other products. A field worker using smart glasses to locate a breaker or other device might be off by 10 or 15 feet using Google's GPS instead of a military-grade solution more common to the energy industry, which can locate equipment to within one centimeter. Additionally, smart glasses don't necessarily allow safety glasses to be worn over them. Integrating data from smart glasses with Duke's internal databases could prove difficult.

Smart glasses are like smartphones. Without integration with internal content and the right applications, they would not be so useful. The value of wearable computing devices isn't from transferring the same information from a laptop or smartphone to a smartwatch or eyeglass display. Rather, it's about finding ways to use wearables to augment and enhance business processes. Successful adoption of wearable computing depends not only on cost effectiveness but on the development of new and better apps and integration with existing IT infrastructure and the organization's tools for managing and securing mobile devices (see the chapter-ending case study).

Sources: George Thangadurai, "Wearables at Work: Why Enterprise Usage Is Outshining Consumer Usage," *IoT Agenda*, March 8, 2018; Josh Garrett, "Wearables: The Next Wave of Enterprise IoT?" *IoT Agenda*, February 1, 2018; and Lucas Mearian, "Is Google Glass Really Ready for the Enterprise?" *Computerworld*, August 1, 2017.

CASE STUDY QUESTIONS

1. Wearables have the potential to change the way organizations and workers conduct business. Discuss the implications of this statement.
2. What management, organization, and technology issues would have to be addressed if a company was thinking of equipping its workers with a wearable computing device?
3. What kinds of businesses are most likely to benefit from wearable computers? Select a business and describe how a wearable computing device could help that business improve operations or decision making.

popularly called *"bring your own device" (BYOD)*. **BYOD** is one aspect of the **consumerization of IT**, in which new information technology that first emerges in the consumer market spreads into business organizations. Consumerization of IT includes not only mobile personal devices but also business uses of software services that originated in the consumer marketplace as well, such as Google and Yahoo search, Gmail, Google Maps, Dropbox, and even Facebook and Twitter.

Consumerization of IT is forcing businesses to rethink the way they obtain and manage information technology equipment and services. Historically, at least in large firms, the IT department was responsible for selecting and managing the information technology and applications used by the firm and its employees. It furnished employees with desktops or laptops that were able to access corporate systems securely. The IT department maintained control over the firm's hardware and software to ensure that the business was being protected and that information systems served the purposes of the firm and its management. Today, employees and business departments are playing a much larger role in technology selection, in many cases demanding that employees be able to use their own personal computers, smartphones, and tablets to access the corporate network. It is more difficult for the firm to manage and control these consumer technologies and make sure they serve the needs of the business. The chapter-ending case study explores some of these management challenges created by BYOD and IT consumerization.

Quantum Computing

Quantum computing uses the principles of quantum physics to represent data and perform operations on these data. While conventional computers handle bits of data as either 0 or 1 but not both, quantum computing can process units of data as 0, 1, or both simultaneously. A quantum computer would gain enormous processing power through this ability to be in multiple states at once, allowing it to solve some scientific and business problems millions of times faster than can be done today. IBM has made quantum computing available to the general public through IBM Cloud. Google's Alphabet, Microsoft, Intel, and NASA and are also working on quantum computing platforms. Quantum computing is still an emerging technology, but its real-world applications are growing.

Virtualization

Virtualization is the process of presenting a set of computing resources (such as computing power or data storage) so that they can all be accessed in ways that are not restricted by physical configuration or geographic location. Virtualization enables a single physical resource (such as a server or a storage device) to appear to the user as multiple logical resources. For example, a server or mainframe can be configured to run many instances of an operating system (or different operating systems) so that it acts like many different machines. Each virtual server "looks" like a real physical server to software programs, and multiple virtual servers can run in parallel on a single machine. VMware is the leading virtualization software vendor for Windows and Linux servers.

Server virtualization is a common method of reducing technology costs by providing the ability to host multiple systems on a single physical machine. Most servers run at just 15 to 20 percent of capacity, and virtualization can boost server utilization rates to 70 percent or higher. Higher utilization rates translate into fewer computers required to process the same amount of work, reduced data center space to house machines, and lower energy usage. Virtualization also facilitates centralization and consolidation of hardware administration.

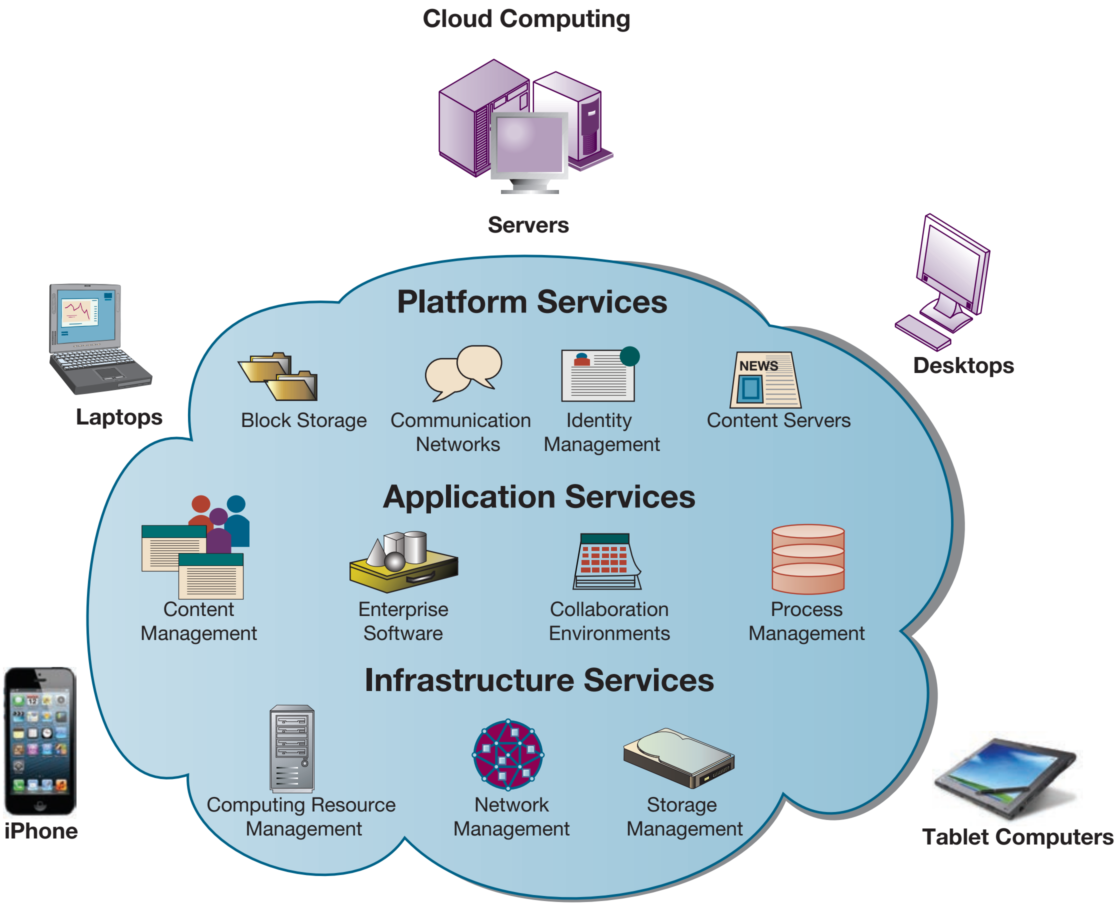
Virtualization also enables multiple physical resources (such as storage devices or servers) to appear as a single logical resource, as in **software-defined storage (SDS)**, which separates the software for managing data storage from storage hardware. Using software, firms can pool and arrange multiple storage infrastructure resources and efficiently allocate them to meet specific application needs. SDS enables firms to replace expensive storage hardware with lower-cost commodity hardware and cloud storage hardware. There is less under- or over-utilization of storage resources (Letschin, 2016).

Cloud Computing

It is now possible for companies and individuals to perform all of their computing work using a virtualized IT infrastructure in a remote location, as is the case with cloud computing. Cloud computing is a model of computing in which computer processing, storage, software, and other services are provided as a shared pool of virtualized resources over a network, primarily the Internet. These "clouds" of computing resources can be accessed on an as-needed basis from any connected device and location. Figure 5.9 illustrates the cloud computing concept.

FIGURE 5.9 CLOUD COMPUTING PLATFORM

In cloud computing, hardware and software capabilities are a pool of virtualized resources provided over a network, often the Internet. Businesses and employees have access to applications and IT infrastructure anywhere, at any time, and on any device.



The U.S. National Institute of Standards and Technology (NIST) defines cloud computing as having the following essential characteristics (Mell and Grance, 2009):

- **On-demand self-service:** Consumers can obtain computing capabilities such as server time or network storage as needed automatically on their own.
- **Ubiquitous network access:** Cloud resources can be accessed using standard network and Internet devices, including mobile platforms.
- **Location-independent resource pooling:** Computing resources are pooled to serve multiple users, with different virtual resources dynamically assigned according to user demand. The user generally does not know where the computing resources are located.
- **Rapid elasticity:** Computing resources can be rapidly provisioned, increased, or decreased to meet changing user demand.
- **Measured service:** Charges for cloud resources are based on amount of resources actually used.

Cloud computing consists of three different types of services:

- **Infrastructure as a service (IaaS):** Customers use processing, storage, networking, and other computing resources from cloud service providers to run their information systems. For example, Amazon uses the spare capacity of its IT infrastructure to provide a broadly based cloud environment selling IT infrastructure services. These include its Simple Storage Service (S3) for storing customers' data and its Elastic Compute Cloud (EC2) service for running their applications. Users pay only for the amount of computing and storage capacity they actually use. (See the Interactive Session on Organizations). Figure 5.10 shows the range of services Amazon Web Services offers.
- **Software as a service (SaaS):** Customers use software hosted by the vendor on the vendor's cloud infrastructure and delivered as a service over a network. Leading **software as a service (SaaS)** examples are Google's G Suite, which provides common business applications online, and Salesforce.com, which leases customer relationship management and related software services over the Internet. Both charge users an annual subscription fee, although Google has a pared-down free version. Users access these applications from a web browser, and the data and software are maintained on the providers' remote servers.
- **Platform as a service (PaaS):** Customers use infrastructure and programming tools supported by the cloud service provider to develop their own applications. For example, Microsoft offers PaaS tools and services for software development and testing among its Azure cloud services. Another example is Salesforce.com's Salesforce Platform.

Chapter 2 discussed Google Docs, Microsoft Office 365, and related software services for desktop productivity and collaboration. These are among

FIGURE 5.10 AMAZON WEB SERVICES

Amazon Web Services (AWS) is a collection of web services that Amazon provides to users of its cloud platform. AWS is the largest provider of cloud computing services in the United States.

INTERACTIVE SESSION ORGANIZATIONS

Look to the Cloud

If you want to see where computing is taking place, look to the cloud. Cloud computing is now the fastest-growing form of computing. According to Cisco Systems, 94 percent of all computing workloads will run in some form of cloud environment by 2021. This includes both public and private cloud platforms. Dedicated servers will be a distinct minority.

Cloud computing has become an affordable and sensible option for companies of all sizes, ranging from tiny Internet startups to established companies like Netflix and FedEx. For example, Amazon Web Services (AWS) provides subscribing companies with flexible computing power and data storage as well as data management, messaging, payment, and other services that can be used together or individually, as the business requires. Anyone with an Internet connection and a little bit of money can harness the same computing systems that Amazon itself uses to run its retail business. If customers provide specifications on the amount of server space, bandwidth, storage, and any other services they require, AWS can automatically allocate those resources. You don't pay a monthly or yearly fee to use Amazon's computing resources—instead, you pay for exactly what you use. Economies of scale keep costs astonishingly low, and AWS has been able to keep reducing prices. To remain competitive, other cloud computing vendors have had to follow suit.

Cloud computing also appeals to many businesses because the cloud services provider will handle all of the maintenance and upkeep of their IT infrastructures, allowing these businesses to spend more time on higher-value work. Start-up companies and smaller companies are finding that they no longer need to build their own data center. With cloud infrastructures like Amazon's readily available, they have access to technical capability that was formerly available to only much larger businesses. Hi-Media is the Internet publisher of the Fotolog photo blogging website. Hi-Media rebuilt the site and moved it to AWS where it can easily scale computing capacity to meet the demands of Fotolog's 32 million global users who have collectively posted 1 billion photos and 10 billion comments.

Although cloud computing has been touted as a cheap and more flexible alternative to buying and owning information technology, this isn't always the case. For large companies, paying a public cloud provider a monthly service fee for 10,000 or more employees may actually be more expensive than having the company maintain its own IT infrastructure and staff. Companies also worry about unexpected "runaway costs" from using a pay-per-use model. Integrating cloud services with existing IT infrastructures, errors, mismanagement, or unusually high volumes of web traffic will run up the bill for cloud service users.

A major barrier to widespread cloud adoption has been concerns about cloud reliability and security. Problems with Amazon Web Services' Direct Connect service took down several large customers on the morning of March 2, 2018, including enterprise software tool provider Atalassian, Capital One, and Amazon's own Alexa personal assistant. (AWS Direct Connect is used by hybrid cloud customers to set up a secure connection between AWS infrastructure and the customer's on-premises infrastructure.) Amazon's S3 cloud storage service experienced a four-hour outage February 28, 2017, shutting down thousands of websites across the Internet. There were also significant Amazon cloud outages in the preceding five years. As cloud computing continues to mature and the major cloud infrastructure providers gain more experience, cloud service and reliability have steadily improved. Experts recommend that companies for whom an outage would be a major risk consider using another computing service as a backup.

In February 2016 Netflix completed a decade-long project to shut down its own data centers and use Amazon's cloud exclusively to run its business. Management liked not having to guess months beforehand what the firm's hardware, storage, and networking needs would be. AWS would provide whatever Netflix needed at the moment. Netflix also maintains a content-delivery network through Internet service providers and other third parties to speed up the delivery of movies and web traffic between Netflix and its customers. Netflix competes with Amazon in the video-streaming business, and it wanted to retain control of its own content delivery network.

Dropbox, on the other hand, did the opposite. The online file hosting company saved nearly

$75 million in infrastructure costs over two years following a cloud data migration off AWS. Dropbox had been an early AWS success story, but it had never run all of its systems on AWS. Dropbox had originally split its architecture to host metadata that provides information about other data in private data centers and to host file content on the AWS Simple Storage Service (S3). Dropbox subsequently built systems better suited to its needs, which so far has produced big savings following its cloud data migration off AWS. However, that transition was costly. The company spent more than $53 million for custom architectures in three colocation facilities to accommodate exabytes of storage. Dropbox stores the remaining 10 percent of user data on AWS, in part to localize data in the United States and Europe, and it uses Amazon's public cloud to help deliver its services. Experts believe that Dropbox's experience with AWS is not representative of most companies. Dropbox's strategy to build one of the largest data stores in the world depended on owning its computing resources.

Many large companies are moving more of their computing to the cloud but are unable to migrate completely. Legacy systems are the most difficult to switch over. Most midsized and large companies will gravitate toward a hybrid approach. The top cloud providers themselves—Amazon, Google, Microsoft, and IBM—use their own public cloud services for some purposes, but they continue to keep certain functions on private servers. Worries about reliability, security, and risks of change have made it difficult for them to move critical computing tasks to the public cloud.

Honda UK implemented the hybrid cloud model to enable its IT infrastructure to handle sudden spikes in usage of its websites. The company had experienced sudden web server crashes due to bandwidth limitations. Honda UK had initially moved to a private cloud model, which was used during the launch of the Accord Tourer model to handle heavy user demand for its website. Honda UK then started using the public cloud during the launch of the Honda CR-Z. Honda UK had to pay for the cloud service only when the company used it. The pay-as-you-go model helped keep costs in check while ensuring optimum scalability.

Sources: Trevor Jones, "Dropbox Is Likely an Outlier with its Successful Cloud Data Migration off AWS," searchaws.com, February 28, 2018; Andy Patrizio, "Cisco Says Almost All Workloads Will Be Cloud-Based Within 3 Years," *Network World*, February 5, 2018; Tom Krazit, "Widespread Outage at Amazon Web Services' U.S. East Region Takes down Alexa, Atlassian Developer Tools," *GeekWire*, March 2, 2018; DasGupta, "A Case Study: How Hybrid Clouds Should Be Done," Cloudwards.net, January 21, 2018; Robert McMillan, "Amazon Grapples with Outage at AWS Cloud Service," *Wall Street Journal*, March 1, 2017; "AWS Case Study: Hi-Media," www.aws.amazon.com, accessed May 14, 2017; and Kelly Bit, "The $10 Hedge Fund Supercomputer That's Sweeping Wall Street," *Bloomberg Business Week,* May 20, 2015.

CASE STUDY QUESTIONS

1. What business benefits do cloud computing services provide? What problems do they solve?
2. What are the disadvantages of cloud computing?
3. What kinds of businesses are most likely to benefit from using cloud computing? Why?

the most popular software services for consumers, although they are increasingly used in business. Salesforce.com is a leading software service for business. Salesforce.com provides customer relationship management (CRM) and other application software solutions as software services leased over the Internet. Its sales and service clouds offer applications for improving sales and customer service. A marketing cloud enables companies to engage in digital marketing interactions with customers through email, mobile, social, web, and connected products. Salesforce.com also provides a community cloud platform for online collaboration and engagement and an analytics cloud platform to deploy sales, service, marketing, and custom analytics apps.

Salesforce.com is also a leading example of platform as a service (PaaS). Its Salesforce Platform gives users the ability to develop, launch, and manage applications without having to deal with the infrastructure required for creating new software. The Salesforce Platform provides a set of development tools and IT services that enable users to build new applications and run them in the cloud on Salesforce.com's data center infrastructure. Salesforce.com also lists software from other independent developers on its AppExchange, an online marketplace for third-party applications that run on the Salesforce Platform.

A cloud can be private or public. A **public cloud** is owned and maintained by a cloud service provider, such as Amazon Web Services, and made available to the general public or industry group. Public cloud services are often used for websites with public information and product descriptions, one-time large computing projects, developing and testing new applications, and consumer services such as online storage of data, music, and photos. Google Drive, Dropbox, and Apple iCloud are leading examples of these consumer public cloud services.

A **private cloud** is operated solely for an organization. It may be managed by the organization or a third party and may be hosted either internally or externally. Like public clouds, private clouds are able to allocate storage, computing power, or other resources seamlessly to provide computing resources on an as-needed basis. Companies that want flexible IT resources and a cloud service model while retaining control over their own IT infrastructure are gravitating toward these private clouds.

Because organizations using public clouds do not own the infrastructure, they do not have to make large investments in their own hardware and software. Instead, they purchase their computing services from remote providers and pay only for the amount of computing power they actually use (utility computing) or are billed on a monthly or annual subscription basis. The term **on-demand computing** has also been used to describe such services.

Cloud computing has some drawbacks. Unless users make provisions for storing their data locally, the responsibility for data storage and control is in the hands of the provider. Some companies worry about the security risks related to entrusting their critical data and systems to an outside vendor that also works with other companies. Companies expect their systems to be available 24/7 and do not want to suffer any loss of business capability if cloud infrastructures malfunction. Nevertheless, the trend is for companies to shift more of their computer processing and storage to some form of cloud infrastructure. Startups and small companies with limited IT resources and budgets will find public cloud services especially helpful.

Large firms are most likely to adopt a **hybrid cloud** computing model where they use their own infrastructure for their most essential core activities and adopt public cloud computing for less critical systems or for additional processing capacity during peak business periods. Table 5.2 compares the three cloud computing models. Cloud computing will gradually shift firms from having a fixed infrastructure capacity toward a more flexible infrastructure, some of it owned by the firm and some of it rented from giant computer centers owned by computer hardware vendors. You can find out more about cloud computing in the Learning Tracks for this chapter.

Edge Computing

Having all the laptops, smartphones, tablets, wireless sensor networks, and local on-premise servers used in cloud computing systems interacting with a single central public cloud data center to process all their data can be inefficient

TABLE 5.2 CLOUD COMPUTING MODELS COMPARED

TYPE OF CLOUD	DESCRIPTION	MANAGED BY	USES
Public cloud	Third-party service offering computing, storage, and software services to multiple customers and that is available to the public	Third-party service providers	Companies without major privacy concerns Companies seeking pay-as-you-go IT services Companies lacking IT resources and expertise
Private cloud	Cloud infrastructure operated solely for a single organization and hosted either internally or externally	In-house IT or private third-party host	Companies with stringent privacy and security requirements Companies that must have control over data sovereignty
Hybrid cloud	Combination of private and public cloud services that remain separate entities	In-house IT, private host, third-party providers	Companies requiring some in-house control of IT that are also willing to assign part of their IT infrastructures to a public cloud

and costly. **Edge computing** is a method of optimizing cloud computing systems by performing some data processing on a set of linked servers at the edge of the network, near the source of the data. This reduces the amount of data flowing back and forth between local computers and other devices and the central cloud data center.

Edge computing deployments are useful when sensors or other IoT devices do not need to be constantly connected to a central cloud. For example, an oil rig in the ocean might have thousands of sensors producing large amounts of data, perhaps to confirm that systems are working properly. The data do not necessarily need to be sent over a network as soon as they are produced, so the local edge computing system could compile the data and send daily reports to a central data center or cloud for long-term storage. By only sending important data over the network, the edge computing system reduces the amount of data traversing the network

Edge computing also reduces delays in the transmitting and processing of data because data does not have to travel over a network to a remote data center or cloud for processing. This is ideal for situations where delays of milliseconds can be untenable, such as in financial services or manufacturing.

Green Computing

By curbing hardware proliferation and power consumption, virtualization has become one of the principal technologies for promoting green computing. **Green computing, or green IT**, refers to practices and technologies for designing, manufacturing, using, and disposing of computers, servers, and associated devices such as monitors, printers, storage devices, and networking and communications systems to minimize impact on the environment.

According to Green House Data, the world's data centers use as much energy as the output of 30 nuclear power plants, which amounts to 1.5 percent of all energy use in the world. A corporate data center can easily consume over 100 times more power than a standard office building. All this additional power consumption has a negative impact on the environment and corporate operating costs. Data centers are now being designed with energy efficiency in mind, using state-of-the art air-cooling techniques, energy-efficient equipment, virtualization, and other energy-saving practices. Large companies like Microsoft, Google, Facebook, and Apple are starting to reduce their carbon footprint with clean energy–powered data centers with power-conserving equipment and extensive use of wind and hydropower.

High-Performance and Power-Saving Processors

Another way to reduce power requirements and hardware sprawl is to use more efficient and power-saving processors. Contemporary microprocessors now feature multiple processor cores (which perform the reading and execution of computer instructions) on a single chip. A **multicore processor** is an integrated circuit to which two or more processor cores have been attached for enhanced performance, reduced power consumption, and more efficient simultaneous processing of multiple tasks. This technology enables two or more processing engines with reduced power requirements and heat dissipation to perform tasks faster than a resource-hungry chip with a single processing core. Today you'll find PCs with dual-core, quad-core, six-core, and eight-core processors and servers with 16- and 32-core processors.

Intel and other chip manufacturers are working on microprocessors that minimize power consumption, which is essential for prolonging battery life in small mobile digital devices. Highly power-efficient microprocessors, such as the A9, A10, and A11 processors used in Apple's iPhone and iPad and Intel's Atom processor, are used in lightweight smartphones and tablets, intelligent cars, and healthcare devices.

5-4 What are the current computer software platforms and trends?

There are four major themes in contemporary software platform evolution:

- Linux and open source software
- Java, HTML, and HTML5
- Web services and service-oriented architecture
- Software outsourcing and cloud services

Linux and Open Source Software

Open source software is software produced by a community of several hundred thousand programmers around the world. According to the leading open source professional association, OpenSource.org, open source software is free and can be modified by users. Works derived from the original code must also be free. Open source software is by definition not restricted to any specific operating system or hardware technology.

Popular open source software tools include the Linux operating system, the Apache HTTP web server, the Mozilla Firefox web browser, and the Apache OpenOffice desktop productivity suite. Google's Android mobile operating system and Chrome web browser are based on open source tools. You can find out more about the Open Source Definition from the Open Source Initiative and the history of open source software in the Learning Tracks for this chapter.

Linux

Perhaps the most well-known open source software is Linux, an operating system related to Unix. Linux was created by Finnish programmer Linus Torvalds and first posted on the Internet in August 1991. Linux applications are embedded in cell phones, smartphones, tablet computers, and consumer electronics.

Linux is available in free versions downloadable from the Internet or in low-cost commercial versions that include tools and support from vendors such as Red Hat.

Although Linux is not used in many desktop systems, it is a leading operating system for servers, mainframe computers, and supercomputers. IBM, HP, Intel, Dell, and Oracle have made Linux a central part of their offerings to corporations. Linux has profound implications for corporate software platforms—cost reduction, reliability, and resilience—because Linux can work on all the major hardware platforms.

Software for the Web: Java, HTML, and HTML5

Java is an operating system-independent, processor-independent, object-oriented programming language created by Sun Microsystems that has become the leading interactive programming environment for the web. The Java platform has migrated into mobile phones, tablets, automobiles, music players, game machines, and set-top cable television systems serving interactive content and pay-per-view services. Java software is designed to run on any computer or computing device, regardless of the specific microprocessor or operating system the device uses. For each of the computing environments in which Java is used, a Java Virtual Machine interprets Java programming code for that machine. In this manner, the code is written once and can be used on any machine for which there exists a Java Virtual Machine.

Java developers can create small applet programs that can be embedded in web pages and downloaded to run on a web browser. A **web browser** is an easy-to-use software tool with a graphical user interface for displaying web pages and for accessing the web and other Internet resources. Microsoft's Internet Explorer, Mozilla Firefox, Google Chrome, and Apple Safari browsers are examples. At the enterprise level, Java is being used for more complex e-commerce and e-business applications that require communication with an organization's back-end transaction processing systems.

HTML and HTML5

Hypertext Markup Language (HTML) is a page description language for specifying how text, graphics, video, and sound are placed on a web page and for creating dynamic links to other web pages and objects. Using these links, a user need only point at a highlighted keyword or graphic, click on it, and immediately be transported to another document.

HTML was originally designed to create and link static documents composed largely of text. Today, however, the web is much more social and interactive, and many web pages have multimedia elements—images, audio, and video. Third-party plug-in applications like Flash, Silverlight, and Java have been required to integrate these rich media with web pages. However, these add-ons require additional programming and put strains on computer processing. The next evolution of HTML, called **HTML5**, solves this problem by making it possible to embed images, audio, video, and other elements directly into a document without processor-intensive add-ons. HTML5 makes it easier for web pages to function across different display devices, including mobile devices as well as desktops, and it will support the storage of data offline for apps that run over the web.

Other popular programming tools for web applications include Ruby and Python. Ruby is an object-oriented programming language known for speed and ease of use in building web applications, and Python (praised for its clarity) is being used for building cloud computing applications.

Web Services and Service-Oriented Architecture

Web services refer to a set of loosely coupled software components that exchange information with each other using universal web communication standards and languages. They can exchange information between two different systems regardless of the operating systems or programming languages on which the systems are based. They can be used to build open standard web-based applications linking systems of two different organizations, and they can also be used to create applications that link disparate systems within a single company. Different applications can use web services to communicate with each other in a standard way without time-consuming custom coding.

The foundation technology for web services is **XML**, which stands for Extensible Markup Language. This language was developed in 1996 by the World Wide Web Consortium (W3C, the international body that oversees the development of the web) as a more powerful and flexible markup language than hypertext markup language (HTML) for web pages. Whereas HTML is limited to describing how data should be presented in the form of web pages, XML can perform presentation, communication, and storage of data. In XML, a number is not simply a number; the XML tag specifies whether the number represents a price, a date, or a ZIP code. Table 5.3 illustrates some sample XML statements.

By tagging selected elements of the content of documents for their meanings, XML makes it possible for computers to manipulate and interpret their data automatically and perform operations on the data without human intervention. Web browsers and computer programs, such as order processing or enterprise resource planning (ERP) software, can follow programmed rules for applying and displaying the data. XML provides a standard format for data exchange, enabling web services to pass data from one process to another.

Web services communicate through XML messages over standard web protocols. Companies discover and locate web services through a directory. Using web protocols, a software application can connect freely to other applications without custom programming for each different application with which it wants to communicate. Everyone shares the same standards.

The collection of web services that are used to build a firm's software systems constitutes what is known as a service-oriented architecture. A **service-oriented architecture (SOA)** is set of self-contained services that communicate with each other to create a working software application. Business tasks are accomplished by executing a series of these services. Software developers reuse these services in other combinations to assemble other applications as needed.

Virtually all major software vendors provide tools and entire platforms for building and integrating software applications using web services. Microsoft has incorporated web services tools in its Microsoft .NET platform.

TABLE 5.3 EXAMPLES OF XML

PLAIN ENGLISH	XML
Subcompact	<AUTOMOBILETYPE="Subcompact">
4 passenger	<PASSENGERUNIT="PASS">4</PASSENGER>
$16,800	<PRICE CURRENCY="USD">$16,800</PRICE>

Dollar Rent A Car's systems use web services for its online booking system with Southwest Airline's website. Although both companies' systems are based on different technology platforms, a person booking a flight on Southwest.com can reserve a car from Dollar without leaving the airline's website. Instead of struggling to get Dollar's reservation system to share data with Southwest's information systems, Dollar used Microsoft .NET web services technology as an intermediary. Reservations from Southwest are translated into web services protocols, which are then translated into formats that can be understood by Dollar's computers.

Other car rental companies have linked their information systems to airline companies' websites before. But without web services, these connections had to be built one at a time. Web services provide a standard way for Dollar's computers to "talk" to other companies' information systems without having to build special links to each one. Dollar is now expanding its use of web services to link directly to the systems of a small tour operator and a large travel reservation system as well as a wireless website for cell phones and smartphones. It does not have to write new software code for each new partner's information systems or each new wireless device (see Figure 5.11).

Software Outsourcing and Cloud Services

Today, many business firms continue to operate legacy systems that continue to meet a business need and that would be extremely costly to replace. But they will purchase or rent most of their new software applications from external sources. Figure 5.12 illustrates the rapid growth in external sources of software for U.S. firms.

FIGURE 5.11 HOW DOLLAR RENT A CAR USES WEB SERVICES

Dollar Rent A Car uses web services to provide a standard intermediate layer of software to "talk" to other companies' information systems. Dollar Rent A Car can use this set of web services to link to other companies' information systems without having to build a separate link to each firm's systems.

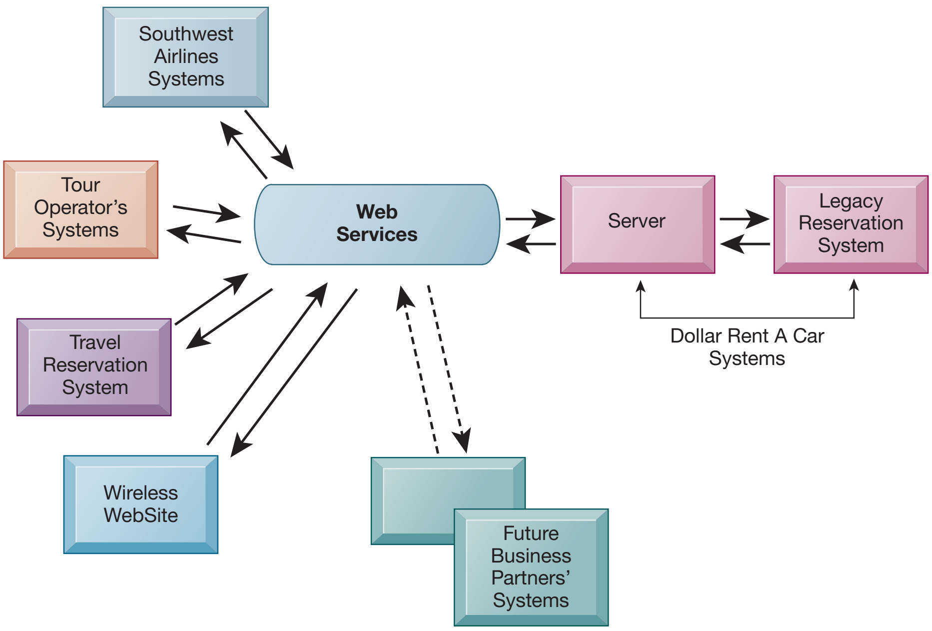
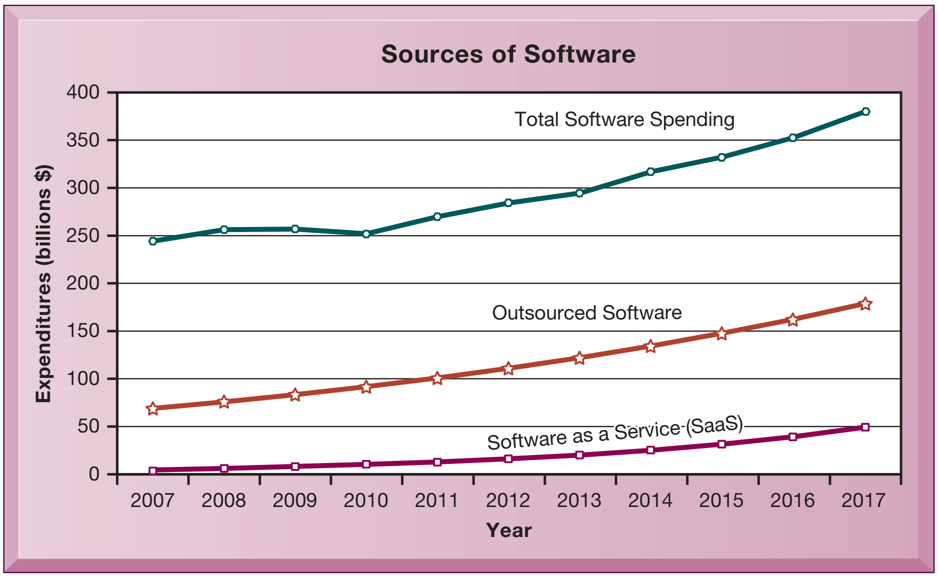


FIGURE 5.12 CHANGING SOURCES OF FIRM SOFTWARE

In 2017, U.S. firms spent an estimated $380 billion on software. About 47 percent ($179 billion) of that originated outside the firm, provided by a variety of vendors. About 13 percent ($49 billion) was provided by SaaS vendors as an online cloud-based service.

Sources: BEA National Income and Product Accounts, 2018.



There are three external sources for software: software packages from a commercial software vendor (most ERP systems), outsourcing custom application development to an external vendor (which may or may not be offshore), and cloud-based software services and tools (SaaS/PaaS).

Software Packages and Enterprise Software

We have already described software packages for enterprise applications as one of the major types of software components in contemporary IT infrastructures. A **software package** is a prewritten commercially available set of software programs that eliminates the need for a firm to write its own software programs for certain functions, such as payroll processing or order handling.

Enterprise application software vendors such as SAP and Oracle have developed powerful software packages that can support the primary business processes of a firm worldwide from warehousing, customer relationship management, and supply chain management to finance and human resources. These large-scale enterprise software systems provide a single, integrated, worldwide software system for firms at a cost much less than they would pay if they developed it themselves. Chapter 9 discusses enterprise systems in detail.

Software Outsourcing

Software **outsourcing** enables a firm to contract custom software development or maintenance of existing legacy programs to outside firms, which often operate offshore in low-wage areas of the world. For example, in 2013, IKEA announced a six-year offshore IT outsourcing deal with German infrastructure solutions firm Wincor Nixdorf. Wincor Nixdorf set up 12,000 point-of- sale (POS) systems in 300 IKEA stores in 25 countries. These systems use Wincor Nixdorf's POS TP.net software to control furniture checkout transactions in each store and consolidate all data across the retail group. Wincor Nixdorf provides IKEA with services that include operation and customization of the systems, as well as updating the software and applications running on them. Having a single software provider offshore helped IKEA reduce the work to run the stores (Existek, 2017). Offshore software outsourcing firms have primarily provided lower-level maintenance, data entry, and call center operations, although more sophisticated and experienced offshore firms, particularly in India, have been hired for new-program development. However, as wages offshore rise and the costs of managing offshore projects are factored in (see Chapter 13), some work that would have been sent offshore is returning to domestic companies.

Cloud-Based Software Services and Tools

In the past, software such as Microsoft Word or Adobe Illustrator came in a box and was designed to operate on a single machine. Today, you're more likely to download the software from the vendor's website or to use the software as a cloud service delivered over the Internet and pay a subscription fee.

Cloud-based software and the data it uses are hosted on powerful servers in data centers and can be accessed with an Internet connection and standard web browser. In addition to free or low-cost tools for individuals and small businesses provided by Google or Yahoo, enterprise software and other complex business functions are available as services from the major commercial software vendors. Instead of buying and installing software programs, subscribing companies rent the same functions from these services, with users paying either on a subscription or per-transaction basis. A leading example of software as a service (SaaS) is Salesforce.com, described earlier in this chapter, which provides on-demand software services for customer relationship management.

In order to manage their relationship with an outsourcer or technology service provider, firms need a contract that includes a **service level agreement (SLA)**. The SLA is a formal contract between customers and their service providers that defines the specific responsibilities of the service provider and the level of service expected by the customer. SLAs typically specify the nature and level of services provided, criteria for performance measurement, support options, provisions for security and disaster recovery, hardware and software ownership and upgrades, customer support, billing, and conditions for terminating the agreement. We provide a Learning Track on this topic.

Mashups and Apps

The software you use for both personal and business tasks today may be composed of interchangeable components that integrate freely with other applications on the Internet. Individual users and entire companies mix and match these software components to create their own customized applications and to share information with others. The resulting software applications are called **mashups**. The idea is to take different sources and produce a new work that is greater than the sum of its parts. You have performed a mashup if you've ever personalized your Facebook profile or your blog with a capability to display videos or slide shows.

Web mashups combine the capabilities of two or more online applications to create a kind of hybrid that provides more customer value than the original sources alone. For instance, ZipRealty uses Google Maps and data provided by an online real estate database. **Apps** are small, specialized software programs that run on the Internet, on your computer, or on your mobile phone or tablet and are generally delivered over the Internet. Google refers to its online services as apps. But when we talk about apps today, most of the attention goes to the apps that have been developed for the mobile digital platform. It is these apps that turn smartphones and tablets into general-purpose computing tools. There are now millions of apps for the IOS and Android operating systems.

Some downloaded apps do not access the web, but many do, providing faster access to web content than traditional web browsers. Apps provide a streamlined non-browser pathway for users to perform a number of tasks, ranging from reading the newspaper to shopping, searching, personal health monitoring, playing games, and buying. They increasingly are used by managers as gateways to their firm's enterprise systems. Because so many people are now accessing the Internet from their mobile devices, some say that apps are "the new browsers." Apps are also starting to influence the design and function of traditional websites as consumers are attracted to the look and feel of apps and their speed of operation.

Many apps are free or purchased for a small charge, much less than conventional software, which further adds to their appeal. The success of these mobile platforms depends in large part on the quantity and the quality of the apps they provide. Apps tie the customer to a specific hardware platform: As the user adds more and more apps to his or her mobile phone, the cost of switching to a competing mobile platform rises.

At the moment, the most commonly downloaded apps are games, news and weather, maps/navigation, social networking, music, and video/movies. But there are also serious apps for business users that make it possible to create and edit documents, connect to corporate systems, schedule and participate in meetings, track shipments, and dictate voice messages (see the Chapter 1 Interactive Session on Management). Most large online retailers have apps for consumers for researching and buying goods and services online.

5-5 What are the challenges of managing IT infrastructure and management solutions?

Creating and managing a coherent IT infrastructure raises multiple challenges: dealing with platform and technology change (including cloud and mobile computing), management and governance, and making wise infrastructure investments.

Dealing with Platform and Infrastructure Change

As firms grow, they often quickly outgrow their infrastructure. As firms shrink, they can get stuck with excessive infrastructure purchased in better times. How can a firm remain flexible if investments in IT infrastructure are fixed-cost purchases and licenses? How well does the infrastructure scale? **Scalability** refers to the ability of a computer, product, or system to expand to serve a large number of users without breaking down. New applications, mergers and acquisitions, and changes in business volume all affect computer workload and must be considered when planning hardware capacity.

Firms using mobile computing and cloud computing platforms will require new policies, procedures, and tools for managing these platforms. They will need to inventory all of their mobile devices in business use and develop policies and tools for tracking, updating, and securing them, and for controlling the data and applications that run on them. Firms often turn to **mobile device management (MDM)** software, which monitors, manages, and secures mobile devices that are deployed across multiple mobile service providers and across multiple mobile operating systems being used in the organization. MDM tools enable the IT department to monitor mobile usage, install or update mobile software, back up and restore mobile devices, and remove software and data from devices that are stolen or lost.

Firms using cloud computing and SaaS will need to fashion new contractual arrangements with remote vendors to make sure that the hardware and software for critical applications are always available when needed and that they meet corporate standards for information security. It is up to business management to determine acceptable levels of computer response time and availability for the firm's mission-critical systems to maintain the level of business performance that is expected.

Management and Governance

A long-standing issue among information system managers and CEOs has been the question of who will control and manage the firm's IT infrastructure. Chapter 2 introduced the concept of IT governance and described some issues it addresses. Other important questions about IT governance are: Should departments and divisions have the responsibility of making their own information technology decisions, or should IT infrastructure be centrally controlled and managed? What is the relationship between central information systems management and business unit information systems management? How will infrastructure costs be allocated among business units? Each organization will need to arrive at answers based on its own needs.

Making Wise Infrastructure Investments

IT infrastructure is a major investment for the firm. If too much is spent on infrastructure, it lies idle and constitutes a drag on the firm's financial performance. If too little is spent, important business services cannot be delivered and the firm's competitors (who spent the right amount) will outperform the under-investing firm. How much should the firm spend on infrastructure? This question is not easy to answer.

A related question is whether a firm should purchase and maintain its own IT infrastructure components or rent them from external suppliers, including those offering cloud services. The decision either to purchase your own IT assets or to rent them from external providers is typically called the *rent-versus-buy* decision.

Cloud computing is a low-cost way to increase scalability and flexibility, but firms should evaluate this option carefully in light of security requirements and impact on business processes and workflows. In some instances, the cost of renting software adds up to more than purchasing and maintaining an application in-house, or firms can overspend on cloud services (Loten, 2018). Yet there are many benefits to using cloud services including significant reductions in hardware, software, human resources, and maintenance costs. Moving to cloud computing allows firms to focus on their core businesses rather than technology issues.

Total Cost of Ownership of Technology Assets

The actual cost of owning technology resources includes the original cost of acquiring and installing hardware and software as well as ongoing administration costs for hardware and software upgrades, maintenance, technical support, training, and even utility and real estate costs for running and housing

TABLE 5.4 TOTAL COST OF OWNERSHIP (TCO) COST COMPONENTS

INFRASTRUCTURE COMPONENT	COST COMPONENTS
Hardware acquisition	Purchase price of computer hardware equipment, including computers, terminals, storage, and printers
Software acquisition	Purchase or license of software for each user
Installation	Cost to install computers and software
Training	Cost to provide training for information systems specialists and end users
Support	Cost to provide ongoing technical support, help desks, and so forth
Maintenance	Cost to upgrade the hardware and software
Infrastructure	Cost to acquire, maintain, and support related infrastructure, such as networks and specialized equipment (including storage backup units)
Downtime	Cost of lost productivity if hardware or software failures cause the system to be unavailable for processing and user tasks
Space and energy	Real estate and utility costs for housing and providing power for the technology

the technology. The **total cost of ownership (TCO)** model can be used to analyze these direct and indirect costs to help firms determine the actual cost of specific technology implementations. Table 5.4 describes the most important components to consider in a TCO analysis.

When all these cost components are considered, the TCO for a PC might run up to three times the original purchase price of the equipment. Gains in productivity and efficiency from equipping employees with mobile computing devices must be balanced against increased costs from integrating these devices into the firm's IT infrastructure and from providing technical support. Other cost components include fees for wireless airtime, end-user training, help desk support, and software for special applications. Costs are higher if the mobile devices run many different applications or need to be integrated into back-end systems such as enterprise applications.

Hardware and software acquisition costs account for only about 20 percent of TCO, so managers must pay close attention to administration costs to understand the full cost of the firm's hardware and software. It is possible to reduce some of these administration costs through better management. Many large firms are saddled with redundant, incompatible hardware and software because their departments and divisions have been allowed to make their own technology purchases.

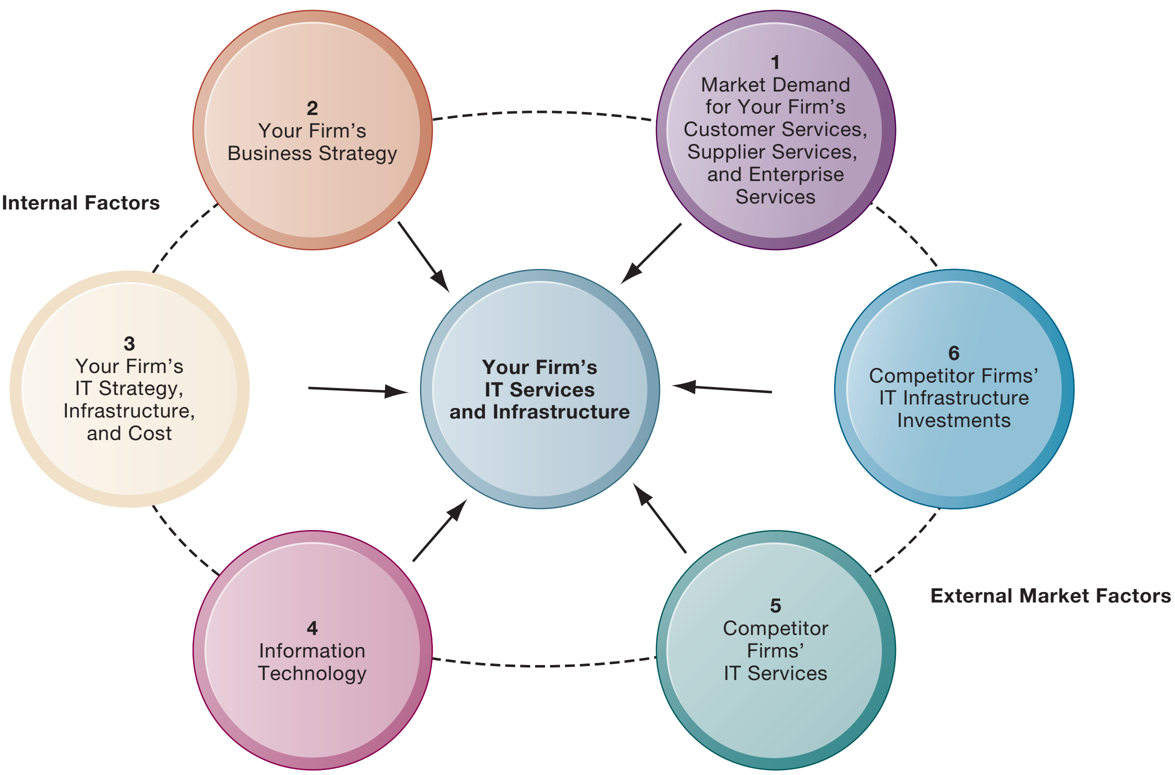
In addition to switching to cloud services, these firms could reduce their TCO through greater centralization and standardization of their hardware and software resources. Companies could reduce the size of the information systems staff required to support their infrastructure if the firm minimizes the number of different computer models and pieces of software that employees are allowed to use. In a centralized infrastructure, systems can be administered from a central location and troubleshooting can be performed from that location.

Competitive Forces Model for IT Infrastructure Investment

Figure 5.13 illustrates a competitive forces model you can use to address the question of how much your firm should spend on IT infrastructure.

FIGURE 5.13 COMPETITIVE FORCES MODEL FOR IT INFRASTRUCTURE

There are six factors you can use to answer the question "How much should our firm spend on IT infrastructure?"



1. **Market demand for your firm's services.** Make an inventory of the services you currently provide to customers, suppliers, and employees. Survey each group, or hold focus groups to find out if the services you currently offer are meeting the needs of each group. For example, are customers complaining of slow responses to their queries about price and availability? Are employees complaining about the difficulty of finding the right information for their jobs? Are suppliers complaining about the difficulties of discovering your production requirements?
2. **Your firm's business strategy.** Analyze your firm's five-year business strategy and try to assess what new services and capabilities will be required to achieve strategic goals.
3. **Your firm's IT strategy, infrastructure, and cost.** Examine your firm's information technology plans for the next five years and assess its alignment with the firm's business plans. Determine the total IT infrastructure costs. You will want to perform a TCO analysis. If your firm has no IT strategy, you will need to devise one that takes into account the firm's five-year strategic plan.
4. **Information technology assessment.** Is your firm behind the technology curve or at the bleeding edge of information technology? Both situations are to be avoided. It is usually not desirable to spend resources on advanced technologies that are still experimental, often expensive, and sometimes unreliable. You want to spend on technologies for which standards have been established; IT vendors are competing on cost, not design; and where there are multiple suppliers. However, you do not want to put off investment in new technologies or allow competitors to develop new business models and capabilities based on the new technologies.

Competitor firm services. Try to assess what technology services competitors offer to customers, suppliers, and employees. Establish quantitative and qualitative measures to compare them to those of your firm. If your firm's service levels fall short, your company is at a competitive disadvantage. Look for ways your firm can excel at service levels.

Competitor firm IT infrastructure investments. Benchmark your expenditures for IT infrastructure against your competitors. Many companies are quite public about their innovative expenditures on IT. If competing firms try to keep IT expenditures secret, you may be able to find IT investment information in public companies' SEC Form 10-K annual reports to the federal government when those expenditures affect a firm's financial results.

Your firm does not necessarily need to spend as much as or more than your competitors. Perhaps it has discovered much less expensive ways of providing services, and this can lead to a cost advantage. Alternatively, your firm may be spending far less than competitors, and experiencing commensurate poor performance and losing market share.

5-6 How will MIS help my career?

Here is how Chapter 5 and this book can help you find a job as an entry-level IT consultant.

The Company

A1 Tech IT Consulting, a national technology consulting firm headquartered in Atlanta, is looking for an entry-level IT consultant. The company partners with technology vendors to create and sell leading-edge technology solutions based on cloud, network, and managed IT services to small, medium-sized, and enterprise-sized companies. The company has 65 employees and is noted for outstanding customer service.

Position Description

The entry-level IT consultant will work with the firm's account managers to maintain good relationships with existing clients and help its technology consultants create solutions and proposals for prospective customers. The company will provide on-the-job training about the technology industry and its technology consulting process. Job responsibilities include:

- Providing research on potential and existing clients and the competitive landscape.
- Managing digital marketing campaigns.
- Assisting in identifying potential business opportunities.
- Preparing periodic reports on screening, tracking, and monitoring clients and prospects.

Job Requirements

- Bachelor's degree or equivalent
- Ability to communicate well with clients by phone, by email, and face-to-face
- Strong organizational, presentation, and writing skills

- Ability to work in a fast-paced environment and collaborate effectively as a team member
- Proficiency in Microsoft Office (Word, Excel, and PowerPoint)
- Strong organizational, presentation, and writing skills and willingness to learn

Interview Questions

1. What do you know about cloud computing and managed IT services? Are you familiar with common operating systems, security, and data management platforms? Have you ever used these services on the job? What did you do with them?
2. Have you had much face-to-face contact with customers? Can you describe what work you did with customers? Have you ever helped customers with a technology problem?
3. Do you have any digital marketing experience?
4. Can you give us an example of a sales-related problem or other business problem that you helped solve? Do you do any writing and analysis? Can you provide examples?
5. What is your level of proficiency with Microsoft Office? What work have you done with Excel spreadsheets?

Author Tips

1. Review this chapter and also Chapters 6 and 8 of this text, paying special attention to cloud computing, networking technology, and managed technology services.
2. Use the web to research the company and how it works with other technology companies to provide its IT services. Learn what you can about these partner companies as well and the tools and services they offer.
3. Inquire exactly how you would be using Microsoft Office, and if possible provide examples of how you used these tools to solve problems in the classroom or for a job assignment. Bring examples of your writing (including some from your Digital Portfolio described in MyLab MIS) demonstrating your analytical skills and project experience.
4. Indicate that you are very interested in learning more about the technology industry and technologies and services used by the company.
5. Review the company's LinkedIn page, Facebook, and Twitter to learn about strategic trends and important issues for this company.

REVIEW **SUMMARY**

5-1 What is IT infrastructure, and what are the stages and drivers of IT infrastructure evolution?

IT infrastructure is the shared technology resources that provide the platform for the firm's specific information system applications. IT infrastructure includes hardware, software, and services that are shared across the entire firm.

The five stages of IT infrastructure evolution are the mainframe era, the personal computer era, the client/server era, the enterprise computing era, and the cloud and mobile computing era. Moore's Law deals with the exponential increase in processing power and decline in the cost of computer technology, stating that every 18 months the power of microprocessors doubles and the price of computing falls in half. The Law of Mass Digital Storage deals with the exponential decrease in the cost of storing data, stating that the number of kilobytes of data that can be stored on magnetic media for $1 roughly doubles every 15 months. Metcalfe's Law states that a network's value to participants grows exponentially as the network takes on more members. The rapid decline in costs of communication and growing agreement in the technology industry to use computing and communications standards are also driving an explosion of computer use.

5-2 What are the components of IT infrastructure?

Major IT infrastructure components include computer hardware platforms, operating system platforms, enterprise software platforms, networking and telecommunications platforms, database management software, Internet platforms, and consulting services and systems integrators.

5-3 What are the current trends in computer hardware platforms?

Increasingly, computing is taking place on a mobile digital platform. Quantum computing is an emerging technology that could dramatically boost processing power through the ability to be in more than one state at the same time. Consumerization of IT is the business use of information technology that originated in the consumer market. Virtualization organizes computing resources so that their use is not restricted by physical configuration or geographic location. In cloud computing, firms and individuals obtain computing power and software as services over a network, including the Internet, rather than purchasing and installing the hardware and software on their own computers. Edge computing helps optimize cloud computing by performing some data processing on a set of linked servers at the edge of the network, near the source of the data. A multicore processor is a microprocessor to which two or more processing cores have been attached for enhanced performance. Green computing includes practices and technologies for producing, using, and disposing of information technology hardware to minimize negative impact on the environment.

5-4 What are the current computer software platforms and trends?

Open source software is produced and maintained by a global community of programmers and is often downloadable for free. Linux is a powerful, resilient open source operating system that can run on multiple hardware platforms and is used widely to run web servers. Java is an operating system– and hardware-independent programming language that is the leading interactive programming environment for the web. HTML5 makes it possible to embed images, audio, and video directly into a web document without add-on programs. Web services are loosely coupled software components based on open web standards that work with any application software and operating system. They can be used as components of web-based applications linking the systems of two different organizations or to link disparate systems of a single company. Companies are purchasing their new software applications from outside sources, including software packages, by outsourcing custom application development to an external vendor (that may be offshore), or by renting online software services (SaaS). Mashups combine two different software services to create new software applications and services. Apps are software applications that run on mobile devices and are delivered over the Internet.

5-5 What are the challenges of managing IT infrastructure and management solutions?

Major challenges include dealing with platform and infrastructure change, infrastructure management and governance, and making wise infrastructure investments. Solution guidelines include using a competitive forces model to determine how much to spend on IT infrastructure and where to make strategic infrastructure investments, and establishing the total cost of ownership (TCO) of information technology assets. The total cost of owning technology resources includes not only the original cost of computer hardware and software but also costs for hardware and software upgrades, maintenance, technical support, and training. Many firms are turning to cloud computing in an effort to reduce their IT platform costs. Firms use tools for mobile device management (MDM) to monitor, manage, and secure mobile devices that are deployed across the enterprise.

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MyLab MIS
To complete the problems with MyLab MIS, go to EOC Discussion Questions in MyLab MIS.

Review Questions

5-1 What is IT infrastructure, and what are the stages and drivers of IT infrastructure evolution?

- Define IT infrastructure from both a technology and a services perspective.
- List each of the eras in IT infrastructure evolution and describe its distinguishing characteristics.
- Define and describe the following: web server, application server, multitiered client/server architecture.
- Describe Moore's Law and the Law of Mass Digital Storage.
- Describe how network economics, declining communications costs, and technology standards affect IT infrastructure.

5-2 What are the components of IT infrastructure?

- List and describe the components of IT infrastructure that firms need to manage.

5-3 What are the current trends in computer hardware platforms?

- Describe the evolving mobile platform, consumerization of IT, and cloud computing.
- Explain how businesses can benefit from virtualization, green computing, and multicore processors.

5-4 What are the current computer software platforms and trends?

- Define and describe open source software and Linux and explain their business benefits.
- Define Java and HTML5 and explain why they are important.
- Define and describe web services and the role played by XML.
- Name and describe the three external sources for software.
- Define and describe software mashups and apps.

5-5 What are the challenges of managing IT infrastructure and management solutions?

- Name and describe the management challenges posed by IT infrastructure.
- Explain how using a competitive forces model and calculating the TCO of technology assets help firms make good infrastructure investments.

Discussion Questions

5-6 MyLab MIS Why is selecting computer hardware and software for the organization an important management decision? What management, organization, and technology issues should be considered when selecting computer hardware and software?

5-7 MyLab MIS Should organizations use software service providers for all their software needs? Why or why not? What management, organization, and technology factors should be considered when making this decision?

5-8 MyLab MIS What are the advantages and disadvantages of cloud computing?

Hands-On MIS Projects

The projects in this section give you hands-on experience in developing solutions for managing IT infrastructures and IT outsourcing, using spreadsheet software to evaluate alternative desktop systems, and using web research to budget for a sales conference. Visit MyLab MIS to access this chapter's Hands-On MIS Projects.

Management Decision Problems

5-9 The University of Pittsburgh Medical Center (UPMC) relies on information systems to operate 19 hospitals, a network of other care sites, and international and commercial ventures. Demand for additional servers and storage technology was growing by 20 percent each year. UPMC was setting up a separate server for every application, and its servers and other computers were running a number of different operating systems, including several versions of Unix and Windows. UPMC had to manage technologies from many different vendors, including Hewlett-Packard (HP), Sun Microsystems, Microsoft, and IBM. Assess the impact of this situation on business performance. What factors and management decisions must be considered when developing a solution to this problem?

5-10 Qantas Airways, Australia's leading airline, faces cost pressures from high fuel prices and lower levels of global airline traffic. To remain competitive, the airline must find ways to keep costs low while providing a high level of customer service. Qantas had a 30-year-old data center. Management had to decide whether to replace its IT infrastructure with newer technology or outsource it. What factors should be considered by Qantas management when deciding whether to outsource? If Qantas decides to outsource, list and describe points that should be addressed in a service level agreement.

Improving Decision Making: Using a Spreadsheet to Evaluate Hardware and Software Options

Software skills: Spreadsheet formulas
Business skills: Technology pricing

5-11 In this exercise, you will use spreadsheet software to calculate the cost of desktop systems, printers, and software.

Use the Internet to obtain pricing information on hardware and software for an office of 30 people. You will need to price 30 PC desktop systems (monitors, computers, and keyboards) manufactured by Lenovo, Dell, and HP. (For the purposes of this exercise, ignore the fact that desktop systems usually come with preloaded software packages.) Also obtain pricing on 15 desktop printers manufactured by HP, Canon, and Brother. Each desktop system must satisfy the minimum specifications shown in tables that you can find in MyLab MIS.

Also obtain pricing on 30 licenses or copies of the most recent versions of Microsoft Office 365 Business and Apache Open Office (formerly Oracle Open Office) and on 30 copies of Microsoft Windows 10 Pro. Each desktop productivity solution should contain software for word processing, spreadsheets, database, and presentations. Prepare a spreadsheet showing your research results for the desktop system, printer, and software combination offering the best performance and pricing per worker over a two-year period. Because every two workers share one printer (15 printers/30 systems), your calculations should assume only half a printer cost per worker.

Improving Decision Making: Using Web Research to Budget for a Sales Conference

Software skills: Internet-based software
Business skills: Researching transportation and lodging costs

5-12 The Foremost Composite Materials Company is planning a two-day sales conference for October 19–20, starting with a reception on the evening of October 18. The conference consists of all-day meetings that the entire sales force, numbering 120 sales representatives and their 16 managers, must attend. Each sales representative requires his or her own room, and the company needs two common meeting rooms, one large enough to hold the entire sales force plus a few visitors (200) and the other able to hold half the force. Management has set a budget of $195,000 for the representatives' room rentals. The company would like to hold the conference in either Miami or Marco Island, Florida, at a Hilton- or Marriott-owned hotel.

Use the Hilton and Marriott websites to select a hotel in whichever of these cities would enable the company to hold its sales conference within its budget and meet its sales conference requirements. Then locate flights arriving the afternoon prior to the conference. Your attendees will be coming from Los Angeles (51), San Francisco (30), Seattle (22), Chicago (19), and Pittsburgh (14). Determine costs of each airline ticket from these cities. When you are finished, create a budget for the conference. The budget will include the cost of each airline ticket, the room cost, and $70 per attendee per day for food.

Collaboration and Teamwork Project

Evaluating Server and Mobile Operating Systems

5-13 Form a group with three or four of your classmates. Choose server or mobile operating systems to evaluate. You might research and compare the capabilities and costs of Linux versus Unix or the most recent version of the Windows operating system for servers. Alternatively, you could compare the capabilities of the Android mobile operating system with iOS for the iPhone. If possible, use Google Docs and Google Drive or Google Sites to brainstorm, organize, and develop a presentation of your findings for the class.

Is BYOD Good for Business?

CASE STUDY

Just about everyone who has a smartphone wants to be able to bring it to work and use it on the job, and many employers would like workers to do so. A survey of BYOD trends by MarketsandMarkets found that adoption rates among North American companies approached 50 percent by the start of 2018. Research from Sapho workplace productivity experts found the average worker saves 81 minutes per week in productivity by using a personal device at work.

Will BYOD become the new normal? Not necessarily. Half of all enterprises believe that BYOD represents a growing problem for their organizations, according to a number of studies. Although BYOD can improve employee job satisfaction and productivity, it also can cause a number of problems if not managed properly. Support for personally owned devices is more difficult than it is for company-supplied devices, the cost of managing mobile devices can increase, and protecting corporate data and networks becomes more difficult.

When every employee brings his or her own device to work, IT departments lose almost all control over the hardware. They can't control what apps or programs are installed, how the devices are secured, or what files are downloaded. In the past, the firm was able to control who had what technology in order to prevent privacy breaches, hacking, and unauthorized access to corporate information. Inability to control the hardware means more vulnerabilities. That is the big tradeoff with BYOD: offering employees greater flexibility while potentially exposing the company to danger.

BYOD advocates have argued that it increases employee productivity, but that is not always the case. When employees bring their own devices to work, they may be tempted to use them on the job for entertainment or catching up with friends. It's incredibly easy for employees to get sucked into an endless black hole of text messaging, YouTube videos, and checking Facebook updates. Productivity will suffer (see the Chapter 7 Interactive Session on Management).

BYOD requires a significant portion of corporate IT resources dedicated to managing and maintaining a large number of devices within the organization. In the past, companies tried to limit business smartphone use to a single platform. This made it easier to keep track of each mobile device and to roll out software upgrades or fixes because all employees were using the same devices or, at the very least, the same operating system. Today, the mobile digital landscape is much more complicated, with a variety of devices and operating systems on the market that do not have well-developed tools for administration and security. Android has over 80 percent of the worldwide smartphone market, but it is more difficult to use for corporate work than Apple mobile devices using the iOS operating system. iOS is considered a closed system and runs only on a limited number of different Apple mobile devices. In contrast, Android's fragmentation makes it more difficult and costly for corporate IT to manage. There are about 25,000 different models of Android-based devices available around the world, according to a report by OpenSignal, which researches wireless networks and devices. Android's huge consumer market share attracts many hackers. Android is also vulnerable because it has an open source architecture and comes in multiple versions.

If employees are allowed to work with more than one type of mobile device and operating system, companies need an effective way to keep track of all the devices employees are using. To access company information, the company's networks must be configured to receive connections from that device. When employees make changes to their personal phone, such as switching cellular carriers, changing their phone number, or buying a new mobile device altogether, companies will need to quickly and flexibly ensure that their employees are still able to remain productive. Firms need a system that keeps track of which devices employees are using, where the device is located, whether it is being used, and what software it is equipped with. For unprepared companies, keeping track of who gets access to what data could be a nightmare.

With the large variety of mobile devices and operating systems available, providing adequate technical support for every employee could be difficult. When employees are not able to access critical data or encounter other problems with their mobile devices, they will need assistance from the information systems department. Companies that rely on desktop computers tend to have many of the same computers with the same specs and operating systems, making tech support that much easier. Mobility introduces a new layer of variety and complexity to tech support that companies need to be prepared to handle.

There are significant concerns with securing company information accessed with mobile devices. If a device is stolen or compromised, companies need ways to ensure that sensitive or confidential information isn't freely available to anyone. Mobility puts assets and data at greater risk than if they were only located within company walls and on company machines. Marble Security Labs analyzed 1.2 million Android and iOS apps and found that the consumer apps on mobile devices did not adequately protect business information. Companies often use technologies that allow them to wipe data from devices remotely or encrypt data so that if the device is stolen, it cannot be used. You'll find a detailed discussion of mobile security issues in Chapter 8.

Intel was a pioneer in the BYOD movement and has successfully implemented an enterprise-wide policy covering more than 30,000 employee mobile devices. Another major issue surrounding a corporate BYOD policy is the potential lack of trust between workers and management when management has access to personal data on employee devices. To deal with this issue, Intel has established clear-cut guidelines informing employees about exactly what information can and can't be seen when administrators manage personal devices. Intel will quickly respond to any questions employees might have regarding BYOD. The company also allows employees to choose among different levels of mobile access to corporate systems, with each tier accompanied by different levels of security.

SAP, a leading global vendor of enterprise software, is another tech company that has implemented BYOD successfully. The company developed a specialized mobile platform for various work-related applications, enabling employees to work from anywhere with their mobile devices. SAP has also created a security system for decommissioning a mobile device within a minute whenever a smartphone or tablet is lost or stolen. All SAP divisions across the globe have reported some form of success with BYOD. SAP Australia/New Zealand reports that the policy is key in attracting younger workers who are attached to their mobile devices and constantly use the apps.

The global reinsurance giant Swiss Re believes every employee should be able to work in the way they choose and has more and more staff using their own smartphones and tablets to access its intranet and personal information management (PIM) apps. Swiss Re successfully implemented BYOD by choosing a secure, highly scalable Enterprise Mobility Management (EMM) system that could support multiple operating systems, and a local partner to manage all of its technical and organizational aspects.

Over the past six years, 4,500 employee-owned iPhones and iPads have been added to the system alongside existing company devices. About one-third of the smartphones and tablets are company-owned and the other two-thirds are owned by employees of Swiss Re. Swiss Re manages these devices using MobileIron's EMM system, which enables global enterprises to secure and manage modern operating systems in a world of mixed-use mobile devices and desktops. It incorporates identity, context, and privacy enforcement to set the appropriate level of access to enterprise data and services.

The multi-OS EMM solution was rolled out with the help of local partner Nomasis AG. Likewise, Android is a possibility in the future. If it meets the company's security requirements, staff wishing to use Android devices will probably be allowed to do so as part of Swiss Re's BYOD strategy, obviously within the framework of MobileIron.

Supporting nearly all current mobile operating systems is a big technical and organizational challenge for Swiss Re, but management feels it has been worthwhile. Mobile devices have helped the company experience a significant rise in user productivity, because staff can access documents more quickly, whether they're in the office or traveling on business.

Blackstone, a global investment and advisory firm, has implemented a BYOD policy, but it has placed limitations on the types of devices employees can use. Blackstone's BYOD policy only allows employees to use their own Apple products such as iPads. For that company, Apple devices were the easiest to support and required little maintenance compared to other mobile tools. Any other devices would add to the workload of Blackstone's IT department, thus eliminating the cost savings that often come with BYOD. Due to Apple's popularity, few employees have objected.

At Venafi, a cybersecurity company, employees have the option of bringing their own smartphones, tablets, and notebooks to work with them or using company-issued devices. The company has a well-developed BYOD policy. Venafi's IT department does not support employees' hardware devices because it would be too difficult to handle all the different mobile devices and software available to consumers. That means employees are responsible for troubleshooting and repairs of their personal equipment. However, Venafi does ensure that each device is securely connected to the corporate network.

According to Tammy Moskites, Venafi CISO and CIO, the biggest challenge in defining a BYOD policy that leaves everyone satisfied has been balancing risk with flexibility. Although Venafi has given employees the choice of using their own mobile devices, it has also written contracts with language describing the terms and conditions for bringing one's own device into work, including the ability to remove company data from the device if needed.

Many corporate BYOD policies restrict access to time-wasting sites like Facebook, YouTube, or Twitter. But Venafi management believes that instead of resorting to measures like blocking YouTube or Facebook and forbidding the use of mobile phones, companies should focus more on performance. As long as the employees are motivated and performing well, they shouldn't be subjected to unnecessary restrictions. Employees typically don't understand the implications of BYOD and the dangers of lax security. Venafi's IT department tries to educate employees about realities of BYOD and gives them the power to use their devices responsibly.

Iftekhar Khan, IT director at Toronto's Chelsea Hotel, remains less sanguine. He believes BYOD might work for his company down the road but not in the immediate future. Khan notes that the hospitality industry and many others still want employees to use corporate-owned devices for any laptop, tablet, or smartphone requiring access to the corporate network. His business has sensitive information and needs that level of control. Although the hotel might possibly save money with BYOD, it's ultimately all about productivity.

Sources: "Swiss Re Chooses MobileIron 'Bring Your Own Device' Technology," www.mobileiron.com, accessed March 9, 2018; "5 BYOD Management Case Studies," Sunviewsoftware.com, accessed March 9, 2018; Stasmayer Incorporated, "The 'Bring Your Own Device' Trend: Is It Worth It?" www.stasmayer.com, accessed March 10, 2018; Lisa Phifer, "The Challenges of a Bring Your Own Device (BYOD) Policy," *Simple MDM*, January 5, 2017; Jonathan Crowl, "The Latest BYOD Trends and Predictions, from Mobile Focus to Endpoint Management." *Mobile Business Insights*, August 14, 2017; Ryan Patrick, "Is a BYOD Strategy Best for Business?" *IT World Canada*, March 22, 2016; Linda Gimmeson, "3 Companies Showing Success With BYOD," Toolbox.com, July 9, 2015; Alan F., "Open Signal: 24,093 Unique and Different Android-Powered Devices Are Available," Phonearena.com, August 5, 2015.

CASE STUDY QUESTIONS

5-14 What are the advantages and disadvantages of allowing employees to use their personal mobile devices for work?

5-15 What management, organization, and technology factors should be addressed when deciding whether to allow employees to use their personal mobile devices for work?

5-16 Evaluate how the companies described in this case study dealt with the challenges of BYOD.

5-17 Allowing employees to use their own smartphones for work will save the company money. Do you agree? Why or why not?

MyLab MIS

Go to the Assignments section of MyLab MIS to complete these writing exercises.

5-18 What are the distinguishing characteristics of cloud computing, and what are the three types of cloud services?

5-19 What is the total cost of ownership of technology assets, and what are its cost components?

Chapter 5 References

Amazon Web Services. "Overview of Amazon Web Services." (April 2017).

Benitez, Jose, Gautam Ray, and Jörg Henseler. "Impact of Information Technology Infrastructure Flexibility on Mergers and Acquisitions." *MIS Quarterly* 42 No. 1 (March 2018).

Butler, Brandon. "Battle of the Clouds: Amazon Web Services vs. Microsoft Azure vs. Google Cloud Platform." *Network World* (February 22, 2017).

Carr, Nicholas. *The Big Switch*. New York: Norton (2008).

Choi, Jae, Derek L. Nazareth, and Hemant K. Jain. "Implementing Service-Oriented Architecture in Organizations." *Journal of Management Information Systems* 26, No. 4 (Spring 2010).

Cisco Systems. "Cisco Global Cloud Index: Forecast and Methodology, 2016–2021 White Paper." (February 1, 2018).

David, Julie Smith, David Schuff, and Robert St. Louis. "Managing Your IT Total Cost of Ownership." *Communications of the ACM* 45, No. 1 (January 2002).

Elumalai, Arul, Kara Sprague, Sid Tandon, and Lareina Yee. "Ten Trends Redefining Enterprise IT Infrastructure." McKinsey & Company (November 2017).

Existek. "Offshore Outsourcing: 3 Examples of Successful IT Outsourcing." (June 22, 2017).

Flamm, Kenneth. "Measuring Moore's Law: Evidence from Price, Cost, and Quality Indexes." University of Texas at Austin Preliminary Draft (2017).

Flinders, Karl. "Ofcom Outsources IT Management to Indian Services Supplier NIIT." *Computer Weekly* (January 12, 2016).

Follow, Jaewon Kang. "IBM Bets on Next-Gen Technologies as it Tries to Stave Off Rivals." TheStreet.com (May 5, 2016).

Gartner, Inc. "Gartner Forecasts Worldwide Public Cloud Services Revenue to Reach $260 Billion in 2017." (October 12, 2017).

___________. "Gartner Says Global IT Spending to Reach $3.7 Trillion in 2018." (January 18, 2018).

Guo, Zhiling, and Dan Ma. "A Model of Competition Between Perpetual Software and Software as a Service." *MIS Quarterly* 42 No. 1 (March 2018).

International Data Corporation. "Worldwide Public Cloud Services Spending Forecast to Double by 2019, According to IDC." (January 21, 2016).

Internet World Stats. "World Internet Usage and Population Statistics." Internetworldstats.com, accessed March 15, 2018.

Kauffman, Robert J., and Julianna Tsai. "The Unified Procurement Strategy for Enterprise Software: A Test of the 'Move to the Middle' Hypothesis." *Journal of Management Information Systems* 26, No. 2 (Fall 2009).

Letschin, Michael. "Six Trends That Will Change How You Think About Data Storage." *Information Management* (February 8, 2016).

Li, Shengli, Hsing Kenneth Cheng, Yang Duan, and Yu-Chen Yang. "A Study of Enterprise Software Licensing Models." *Journal of Management Information Systems* 34 No. 1 (2017).

Loten, Angus. "Rush to the Cloud Creates Risk of Overspending." *Wall Street Journal* (July 25, 2018).

Lyman, Peter, and Hal R. Varian. "How Much Information 2003?" University of California at Berkeley School of Information Management and Systems (2003).

Markoff, John. "Moore's Law Running Out of Room, Tech Looks for a Successor." *New York Times* (May 4, 2016).

Mearian, Lucas. "Data Storage Goes from $1M to 2 Cents Per Gigabyte." *Computerworld* (March 23, 2017).

Mell, Peter, and Tim Grance. "The NIST Definition of Cloud Computing." Version 15. *NIST* (October 17, 2009).

Metz, Cade. "Chips off the Old Block: Computers Are Taking Design Cues from Human Brains." *New York Times* (September 16, 2017).

Moore, Gordon. "Cramming More Components Onto Integrated Circuits," *Electronics* 38, No. 8 (April 19, 1965).

Netmarketshare. "Desktop Operating System Market Share." www.netmarketshare.com, accessed March 10, 2018.

Retana, German F., Chris Forman, Sridhar Narasimhan, Marius Florin Niculescu, and D. J. Wu. "Technology Support and Post-Adoption IT Service Use: Evidence from the Cloud." *MIS Quarterly* 42, No. 3 (September 2018).

Schuff, David, and Robert St. Louis. "Centralization vs. Decentralization of Application Software." *Communications of the ACM* 44, No. 6 (June 2001).

Song, Peijian, Ling Xue, Arun Rai, and Cheng Zha. "The Ecosystem of Software Platform: A Study of Asymmetric Cross-Side Network Effects and Platform Governance." *MIS Quarterly* 42 No. 1 (March 2018).

Stango, Victor. "The Economics of Standards Wars." *Review of Network Economics* 3, Issue 1 (March 2004).

Susarla, Anjana, Anitesh Barua, and Andrew B. Whinston. "A Transaction Cost Perspective of the 'Software as a Service' Business Model." *Journal of Management Information Systems* 26, No. 2 (Fall 2009).

Taft, Darryl K. "Application Development: Java Death Debunked: 10 Reasons Why It's Still Hot." *eWeek* (February 22, 2012).

Uotila, Juha, Thomas Keil, and Markku Maula. "Supply-Side Network Effects and the Development of Information Technology Standards." *MIS Quarterly* 41 No. 4 (December 2017).

Weitzel, Tim. *Economics of Standards in Information Networks*. Heidelberg, New York: Physica-Verlag (2004).