***IT INFRASTRUCTURE AND EMERGING TECHNOLOGIES***

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

**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 with a power- ful operating system 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.

**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 appear- ance 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 American busi- nesses. At first using the DOS operating system, a text-based command lan- guage, and later the Microsoft Windows operating system, the **Wintel PC** com- puter (Windows operating system software on a computer with an Intel microprocessor) became the standard desktop personal computer. Today, 95 percent of the world’s estimated 1.5 billion computers use the Wintel standard.

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 standalone 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.

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** (often called **N-tier**) **client/server architec- tures** in which the work of the entire network is balanced over several different levels of servers, depending on the kind of service being requested.

**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.

**Cloud and Mobile Computing Era (2000 to Present)**

The growing bandwidth power of the Internet has pushed the client/server model one step further, towards 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 a network, often the Internet. These “clouds” of computing resources can be accessed on an as-needed basis from any connected device and location. Currently, cloud computing is the fastest growing form of computing, with global revenue expected to reach close to $89 billion in 2011 and nearly $149 billion by 2014 according to Gartner Inc. technology consul- tants (Cheng and Borzo, 2010; Veverka, 2010).

Thousands or even hundreds of thousands computers are located in cloud data centers, where they can be accessed by desktop computers, laptop computers, netbooks, entertainment centers, mobile devices, and other client machines linked to the Internet, with both personal and corporate computing increasingly moving to mobile platforms. IBM, HP, Dell, and Amazon operate huge, scalable cloud computing centers that provide computing power, data storage, and high-speed Internet connections to firms that want to maintain their IT infrastructures remotely. Software firms such as Google, Microsoft, SAP, Oracle, and Salesforce.com sell software applications as services delivered over the Internet.

We discuss cloud computing in more detail in Section 5.3. The Learning Tracks include a table on 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, telecommunications and 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 directory of Fairchild Semiconductor’s Research and Development Laboratories, an early manufacturer of integrated circuits, 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.

This law would later be interpreted in multiple ways. 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. **Nanotechnology** uses individ- ual atoms and molecules to create computer chips and other devices that are thousands of times smaller than current technologies permit. Chip manufac- turers are trying to develop a manufacturing process that could produce nanotube processors economically (Figure 5-6). IBM has just started making microprocessors in a production setting using this technology.

**The Law of Mass Digital Storage**

A second technology driver of IT infrastructure change is the Law of Mass Digital Storage. The world produces as much as 5 exabytes of unique informa- tion per year (an exabyte is a billion gigabytes, or 1018 bytes). 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

**Metcalfe’s Law and Network Economics**

Moore’s Law and the Law of Mass Storage help us understand why computing resources are now so readily available. But why do people want more comput- ing 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 linearly, the value of the entire system grows exponentially and continues to grow forever 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 Since the first magnetic storage device was used in 1955, the cost of storing a kilobyte of data has fallen exponentially, doubling the amount of digital storage for each dollar expended every 15 months on average.

**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 widespread consumer acceptance of **technology standards**. Technology standards are specifications that establish the compatibility of products and the ability to communicate in a network (Stango, 2004).

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.

Beginning in the 1990s, corporations started moving toward standard comput- ing and communications platforms. The Wintel PC with the Windows operating system and Microsoft Office desktop productivity applications became the stan- dard desktop and mobile client computing platform. Widespread adoption of Unix as the enterprise server operating system of choice made possible the replace- ment of proprietary and expensive mainframe infrastructures. In telecommunica- tions, 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 firm-wide networks, and ultimately, to the Internet.

**5.2 INFRASTRUCTURE COMPONENTS**

IT infrastructure today is composed of seven major components. Figure 5-9 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.

In the past, technology vendors supplying these components were often in competition with one another, offering purchasing firms a mixture of incompati- ble, proprietary, partial solutions. But increasingly the vendor firms have been forced by large customers to cooperate in strategic partnerships with one another. 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 database products its client firms wish to use (even though it sells its own database management software called DB2).

**COMPUTER HARDWARE PLATFORMS**

U.S. firms will spend about $109 billion in 2010 on computer hardware. This component includes client machines (desktop PCs, mobile computing devices such as netbooks and laptops but not including iPhones or BlackBerrys) and server machines. The client machines use primarily Intel or AMD micro- processors. In 2010, there will be about 90 million PCs sold to U.S. customers (400 million worldwide) (Gartner, 2010).

The server market uses mostly Intel or AMD processors in the form of blade servers in racks, but also includes Sun SPARC microprocessors and IBM POWER chips specially designed for server use. **Blade servers**, which we discussed in the chapter-opening case, are ultrathin computers consisting of a circuit board with processors, memory, and network connections that are stored in racks. They take up less space than traditional box-based servers. Secondary storage may be provided by a hard drive in each blade server or by external mass-stor- age drives.

**OPERATING SYSTEM PLATFORMS**

In 2010, Microsoft Windows comprises about 75 percent of the server operating system market, with 25 percent of corporate servers using some form of the **Unix** operating system or **Linux**, an inexpensive and robust open source rela- tive 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 (IDC, 2010).

Unix and Linux are scalable, reliable, and much less expensive than main- frame operating systems. They can also run on many different types of proces- sors. The major providers of Unix operating systems are IBM, HP, and Sun, each with slightly different and partially incompatible versions.

At the client level, 90 percent of PCs use some form of Microsoft Windows **operating system** (such as Windows 7, Windows Vista, or Windows XP) to man- age the resources and activities of the computer. However, there is now a much greater variety of 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 com- puting using netbooks. Programs are not stored on the user’s PC but are used over the Internet and accessed through the Chrome Web browser. User data resides on servers across the Internet. Microsoft has introduced the *Windows Azure* operating system for its cloud services and platform. **Android** is a mobile operating system developed by Android, Inc. (purchased by Google) and later the Open Handset Alliance as a flexible, upgradeable mobile device platform.

**ENTERPRISE SOFTWARE APPLICATIONS**

In addition to software for applications used by specific groups or business units, U.S. firms will spend about $165 billion in 2010 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 pro- vides a more detailed discussion of each.

The largest providers of enterprise application software are SAP and Oracle (which acquired PeopleSoft). Also included in this category is middleware software supplied by vendors such as BEA 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 that have not yet implemented enterprise applications.

**NEW TO THE TOUCH**

When Steve Jobs first demonstrated “the pinch”—the two-finger gesture for zooming in and out of photos and Web pages on the iPhone, he not only shook up the mobile phone industry—the entire digital world took notice. The Apple iPhone’s multitouch features dramatized new ways of using touch to interact with software and devices.

Touch interfaces are not new. People use them every day to get money from ATMs or to check into flights at airport kiosks. Academic and commercial researchers have been working on multitouch technology for years. What Apple did was to make multitouch more exciting and relevant, popularizing it just as it did in the 1980s with the mouse and the graphical user interface. (These had also been invented elsewhere.)

Multitouch interfaces are potentially more versatile than single-touch interfaces. They allow you to use one or more fingers to perform special gestures that manipulate lists or objects on a screen without moving a mouse, pressing buttons, turning scroll wheels, or striking keys. They take different actions depending on how many fingers they detect and which gestures a user performs. Multitouch gestures are easier to remember than commands because they are based on ingrained human move- ments that do not have to be learned, scientists say.

The iPhone’s Multi-Touch display and software lets you control everything using only your fingers. A panel underneath the display’s glass cover senses your touch using electrical fields. It then transmits that information to a LCD screen below it. Special software recognizes multiple simultaneous touch points, (as opposed to the single-touch screen, which recognizes only one touch point.) You can quickly move back and forth through a series of Web pages or photos by “swiping,” or placing three fingers on the screen and moving them rapidly sideways. By pinching the image, you can shrink or expand a photo. Apple has made a concerted effort to provide multitouch features in all of its product categories, but many other consumer technology companies have adopted multitouch for some of their products. Synaptics, a leading supplier of touchpads for laptop makers who compete with Apple, has announced that it is incorporating several multitouch features into its touchpads.

Microsoft’s Windows 7 operating system sports multitouch features: When you pair Windows 7 with a touch-screen PC, you can browse online newspa- pers, flick through photo albums, and shuffle files and folders using nothing but your fingers. To zoom in on something on the screen of a multitouch-com- patible PC, you would place two fingers on the screen and spread them apart. To right-click a file, touch it with one finger and tap the screen with a second.

A number of Microsoft Windows PCs have touch screens, with a few Windows laptops emulating some of the multitouch features of Apple computers and handhelds. Microsoft’s Surface computer runs on Windows 7 and lets its business customers use multitouch in a table-top display. Customers of hotels, casinos, and retail stores will be able to use multitouch finger gestures to move around digital objects such as photos, to play games, and to browse through product options. The Dell Latitude XT tablet PC uses multitouch, which is helpful to people who can’t grasp a mouse and want the functionality of a traditional PC. They can use a finger or a stylus instead. The Android operating system for smartphones has native support for multi-touch, and handsets such as the HTC Desire, Nexus One, and the Motorola Droid have this capability.

Hewlett-Packard (HP) now has laptops and desktops that use touch technology. Its TouchSmart computer lets you use two fingers at once to manipu- late images on the screen or to make on-screen gestures designating specific commands without using cursors or scroll bars. To move an object, you touch it with a finger and drag it to its new location. Sliding your finger up and down or sideways smoothly scrolls the display.

**NETWORKING/TELECOMMUNICATIONS PLATFORMS**

U.S. firms spend $100 billon a year on networking and telecommunications hardware and a huge $700 billion on networking services (consisting mainly of telecommunications and telephone company charges for voice lines and Internet access; these are not included in this discussion). Chapter 7 is devoted to an in-depth description of the enterprise networking environment, including the Internet. Windows Server is predominantly used as a local area network operating system, followed by Linux and Unix. Large enterprise wide area networks primarily 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).

The leading networking hardware providers are Cisco, Alcatel-Lucent, Nortel, and Juniper Networks. 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 (see the Chapter 3 opening case). This market is exploding with new providers of cellular wireless, high-speed Internet, and Internet telephone services.

**INTERNET PLATFORMS**

Internet platforms overlap with, and must relate to, the firm’s general network- ing infrastructure and hardware and software platforms. U.S. firms spent an estimated $40 billion annually on Internet-related infrastructure. These expen- ditures were for hardware, software, and management services to support a firm’s Web site, 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 Web sites.

The Internet revolution created a veritable explosion in server computers, with many firms collecting thousands of small servers to run their Internet operations. Since then there has been a steady push toward server consolida- tion, reducing the number of server computers by increasing the size and power of each. The Internet hardware server market has become increasingly concentrated in the hands of IBM, Dell, and HP/Compaq, as prices have fallen dramatically.

The major Web software application development tools and suites are supplied by Microsoft (Microsoft Expression Web, SharePoint Designer, and the Microsoft .NET family of development tools); Oracle-Sun (Sun’s Java is the most widely used tool for developing interactive Web applications on both the server and client sides); and a host of independent software developers, includ- ing Adobe (Flash and text tools like Acrobat), and Real Media (media software). 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 3 and 14) significant changes in business processes and procedures, training and educa- tion, and software integration. Leading consulting firms providing this exper- tise include Accenture, IBM Global Services, HP Enterprise Services, Infosys, and Wipro Technologies.

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.

**CONTEMPORARY HARDWARE PLATFORM TRENDS**

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. We look at seven hardware trends: the emerging mobile digital platform, grid computing, virtualization, cloud computing, green computing, high-performance/power- saving processors, and autonomic computing.

**THE EMERGING MOBILE DIGITAL PLATFORM**

New mobile digital computing platforms have emerged as alternatives to PCs and larger computers. Cell phones and smartphones such as the BlackBerry and iPhone have taken on many func- tions of handheld computers, including transmission of 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 low-cost lightweight subnotebooks called **netbooks** optimized for wireless communication and Internet access, with core computing functions such as word processing; tablet computers such as the iPad; and digital e-book readers such as Amazon’s Kindle with some Web access capabilities.

In a few years, smartphones, netbooks, and tablet computers will be the primary means of accessing the Internet, with business computing moving increasingly from PCs and desktop machines to these mobile devices. For example, senior executives at General Motors are using smartphone applica- tions that drill down into vehicle sales information, financial performance, manufacturing metrics, and project management status. At medical device maker Astra Tech, sales reps use their smartphones to access Salesforce.com customer relationship management (CRM) applications and sales data, checking data on sold and returned products and overall revenue trends before meeting with customers.

**GRID COMPUTING**

**Grid computing**, involves connecting geographically remote computers into a single network to create a virtual supercomputer by combining the computa- tional power of all computers on the grid. Grid computing takes advantage of the fact that most computers use their central processing units on average only 25 percent of the time for the work they have been assigned, leaving these idle resources available for other processing tasks. Grid computing was impossible until high-speed Internet connections enabled firms to connect remote machines economically and move enormous quantities of data.

Grid computing requires software programs to control and allocate resources on the grid. Client software communicates with a server software application. The server software breaks data and application code into chunks that are then parceled out to the grid’s machines. The client machines perform their traditional tasks while running grid applications in the background.

The business case for using grid computing involves cost savings, speed of computation, and agility, as noted in the chapter-opening case. The chapter- opening case shows that by running its applications on clustered servers on a grid, BART eliminated unused computer resources, used existing resources more efficiently, and reduced costs and power consumption.

**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 so that it acts like many different machines. Virtualization also enables multiple physical resources (such as storage devices or servers) to appear as a single logical resource, as would be the case with storage area net- works or grid computing. Virtualization makes it possible for a company to handle its computer processing and storage using computing resources housed in remote locations. VMware is the leading virtualization software vendor for Windows and Linux servers. Microsoft offers its own Virtual Server product and has built virtualization capabilities into the newest version of Windows Server.

**Business Benefits of Virtualization**

By providing the ability to host multiple systems on a single physical machine, virtualization helps organizations increase equipment utilization rates, conserv- ing data center space and energy usage. Most servers run at just 15-20 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, as illustrated by BART’s experience with vir- tualization in the chapter-opening case.

In addition to reducing hardware and power expenditures, virtualization allows businesses to run their legacy applications on older versions of an operating system on the same server as newer applications. Virtualization also facilitates centralization and consolidation of hardware administration. It is now possible for companies and individuals to perform all of their computing work using a virtualized IT infrastructure, as is the case with cloud computing. We now turn to this topic.

**CLOUD COMPUTING**

Earlier in this chapter, we introduced cloud computing, in which firms and individuals obtain computer processing, storage, software, and other services as a pool of virtualized resources over a network, primarily the Internet. These resources are made available to users, based on their needs, irrespective of their physical location or the location of the users themselves. 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:** Individuals can obtain computing capabilities such as server time or network storage on their own.
* **Ubiquitous network access:** Individuals can use standard network and Internet devices, including mobile platforms, to access cloud resources.
* **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 com- puting 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:
  + **Cloud infrastructure as a service:** 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.
  + **Cloud platform as a service:** Customers use infrastructure and program- ming tools hosted by the service provider to develop their own applications. For example, IBM offers a Smart Business Application Development & Test service for software development and testing on the IBM Cloud. Another example is Salesforce.com’s Force.com, described in the chapter-ending case study, which allows developers to build applications that are hosted on its servers as a service.
  + **Cloud software as a service:** Customers use software hosted by the vendor on the vendor’s hardware and delivered over a network. Leading examples are Google Apps, which provides common business applications online and Salesforce.com, which also leases CRM and related software services over the Internet. Both charge users an annual subscription fee, although Google Apps also 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.  A cloud can be private or public. A **public cloud** is maintained by an exter- nal service provider, such as Amazon Web Services, accessed through the Internet, and available to the general public. A **private cloud** is a proprietary network or a data center that ties together servers, storage, networks, data, and applications as a set of virtualized services that are shared by users inside a company. 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. Financial institutions and health care

providers are likely to gravitate toward private clouds because these organiza- tions handle so much sensitive financial and personal data. We discuss cloud security issues in Chapter 8.

Since organizations using cloud computing generally do not own the infra- structure, 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.

For example, Envoy Media Group, a direct-marketing firm that offers highly- targeted media campaigns across multiple channels, including TV, radio, and Internet, hosts its entire Web presence on Azimuth Web Services. The “pay as you go” pricing structure allows the company to quickly and painlessly add servers where they are needed without large investments in hardware. Cloud computing reduced costs about 20 percent because Envoy no longer had to maintain its own hardware or IT personnel.

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. There are also questions of system reliability. Companies expect their systems to be available 24/7 and do not want to suffer any loss of business capability if their IT infrastructures malfunction. When Amazon’s cloud went down in December 2009, subscribers on the U.S. east coast were unable to use their systems for several hours. Another limitation of cloud computing is the possibility of making users dependent on the cloud computing provider.

There are some who believe that cloud computing represents a sea change in the way computing will be performed by corporations as business computing shifts out of private data centers into cloud services (Carr, 2008). This remains a matter of debate. Cloud computing is more immediately appealing to small and medium-sized businesses that lack resources to purchase and own their own hardware and software. However, large corporations have huge investments in complex proprietary systems supporting unique business processes, some of which give them strategic advantages. For them, the most likely scenario is a hybrid computing model where firms 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. 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 hard- ware vendors.

**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 technolo- gies 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.

Reducing computer power consumption has been a very high “green” priority. As companies deploy hundreds or thousands of servers, many are spending almost as much on electricity to power and cool their systems as they did on purchasing the hardware. The U.S. Environmental Protection Agency estimates that data centers will use more than 2 percent of all U.S. electrical power by 2011. Information technology is believed to contribute about 2 percent of the world’s greenhouse gases. Cutting power consumption in data centers has become both a serious business and environmental challenge. The Interactive Session on Organizations examines this problem.

**AUTONOMIC COMPUTING**

With large systems encompassing many thousands of networked devices, computer systems have become so complex today that some experts believe they may not be manageable in the future. One approach to dealing with this problem is to employ autonomic computing. **Autonomic computing** is an industry-wide effort to develop systems that can configure themselves, optimize and tune themselves, heal themselves when broken, and protect themselves from outside intruders and self-destruction.

You can glimpse a few of these capabilities in desktop systems. For instance, virus and firewall protection software are able to detect viruses on PCs, automatically defeat the viruses, and alert operators. These programs can be updated automatically as the need arises by connecting to an online virus protection service such as McAfee. IBM and other vendors are starting to build autonomic features into products for large systems.

**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 dissipa- tion to perform tasks faster than a resource-hungry chip with a single process- ing core. Today you’ll find dual-core and quad-core processors in PCs and servers with 8-, 10-, 12-, and 16-core processors.

Intel and other chip manufacturers have also developed microprocessors that minimize power consumption. Low power consumption is essential for prolonging battery life in smartphones, netbooks, and other mobile digital devices. You will now find highly power-efficient microprocessors, such as ARM, Apple’s A4 processor, and Intel’s Atom in netbooks, digital media players, and smartphones. The A4 processor used in the latest version of the iPhone and the iPad consumes approximately 500–800 milliwatts of power, about 1/50 to 1/30 the power consumption of a laptop dual-core processor.

**Linux**

Perhaps the most well known open source software is Linux, an operating system related to Unix. Linux was created by the Finnish programmer Linus Torvalds and first posted on the Internet in August 1991. Linux applications are embedded in cell phones, smartphones, netbooks, and consumer electronics. Linux is avail- able 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 major force in local area networks, Web servers, and high-performance computing work, with over 20 percent of the server operating system market. IBM, HP, Intel, Dell, and Oracle-Sun have made Linux a central part of their offerings to corporations.

The rise of open source software, particularly Linux and the applications it supports, has profound implications for corporate software platforms: cost reduction, reliability and resilience, and integration, because Linux works on all the major hardware platforms from mainframes to servers to clients.

**SOFTWARE FOR THE WEB: JAVA AND AJAX**

**Java** is an operating system-independent, processor-independent, object- oriented programming language that has become the leading interactive environment for the Web. Java was created by James Gosling and the Green Team at Sun Microsystems in 1992. In November 13, 2006, Sun released much of Java as open source software under the terms of the GNU General Public License (GPL), completing the process on May 8, 2007.

The Java platform has migrated into cellular phones, smartphones, automo- biles, music players, game machines, and finally, into 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, Sun created a Java Virtual Machine that 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, and Google Chrome browser are examples. At the enterprise level, Java is being used for more complex e-commerce and back-end transaction processing systems.

**Ajax**

Have you ever filled out a Web order form, made a mistake, and then had to start all over gain after a long wait for a new order form page to appear on your computer screen? Or visited a map site, clicked the North arrow once, and waited some time for an entire new page to load? **Ajax** (Asynchronous JavaScript and XML) is another Web development technique for creating inter- active Web applications that prevents all of this inconvenience.

Ajax allows a client and server to exchange small pieces of data behind the scene so that an entire Web page does not have to be reloaded each time the user requests a change. So if you click North on a map site, such as Google Maps, the server downloads just that part of the application that changes with no wait for an entirely new map. You can also grab maps in map applications and move the map in any direction without forcing a reload of the entire page. Ajax uses JavaScript programs downloaded to your client to maintain a near-continuous conversation with the server you are using, making the user experience more seamless.

**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 stan- dards 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. Web services are not tied to any one operating system or program- ming language, and different applications can use them to communicate with each other in a standard way without time-consuming custom coding.

**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. There are three external sources for software: software packages from a commercial software vendor, outsourcing custom application development to an external vendor, and cloud-based software services and tools.

**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 infra- structures. 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-PeopleSoft have developed powerful software packages that can support the primary business processes of a firm worldwide from warehousing, customer relation- ship management, supply chain management, and finance to human resources.

**Software Outsourcing**

Software **outsourcing** enables a firm to contract custom software develop- ment or maintenance of existing legacy programs to outside firms, which often operate offshore in low-wage areas of the world. According to the indus- try analysts, 2010 offshore outsourcing revenues in the United States will be approximately $50 billion, and domestic outsourcing revenues will be $106 billion (Lohr, 2009). The largest expenditure here is paid to domestic U.S. firms providing middleware, integration services, and other software support that are often required to operate larger enterprise systems.

For example, in March 2008, Royal Dutch Shell PLC, the world’s third largest oil producer, signed a five-year, $4 billion outsourcing deal with T-Systems International GmbH, AT&T, and Electronic Data Systems (EDS). The agree- ment assigned AT&T responsibility for networking and telecommunications, T-Systems for hosting and storage, and EDS for end-user computing services and for integration of the infrastructure services. Outsourcing this work has helped Shell cut costs and focus on systems that improve its competitive posi- tion in the oil and gas market.

**Mashups and Apps**

The software you use for both personal and business tasks may consist of large self-contained programs, or it may be composed of interchangeable compo- nents 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 dif- ferent 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, EveryBlock Chicago combines Google Maps with crime data for the city of Chicago. Users can search by location, police beat, or type of crime, and the results are displayed as color-coded map points on a Google Map. Amazon uses mashup technologies to aggregate product descrip- tions with partner sites and user profiles.

**Apps** are small pieces of software that run on the Internet, on your com- puter, or on your cell phone and are generally delivered over the Internet. Google refers to its online services as apps, including the Google Apps suite of desktop productivity tools. 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 other mobile handheld devices into general-purpose computing tools.

**5.5 MANAGEMENT ISSUES**

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 when most of the 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, merg- ers and acquisitions, and changes in business volume all impact computer workload and must be considered when planning hardware capacity.

Firms using mobile computing and cloud computing platforms will require new policies and procedures 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 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 avail- able 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 they expect.

**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 infor- mation 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 firm financial performance. If too little is spent, important business services cannot be delivered and the firm’s competitors (who spent just the right amount) will outperform the under- investing firm. How much should the firm spend on infrastructure? This question is not easy to answer.

**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 administra- tion costs for hardware and software upgrades, maintenance, technical support, training, and even utility and real estate costs for running and housing 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 5-3 describes the most important TCO components to consider in a TCO analysis.

**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 spread- sheet software to evaluate alternative desktop systems, and using Web research to budget for a sales conference.

**Management Decision Problems**

1. *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 HP, Sun Microsystems, Microsoft, and IBM. Assess the impact of this situation on business performance. What factors and management decisions must be consid- ered when developing a solution to this problem?*
2. *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. Should Qantas outsource to a cloud computing vendor?*

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

Software skills: Spreadsheet formulas Business skills: Technology pricing

In this exercise, you will use spreadsheet software to calculate the cost of desk- top systems, printers, and software.

You have been asked to obtain pricing information on hardware and software for an office of 30 people. Using the Internet, get pricing for 30 PC desktop systems (monitors, computers, and keyboards) manufactured by Lenovo, Dell, and HP/Compaq as listed at their respective corporate Web sites. (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 Dell. Each desktop system must satisfy the minimum specifications shown in the following table:

**Improving Decision Making: Using Web Research to**

**Budget for a Sales Conference**

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

The Foremost Composite Materials Company is planning a two-day sales conference for October 15–16, starting with a reception on the evening of October 14. The conference consists of all-day meetings that the entire sales force, numbering 125 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 visitors (200 total) and the other able to hold half the force. Management has set a budget of $120,000 for the representatives’ room rentals. The hotel must also have such services as overhead and computer projectors as well as business center and banquet facilities. It also should have facilities for the company reps to be able to work in their rooms and to enjoy themselves in a swimming pool or gym facility. The company would like to hold the confer- ence in either Miami or Marco Island, Florida.

Foremost usually likes to hold such meetings in Hilton- or Marriott-owned hotels. Use the Hilton and Marriott Web sites to select a hotel in whichever of these cities that would enable the company to hold its sales conference within its budget.