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ANNABEL Z. DODD

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—William Van Hefner, President, Vantek Communications, Inc.

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—Andrew Allentuck, Columnist, *Financial Post*, Toronto

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—Joe McGrath, SVP, Information Technologies,
Sunovion Pharmaceuticals, Inc.

"Dodd's work has been very helpful in the past in taking complex technical topics and translating them into actionable business items for my MBA students. Her book doesn't gloss over the details, but rather explains why they are important in the twenty-first century information age."

—Andrew Urbaczewski, Ph.D., Chair, Department of
Management Studies, Associate Professor of MIS,
College of Business, University of Michigan—Dearborn

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To Bob, Judy, Nancy, Laura, Steve, Bobby, Elizabeth,
Julia, Gabriel, Michael, Moses, Delancey, and Harry.

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Contents

Preface

Innovations in mobile networks and the Internet have eliminated barriers to communications created by geographic distances. People in different countries easily and often inexpensively communicate with one another via mobile devices, computers, and landline phones. Students who travel abroad for their education and workers who relocate for jobs stay in touch with friends and family through social media such as Facebook and Baidu as well as Internet calling services such as Skype.

The widespread availability of Internet access from wireless and wired devices is an important factor in the establishment of new innovative companies.

In the past 20 years, widespread availability of broadband for residential and business computers has enabled the emergence of new businesses that have taken advantage of the lower costs of using the Internet to distribute services. These ventures all have one thing in common: a leader with a vision and drive to succeed. For example, Jeff Bezos, founder of Amazon, developed innovative ways for consumers to read reviews of books and products, and simplified the purchasing process. The vision of Steve Jobs at Apple was for high-quality, innovative, easy-to-use computers, portable music players, and tablet computers. Internet-based companies have forever altered the retail and business-to-business models. Book publishing, book sales, and distribution and sales of music, TV shows, and movies are just a few of the industries that have undergone radical transformations.

The advent of affordable mobile services worldwide has greatly enhanced communications. Before mobile networks achieved global prevalence, many people did not have access to basic telephone service. Communications to Latin America, certain countries in Asia, and Africa were costly and cumbersome.

Mobile networks have made it easier for businesses to operate throughout the world by facilitating the communications among remote staff members and headquarters. However, quite often, poor physical infrastructure such as inconsistent electrical availability and impassable roads, along with corruption, pose barriers to operating businesses in many emerging economies. In addition, high rates of poverty in parts of Latin America, certain Asian countries, and Africa mean that much of the population can only purchases mobile services if they are at extremely low prices. This limits carriers' profits and incentives to upgrade networks.

The expansion of mobile services in emerging markets has created growth opportunities for established carriers from Europe, the Middle East, and certain countries in Asia. Spanish carrier Telefónica is now the second largest carrier in Latin America, where it has experienced high growth because most people have subscribed to mobile services for the first time in the past ten years. By contrast, its European operations have lower profits and little growth.

Mobile networks have had a particularly dramatic effect on countries that previously had scant resources for wired broadband facilities in even the largest cities. In these countries, populations often have mobile phones as their first means of electronic communication. The availability of low-cost mobile devices is also having a positive impact on the economies of developing countries and the lives of their citizens. For example, mobile banking has enabled people who previously had no access to banks to receive money and pay bills via their smartphone handsets.

The popularity of mobile networks for data as well as voice has strained network capacity. In the face of this demand, mobile carriers are upgrading networks to fourth-generation protocols such as Long-Term Evolution (LTE) and Worldwide Interoperability for Microwave Access 2 (WiMAX 2). These upgrades will make available for the first time high-speed Internet access to many small businesses and consumers in emerging countries and rural areas.

However, these network upgrades are costly. For this reason, many carriers have upgraded to intermediate solutions that increase speeds but don't offer as much capacity as LTE and WiMAX. In the long run, most carriers will upgrade to fourth-generation networks as manufacturing costs decrease.

But improvements in Internet capabilities have a dark side: loss of privacy and, sometimes, government surveillance. One of my international students at Northeastern University told the class a chilling incident about how his government monitors the postings of students on social networks from half-way around the globe. One of his friends criticized his country on Facebook while he attended college in the United States. When he went home for a visit, he was arrested at the airport on the basis of these critical remarks. His family has had no information about him since his arrest, and fear that he has been executed. This experience and others like it illustrate the ominous ability of governments to monitor online messages.

However, monitoring behavior on the Internet is an important tool in foiling security breaches that threaten business continuity, national defense, the viability of critical networks, the water supply, and the electric grid. A serious attack on strategic resources has the potential to cripple countries and cause widespread harm.

Another example of monitoring behavior online is when companies track an individual's browsing activities. For example, when consumers download *apps* (applications), browse the Internet, or fill out surveys, companies often collect information, such as age, address, educational level, and gender. Internet companies sell the data, sometimes without obtaining consumers' consent, to marketing companies that use the information to develop advertising strategies that target particular population segments. This results in the loss of consumer control over how their personal information is used.

Internet and wireless services have enabled changes in the ways consumers and enterprises access and store programs and files. In an effort to save staffing and operational costs, enterprises are using cloud computing. With cloud computing, applications such as e-mail, human resources, sales force automation, and accounts receivable are managed at a provider's data centers over the Internet. Residential consumers have also embraced cloud computing and use it to store and play music, create documents, and store backup copies of documents.

Organizations that are hesitant to place critical applications under the control of outside providers are taking advantage of new technologies to support centralized applications that require less space and energy, and fewer full-time staff members to support them.

They make their data center operations more efficient by centralizing services and eliminating those in branch offices, which reduces the required staffing. They have also embraced server virtualization, whereby multiple applications and operating systems are installed on a single server. This decreases the number of servers that need to be supported, which saves space and energy consumption.

Higher-speed, more-reliable networks are important factors that have enabled these efficiencies. As a result of network-based services, network criticality has increased, as have the need for higher speeds and capacity. Consumers and commercial organizations take network availability for granted. However, carriers have invested heavily in upgrading landline networks to meet these demands for capacity and connectivity.

Mobile and landline carrier consolidation is occurring worldwide, and many providers have global and nationwide operations. In parts of the world, two or three large providers control the majority of networks. This low level of competition results in high prices for Internet access and decreases the impetus for network innovation. By contrast, in countries such as India, which has a large number of mobile carriers, competition has resulted in low-priced mobile services. Low prices, however, have led to low profit margins.

The affordability of mobile services and the growing percentage of the population worldwide with access to the Internet pose difficult issues. For example, in countries with robust networks, commercial organizations expect employees to be always available via e-mail and text messaging. It has become more difficult to "tune out" and take a real break from work.

Moreover, it is challenging to balance the need to protect national security and personal financial data from hackers with the need to protect the privacy of citizens from government monitoring. It is additionally challenging to protect the privacy of consumers while recognizing that businesses need to understand market forces by monitoring consumer browsing behavior. These difficult issues won't be resolved by technological solutions alone.

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About the Author

Annabel Z. Dodd is an adjunct faculty member at Northeastern University's School of Professional Studies, where she teaches courses on wireless mobile services and data communications in the Master's Degree Program in Informatics. She has been an adjunct professor in the Master of Science in Technology Management program at the State University of New York at Stony Brook, where she taught in a joint program with The Institute of Industrial Policy Studies, Seoul, South Korea. In addition, the Fundación de la Innovación Bankinter, selected her to participate in their Future Trends Forum in Madrid in 2004, 2005, and 2007. Formerly in marketing at New England Telephone (now Verizon Communications) and Telecommunications Manager at Dennison Manufacturing Company (now Avery Dennison), Annabel consults with major corporations and institutions and gives seminars to organizations worldwide. The Massachusetts Network Communications Council honored her as the Professor of the Year. *The Essential Guide to Telecommunications* has been translated into nine languages since its first edition, which was published in 1997. You can find more information at her web site, www.doddontheline.com.

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Part I

Enabling Technologies, Data Centers, and VoIP PBXs

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1 Computing and Enabling Technologies

In this chapter:

The pace of technological advancement is faster today than ever before. The pace of change in networks began increasing in the late 1980s, and further escalated in the late 1990s with the increase in the number of personal computers at enterprises and homes, growing mobile phone usage, and the growth in both total Internet and multimedia traffic. Unlike earlier improvements during the 1900s, these more recent changes directly impact the way people socialize and how day-to-day business is conducted.

Initially, even with the proliferation of corporate personal computers in the 1980s, electronic communication among staff members was restricted to within the same building. Gradually, increasing speeds of internal networks and affordable fiber links between buildings made it feasible to link all sites within organizations. Later, the advent of powerful microprocessors and manufacturing economies of scale made computer ownership feasible for residential consumers. Affordable, high-speed Internet access for consumers as well as business customers created the tsunami of rapid change.

This escalation was made possible in large part by the introduction of fiber optics, the development of multiprocessing computer chips integrated into various types of network equipment, and the decrease in prices of mass computer storage. These factors along with the shrinking size of components are continuing to lead to vast improvements in mobile networks and mobile devices as well as land-based networks and consumer electronics. Children born in the twenty-first century have trouble imagining a world without e-mail and cell phones. These innovations will lead to even faster changes in the future.

A significant shift in computing is occurring with the introduction of *virtualization*, which came about because of more powerful networks and computers. Server virtualization is the capability of servers to store and run multiple operating systems, each running multiple applications. Servers are specialized computers that host applications such as e-mail or web pages. They can also host applications such as accounting and sales automation packages. The capability of virtualization to consolidate a large number of servers has resulted in the capability of data centers to consume less space and electricity and require fewer administrative tasks. It has also brought down the costs for large third-party providers to manage expansive data centers.

Virtualization and powerful networks are the key factors that have enabled *cloud computing* offerings to be viable. Cloud computing is when consumers, small businesses, and large organizations move some or all of their computing needs to external providers, who typically maintain large data centers. Clients usually access the applications and data that reside in these data centers via the Internet.

Because it is relatively new, most large commercial customers start out by using the cloud for applications that are important but not critical to their core offerings. These include human resources systems such as those designed for expense and vacation reporting. Although institutions have a high degree of interest in cloud computing, concerns about security, control over corporate data, providers' storage and server capacity, and cloud provider stability still exist.

In addition to the aforementioned technologies, Wide Area Network (WAN) acceleration and optimization, compression, and multiplexing increase the functionality of networks. WAN acceleration improves response times in the networks of commercial organizations when staff members access applications and download files from central sites. Without WAN acceleration and optimization, unacceptable delays would occur because of the way these applications are accessed and transmitted, even on high-speed networks.

Another major factor in broadening how mobile networks are used is compression, which uses complex mathematical formulas (algorithms) to decrease the amount of voice, data, and video to be sent over networks. Compression shrinks the amount of data to be sent and re-creates it at close to the same quality at the receiving end. In particular, it enables video and music to be carried efficiently over mobile networks without using up enormous amounts of network capacity. It's an underlying element in the capability of smartphones to download applications (apps) and use them to access services over the Internet.

Finally, multiplexing has enormously increased the capacity of fiber-optic networks. High-speed multiplexers powered by multi-core microchips provide the electronics that increase the capacity of a single pair of fibers by creating multiple streams, transmitting multiple light streams simultaneously rather than just sending a single stream. Without multiplexing, the capacity of the Internet would be vastly lower. Costs to build modern networks would be far more expensive because more cabling would be required to connect continents together, customers to the Internet, and cities to each other.

KEY UNDERLYING TECHNOLOGIES........................

The three technologies discussed in this section—fiber-optic cabling, multi-core processors, and memory—are the building blocks of modern networks. They enable networks to carry more information, faster. Decreasing memory costs have led to affordable personal computers and the ability to store vast amounts of information, accessible via fiber-optic-based networks at lower costs.

Fiber-Optic Cabling: Underpinning High-Speed Networks

Without fiber-optic cabling it would not be possible for the Internet to reach the speed and capacity required to link populations around the globe. Before the introduction of fiber cabling by MCI (now part of Verizon Communications) in 1983 for intercity routing, networks were labor-intensive to build and maintain. Copper cabling is heavier, and has less capacity than fiber cabling, and copper-based networks require more equipment to deploy and maintain.

Electrical signals used to transmit voice and data over copper cabling are subject to fading over relatively short distances. Consequently, amplifiers are needed every mile and a half to boost the electrical signals carried on copper-based networks. It requires many technicians to install and repair these amplifiers.

In contrast, data on fiber-optic cabling is carried as non-electric pulses of light. These non-electric signals can travel 80 miles before having to be regenerated. This is an enormous savings in labor and allows new organizations to lay miles of fiber between cities, creating competition among local, established telephone companies worldwide.

The most significant advantage of fiber-optic cabling is its enormous capacity compared to copper cabling and mobile services. Light signals on optical cabling pulse on and off at such high speeds that they are able to handle vastly greater amounts of information than any other media.

Once fiber-optic cabling was in place, electronics were developed in the form of *wavelength-division multiplexing*, which further expanded fiber's capacity. These multiplexers essentially split a single fiber into numerous channels, each able to transmit a high-speed stream of light pulses, as shown in Figure 1-1. The current generation of multiplexers are capable of transmitting up to 88 channels of information, each operating at 100 gigabits per second (Gbps).

Fiber optics and its associated electronics have evolved to the point where a consortium of companies including Google, Japanese carrier KDDI, Singapore Telecommunications, and India's Reliance Globalcom are constructing and will operate a six-pair fiber undersea cable with a capacity of 17 terabits per second (Tbps). (One terabit equals 1,000Gb.) That's fast enough to transmit every book in the British Library 20 times per second.

The undersea cable will run from Singapore to Japan, with extensions to Hong Kong, Indonesia, the Philippines, Thailand, and Guam. At the time of this writing, it was scheduled to begin operation sometime in 2012. For older networks, once high-quality fiber is installed in trenches, electronics can be added to increase its capacity

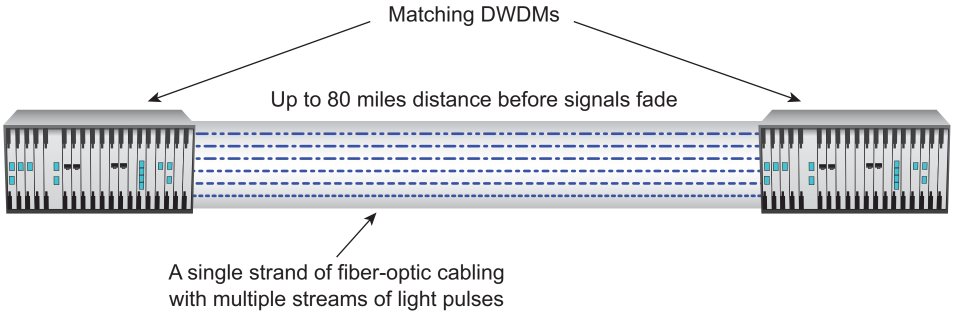


Figure 1-1 *A fiber-optic cable with Dense Wavelength-Division Multiplexers (DWDMs) attached.*

to handle the growing amounts of traffic, including high-definition video transmitted along its routes. The costs to dig trenches and lay fiber are many times higher than the costs to upgrade fiber to handle more traffic. This is why spare fiber pairs are included when new fiber-optic cabling is installed.

Faster, Lower-Priced Processors: Decreasing Memory Costs

Faster multi-core processors, such as those manufactured by Intel, are an integral part of the high-speed electronics used on fiber-optic links. They enable these networks to process multiple streams of light signals simultaneously. They are also at the core of network switches, continually transmitting increasing amounts of data at ever-higher speeds. Additionally, these processors facilitate the capability of personal computers to handle graphics and video transmitted via the Internet.

Many processors used in consumer electronics and mobile phones are based on architecture by ARM Holdings, Plc. This architecture now incorporates 32-bit processing (the ability to process data in chunks of 32 bits), which means that they process data faster. Moreover, they are small and inexpensive, and they use only small amounts of power. Figure 1-2 depicts a prototype of an ARM chip on a circuit board. Low power consumption results in longer battery life in mobile devices. ARM chips are designed by semiconductor firm ARM Holdings, Plc, and are available to electronics manufacturers who pay licensing fee plus royalties up front for each chip designed. According to its web site, 95 percent of mobile devices sold worlwide are equipped with ARM chips.

Figure 1-2 *The ARM chip is 12 millimeters by 12 millimeters. (Twelve millimeters equals .48 inches.) New mobile devices have at least two chips installed. (Photo courtesy ARM Holdings, Plc.)*

Low-cost memory has it made it feasible to embed memory in low-cost consumer electronics and smartphones. It has also enabled enterprises and cloud providers to purchase vast amounts of hard-drive capacity for archival purposes. Thus, companies such as Carbonite, based in Boston, are able to purchase enough memory to offer redundant hard-drive capacity to back up the entire content of a typical consumer computer for less than $30 per year.

SENDING DATA IN PACKETS ....

All Internet traffic, and the vast majority of high-speed data network traffic, is sent in *packets*. Putting data into packets is analogous to packaging it in envelopes. Packet switching was developed by Rand Corporation in 1962 for the United States Air Force and utilized in 1969 in the Advanced Research Projects Agency (ARPANET) of the Department of Defense. ARPANET was the precursor to today's Internet. The Department of Defense wanted a more reliable network with route diversity capability. Developers envisioned greater reliability with packet switching in the ARPANET, where all locations could reach one another.

Packet networks—which includes the Internet—are often more reliable and can better handle peak traffic periods than older, traditional networks, because diverse packets from the same message are routed via different paths, depending on both availability and congestion. In a national emergency such as the September 11, 2001 attacks in the United States on the Pentagon in Washington, DC, and the World Trade Center in New York City, the Internet still functioned when many portions of the public voice and cellular networks were either out of service or so overwhelmed with traffic that people could not make calls.

If one route on a packet network is unavailable, traffic is rerouted onto other routes. In addition, unlike older voice networks, the Internet does not depend on a few large switches to route traffic. Rather, if one router fails, another router can route traffic in its place.

Routing Efficiencies

Packet networks are able to handle peak congestion periods better than older types of networks because traffic is balanced between routes. This ensures that one path is not overloaded while a different route carries only a small amount of traffic. Sending data from multiple computers on different routes uses resources efficiently because packets from multiple devices continue to be transmitted without waiting until a single "heavy user" has finished its entire transmission. Thus, if one route is congested, packets are transmitted on other routes that have more availability.

Packet Contents: User Data versus Overhead

Each packet is made up of user data; data bits, digital voice or video, and specialized header information, such as addressing, billing, sender information, and error correcting bits. Error correction might indicate if the packet is damaged, if the receiver is ready to start receiving, or if the packet has been received. The end of the packet contains information to let the network know when the end of the packet has been reached. Header, end-of-packet data, and other signaling data are considered *overhead*. *User data* (also referred to as the payload) is the actual content of the e-mail message or voice conversation.

Throughput

Throughput is the amount of user information transmitted, not the actual speed of the line. The disadvantage of frequent error messages and other protocol-related bits is that overhead bits often consume large amounts of bandwidth. Throughput only measures actual user data transmitted over a fixed period of time. Protocols with many bits for error control messages and other types of overhead have lower throughput. Technologies such as WAN optimization are used to mitigate the effect of delays associated with these protocols. (See the section "Wide Area Network Acceleration and Optimization," later in this chapter, for more information.)

So, What Are Carriers, ISPs, and WISPs?

At one time, the term "carrier" referred to local telephone companies, such as Verizon Communications, that carried voice and data traffic for consumers and commercial organizations. Prior to 1996, cable television companies, such as Comcast, were strictly cable television operators. Now, all companies that provide outside cabling or mobile infrastructure and operate networks are generally referred to as carriers. These include cable television operators, mobile telephone companies, long distance providers and traditional local telephone companies. Cable TV operators, mobile carriers, and traditional local telephone companies transmit voice, data, and television signals as well as providing connections to the Internet. To complicate matters further, carriers are also referred to as operators and providers.

Continued

ISPs such as AOL (America OnLine) primarily supply the connections to the Internet and information services over a carriers' cabling, and sometimes provide the switching infrastructure. ISPs also provide wireless services, e-mail hosting, and other services over a carriers' infrastructure. Wireless ISPs (WISPs) offer a variety of wireless services such as Internet access in areas without broadband landline facilities. See Chapter 7, "Mobile and Wi-Fi Networks," for more information on WISPs.

DEEP PACKET INSPECTION: TRAFFIC MANAGEMENT AND MONITORING

Deep Packet Inspection (DPI) is one tool that network operators use to manage and understand network traffic. It accomplishes this by analyzing the contents of packets transmitted on network operators' landline and mobile networks. For the most part, DPI examines the content in the headers of packets rather than user content. It inspects and looks for patterns in header information, such as error correction, quality of service, and end-of-message bits, not the e-mail messages themselves.

DPI is an application that can potentially be used by carriers to discriminate against competitors' traffic. For example, using DPI, a carrier can slow down or block traffic generated by competitors' services. See Chapter 6, "The Internet," for information on network neutrality. Network neutrality refers to carriers treating their own and competitors' traffic in an equal manner.

Governments can also use DPI to monitor and censor e-mail messages that they might consider harmful. This can be a double-edged sword, however, as DPI can be used, for example, to track terrorists or people critical of the government.

DPI helps carriers, ISPs, large universities, and enterprises to understand as well as manage their traffic.

Providers can use it to do the following:

- Prioritize traffic
- Maintain control over proprietary information
- Protect networks against hackers
- Block traffic to certain sites
- Plan network capacity requirements

Large, modern packet networks typically carry a mix of rich media traffic, including television, movies, game, voice, and music streams, as well as data. (Previously, packet networks transmitted only data, which requires less capacity and no special treatment.) Faster processers and more affordable memory have led to new DPI switches that enable carriers, large universities, and enterprises to manage congestion in real time as well as offer new services on these diverse mobile and landline networks. In addition, organizations use it to block access to specific non-business-associated web locations such as Facebook (the social network site) to cut down on unnecessary traffic on their networks and increase employee productivity.

Don Bowman, chief technology officer at Sandvine Incorporated, was cited in the article “Flattened networks, creative pricing drives bigger DPI boxes” (Karpinski, Rich, *Telephony Online*, September 9, 2009). The article paraphrased Bowman’s statement that DPI is more commonly implemented in countries with mature networks to help them manage their networks than in developing countries where the emphasis is on building new, high-speed networks, not in fine-tuning them. DPI can be used to manage traffic in the following scenarios:

- On a specific carrier’s Internet networks
- Between residential customers and their carriers
- On mobile networks
- Between enterprise locations
- On enterprise links to the Internet
- Within the internal networks of an enterprises

It further enables telephone companies to categorize traffic in real time to support more flexible price offerings for mobile carriers’ data packages. This is an important competitive advantage, particularly in countries with more than two mobile carriers who compete on pricing and flexibility of the packages that they offer.

DPI systems have the capability to exchange information with a carrier’s billing system to support specialized offerings for data plans covering e-mail, songs, games, video, and web browsing. A mobile carrier might offer plans in which customers are allowed to use 300Mb of data for a fixed price, with metered pricing kicking in on anything over 300Mb.

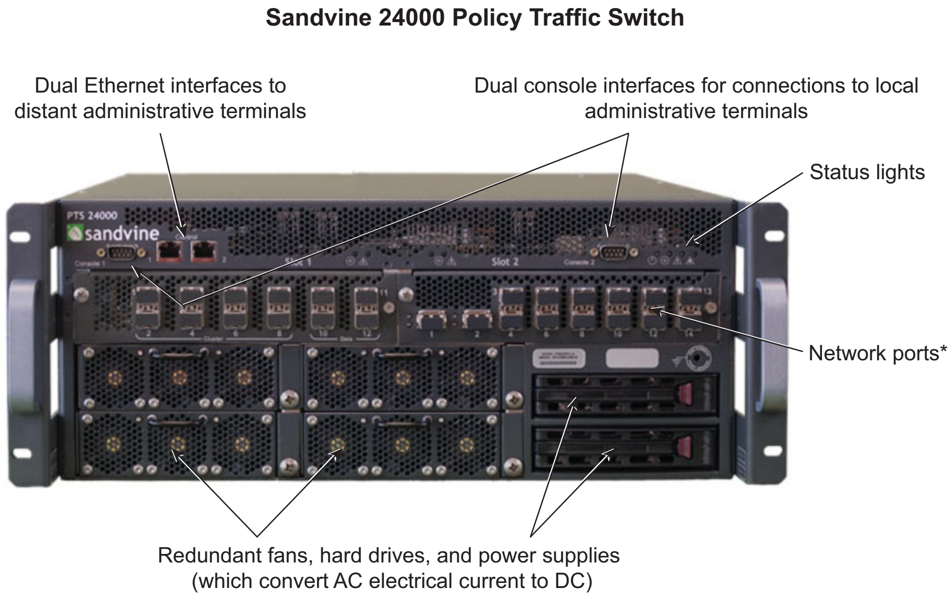
Metered pricing is a billing practice in which customers are charged by usage, rather than a flat rate, for unlimited or predetermined amounts of minutes or data bits. DPI switches tied into a carrier’s network can be configured to notify a user when she has used up her plan’s allotted minutes or data bits and will be henceforth charged additionally for any additional phone calls or data transmissions.

How Deep Packet Inspection Works

DPI is able to provide information on network conditions because of its capability to see more fields in packets than only the "send to" address. Discerning only a packet's address is analogous to looking at the address of an envelope. DPI provides the capability to determine which application the packet is using by examining patterns within packets. It can distinguish *Voice over Internet Protocol* (VoIP) traffic from data, gaming, and video traffic so that video or gaming traffic within a carrier network can be given the treatment required to maintain optimum performance.

DPI software develops a database of patterns, also referred to as *signatures*. Each signature or pattern is associated with a particular application such as peer-to-peer music sharing or protocols such as VoIP. It can also be associated with traffic from certain hackers or even terrorists attempting to launch malicious attacks with a goal of disrupting Internet or government sites. The DPI software matches its own database of patterns found in packets to those associated with particular applications, and network attacks.

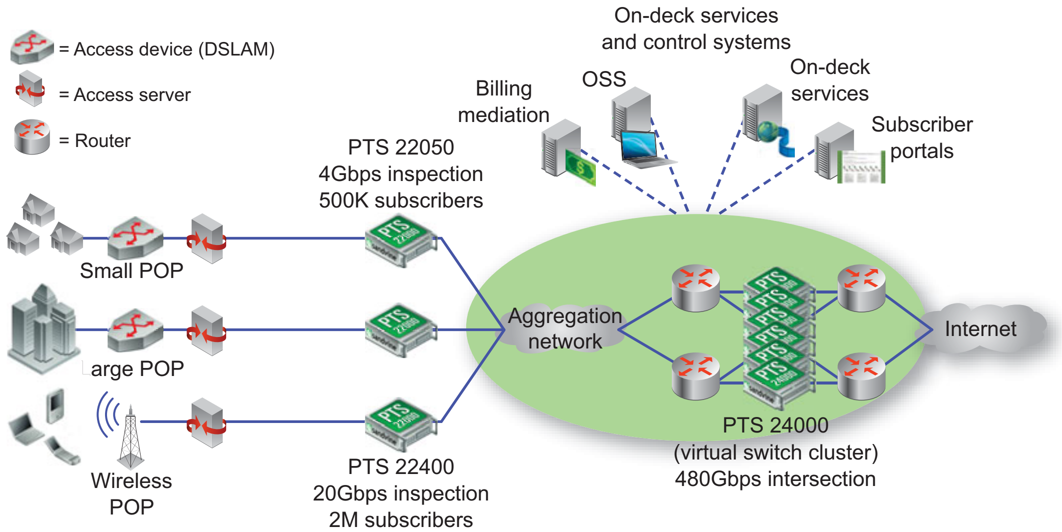
DPI software can be installed in stand-alone switches connected to an ISP or carrier's network or as part of routers (see Figures 1-3 and 1-4). Routers are used to connect traffic to the Internet as well as to select routes to other networks.



* Network ports interface with third-party systems, such as billing and charging operations, DPI applications, and subscriber profile databases.

Figure 1-3 A Sandvine DPI switch. (Courtesy Sandvine, Inc.)

Policy Traffic Switch (PTS) Manages Traffic in an ISP's Networks



"On-deck services" are those that the carrier or ISP offers directly such as video-on-demand and self-service portals.

"Control systems" are applications such as billing and charging used to bill customers and manage networks. Deep packet switches typically interface with on-deck services and control systems.

Figure 1-4 *Access devices such as Digital Subscriber Line Access Multiplexers (DSLAMs) connect to customers' modems. The POP (Point of Presence) is the location of the ISP's switching equipment. Managed services include e-mail, text messaging, and content from CNN. (Courtesy Sandvine, Inc.)*

Using DPI to Manage Networks in Private and Public Educational Institutions

In addition to ISPs, universities, colleges, and high schools also use DPI to manage traffic. Large universities often transmit cable TV to dorm rooms and classrooms over the same fiber networks used for all of their data and voice traffic. Educational institutions often carry IP video downloaded from the Internet to classrooms. The DPI software prioritizes video transmitted over these internal networks. Prioritizing video ensures that the video is of acceptable quality. If it's not prioritized, packets might be dropped when the school's network is congested, causing images to freeze.

In other cases, universities and ISPs have been served warrants from law enforcement agencies asking that they turn over the names of students or others who download music illegally from music sharing sites or peer-to-peer Internet sites. These agencies can use DPI services to identify these individuals. In 2009, several music companies sued a 25-year-old graduate student for illegal music downloads and won a $670,000 judgment. In another case, music companies won a $1.2 million judgment case against a single mother. Public sympathy for these defendants has forced music companies to stop suing individuals and begin working with ISPs who can use DPI in an attempt to stop illegal music sharing.

Government Use of Deep Packet Inspection: Packet Capture

Deep Packet Inspection (DPI) is an important tool for managing traffic on complex networks, carrying different types of traffic. However, carriers can also use it to aid government efforts. Some governments have requested that carriers use it to prevent information about political situations from being disseminated to the rest of the world. Many governments have asked that carriers deploy DPI to ferret out terrorist plots, drug trafficking, and other criminal activities.

Depending on how it's configured, most DPI equipment can monitor either the header only or the header plus the user data (payload) of e-mail and instant messages. Capturing the payload of a message is referred to as *data capture*. Data capture can be used to store messages for later scrutiny or to scan messages in real time. Either function requires fast processors and massive storage archives.

With the capability to recognize user data in packets, DPI equipment can be used to monitor e-mail messages by detecting keywords. For example, according to an article in the *Wall Street Journal*, "Iran's Web Spying Aided by Western Technology" (Rhoads, Christopher, June 22, 2009), during its 2009 presidential elections, the Iranian government used DPI to monitor e-mail messages from citizens who they suspected were opposed to the government's candidate. In addition, they attempted to block e-mail messages that contained information about street demonstrations opposing the government's candidate.

DPI software that is programmed to only monitor addressing within packet headers can block messages and browsers from accessing particular web sites. This has happened in numerous countries worldwide. However, some citizens figure out ways to circumvent efforts to block them from reaching particular web sites.

COMPRESSION

Compression reduces the size of video, data, image, and voice files. This decreases the amount of network capacity needed to transmit files. Compression increases throughput without changing the actual speed of the line.

NOTE

When compressed music and video files are downloaded from the Internet, video or voice is re-created at the receiving end by using less-powerful, lower-cost but acceptable *asynchronous* compression. Streaming compression algorithms assume that the end user will have less processing power to decode transmissions than the developers and broadcasters that encode the video and audio.

Enterprises typically use *synchronous* compression to re-create text, image and numeric files exactly as they were sent by using web acceleration and optimization. (See the section "Wide Area Network Acceleration and Optimization," later in this chapter.)

With compression, a song can be downloaded in seconds rather than minutes because fewer bits need to be sent. At the receiving end, compatible compression software or hardware re-creates the compressed chunks into close to or the same image or sound that was sent. Text is re-created exactly as it was before it was compressed so that numeric information or product information is not altered. However, when it's received, compression might re-create video and voice in varying degrees of lower video resolution or voice quality with acceptable, often barely noticeable, alterations.

Compression used with text and facsimile often reduces the amount of data to be transmitted by removing white spaces and by abbreviating the most frequently appearing letters. For instance, repeated letters are abbreviated into 3-bit codes instead of 8-bit codes. In a similar fashion, one method of video compression transmits only the changed image, not the same image over and over. In a video conference, nothing is transmitted after the initial image of a person until that person moves or speaks. Fixed objects such as walls, desks, and backgrounds are not repeatedly transmitted.

There are a number of standardized compression *algorithms* (mathematical formulas used to perform operations such as compression) that enable compressed text and video to be transmitted in a format that can be easily decompressed at the receiving end. The following is a list of commonly used compression protocols:

- Various *MPEG* standards are used to compress and decompress audio and video. MPEG stands for Moving Picture Experts Group.
- *MP3* is used for downloading music and other files to iPods.
- Apple's iPod uses *Advanced Audio Coding* (AAC).
- Most Windows-based personal computers have *WinZip* compression.
- *Zipit* is installed on Macintosh computers running OS 10.x.x.

See Table 1-1 in the "Appendix" section at the end of this chapter for a more complete listing of compression standards.

Compression: The Engine behind TV on the Internet

Video and multimedia capabilities have transformed how people use the Internet. Television and movies at sites such as Hulu (a joint venture of Comcast's NBC Universal, News Corporation's Fox Entertainment Group, and Walt Disney Company) and YouTube (a part of Google) enable people to get their entertainment, sports events, and news in video formats from the Internet. Viewers now expect good-quality video over their broadband connections, where in addition to TV and movies, they can view real-time sporting events. To take advantage of these capabilities, broadcasters and cable networks are creating strategic plans to include broadband streaming in their product mix.

In another nod to the future, new television sets have the capability to connect directly to the Web so that people can stream and watch broadband programming more easily on their high-definition, digital televisions. These changes have been made possible by advancements in compression.

Streaming: Listening and Viewing without Downloading

For the most part, when people watch television and movies on the Internet, the content is streamed to them. They do not own or keep copies of what they're viewing.

Streaming is different from downloading. Downloading requires an entire file to be downloaded before it can be viewed or played. With streaming, the user can listen to music or view a video in real time, but cannot store it for later use. When users download from sites such as iTunes, they can store the music files on their computer's hard drive. Spotify is a European site that offers free streaming and monthly subscriptions for €10 to download music. Free streaming music is also available at sites such as Pandora Internet Radio, where users select artists as examples of the type of music they want to listen to. Pandora then streams that genre of music to them.

Streaming and downloading music has caused the music industry and artists' royalties to shrink considerably. Customers now buy their music primarily from vendors such as iTunes, not in the form of CDs, and some users, particularly teenagers, download music without paying from sites such as LiveWire and Kazaa. According to an April 9, 2008 survey by investment bank Piper Jaffray, 61 percent of students surveyed download music illegally. Low royalties have forced popular singers to depend on concert sales for the majority of their income.

Advancements in Compression

Improvements in video compression have been largely fueled by developments in video production hardware, such as faster, multi-processing chips, and by developments in software, such as Adobe's Flash and Microsoft's Silverlight. These new processors along with superior mathematical algorithms enable larger chunks of media to be compressed more rapidly. Flash is a multi-platform software program that developers use to create animation in electronic games, web-based video conferencing, and video. Flash was previously installed on some mobile devices (not Apple tablets or portable music players, which are compatible only with HTML5) and on many video web sites. However, Adobe now uses HTML5 programming techniques for mobile devices. Free versions of the software are often bundled into personal computers so that people can view video created in Flash. Adobe Systems, Inc., owns the rights to and develops Flash.

On2 Technologies, Inc., is the creator of the video compression used in Flash software. According to John Luther, WebM project manager at Google Inc., in the past four years there have been significant developments in video due in large part to improvements in Flash. Now, video downloaded or streamed from the Web works the same on Apple and Windows computers with different types of compression installed. This is because Google has created software extensions that reside on the same chips and support both Apple's QuickTime and Microsoft's Windows Media Player. *Extensions* are add-ons that extend the capabilities of other software or hardware.

Thus, people who download video in the form of movies or sporting events, as an example, are generally no longer aware that they need a special type of compression software. Apple mobile devices are exceptions because they use HTML5 for viewing video. Developers are increasingly using HTML5 programming techniques for compatibility with Apple and other devices.

Using Codecs to Compress and Digitize Speech

Speech, audio, and television signals are analog in their original form. Analog signals are transmitted in waves; digital signals are transmitted as on and off bits. Before they are transmitted over digital landlines or wireless networks, codecs compress (encode) analog signals and convert them to digital bits. Codecs sample speech at different amplitudes along the sound wave and convert it to a one or a zero. At the receiving end, decoders convert the ones and zeros back to analog sound or video waves.

Codecs are located in cellular handsets, telephones, high-definition TV transmitters, set-top boxes, televisions, IP telephones, and radios. Codecs also compress voice in speech recognition and voicemail systems. With compression, codecs do not have to sample every height on the sound wave to achieve high-quality sound. They might skip silence or predict the next sound, based on the previous sound. Thus, fewer bits per second are transmitted to represent the speech.

INCREASING NETWORK CAPABILITIES VIA MULTIPLEXING

Multiplexing combines traffic from multiple devices or people into one stream so that they can share a circuit or path through a network. Each source does not require a separate, dedicated link.

Like compression, companies and carriers can use multiplexing to send more information on wireless airwaves, fiber networks, and internal Local Area Networks (LANs). However, unlike compression, multiplexing does not alter the actual data sent. Rather, the multiplexer at the transmitting end combines messages from multiple devices and sends them on the same wire, wireless, or fiber medium to their destination, whereupon a matching device distributes them locally.

One important goal is to make more efficient use of the most expensive portion of a carrier's network so that the carrier can handle the vast amounts of traffic generated by devices such as *smartphones* (multipurpose mobile phones with both Internet access and voice capabilities) and computers. Multiplexing is also used by enterprises that link offices together or access the Internet by using only one circuit (a path between sites) rather than paying to lease multiple circuits from their provider. The two most commonly used types of multiplexing are time division and statistical.

Time-Division Multiplexing

Time-Division Multiplexing (TDM) is a digital multiplexing scheme that saves capacity for each device or voice conversation. Once a connection is established, capacity is saved even when the device is not sending information. For example, if a call is put on hold, no other device can use this spare capacity. Small slices of silence with thousands of calls in progress result in high amounts of unused network capacity. This is the reason TDM is being gradually replaced in high-traffic portions of networks by Voice over Internet Protocol (VoIP) technologies, in which voice packets are interspersed with data and video traffic more efficiently, without wasting capacity. Thus, network capacity is not wasted during pauses in voice or data traffic.

Both T1 and T3 use TDM and carry voice, video, and data over a single circuit. In North America and Japan, T3 carries 672 conversations over one line at a speed of 45Mbps. T3 is used for large enterprises, call centers, and Internet access. Small and midsize organizations commonly use T1 for Internet access. T1 carries 24 streams over one circuit at 1.54Mbps. Matching multiplexers are required at the sending and receiving ends of each channel.

Statistical Multiplexing and Achieving Efficient Utilization via Priority Network Services

Unlike TDMs, *statistical multiplexers* do not guarantee capacity for each device connected to them. Rather, they transmit voice, data, and images on a first-come, first-served basis, as long as there is capacity. Ethernet is an example of statistical multiplexing. It can be used in a Wide Area Network (WAN) to connect customers to the Internet. It is also the most common method of accessing LANs within buildings. On Ethernet LANs, if more than one device attempts to access the LAN simultaneously, there is a collision and the devices try again later. Ethernet used for LAN access is located in each network-connected device, such as a printer, computer, or security monitor.

Statistical multiplexers support more devices than TDMs because they don't need to save capacity when a device is not active. Carriers sell WAN Internet access via Gigabit Ethernet offerings, supporting a range of speeds from 10Mbps to 10Gbps. If there is a surge in traffic, such as during peak times, the carrier can temporarily slow down traffic. However, because Gigabit Ethernet's statistical multiplexing has the capability to prioritize traffic, customers who contract for more costly, high-priority service can obtain higher speeds than customers with lower-priority service during traffic spikes.

Bytes versus Bits: Measuring Capacity and Speed

Federal and state requirements mandating retention of e-mail, financial, and other documents as well as corporations retaining all of their files rather than filtering out just what is needed have resulted in computer data storage in the petabytes range. A petabyte equals 1,000,000,000,000,000 characters or 1,000 gigabytes.

People often use the terms "bits," and "bytes" interchangeably. Their meanings, however, differ significantly. *Bits per second* (bps) refers to the actual number of bits sent in a given time from point A to point B, or the number of bits transmitted each second. It is also represented as millions of bits per second (Mbps), gigabits per second (Gbps), and terabits per second (Tbps). Simply put, it is the number of bits that can be transmitted in one second.

Continued

Bps (with a capital "B") stands for *bytes per second* by convention. Speeds are represented by the bps acronym. Here are some examples:

- Gigabit Ethernet, used in carrier and enterprise networks, can carry data at speeds of one gigabit per second (1Gbps) to 100 gigabits per second (100Gbps).
- Terabit speed routers deployed on the Internet are capable of transmitting at a rate of 1,000 gigabits or 1 terabit; 10 terabits per second = 10,000,000,000,000 bps.

Bits organized into groups of 8 bits are bytes. Each byte can be a letter character, punctuation, or a space. Computer hard-drive capacity is measured in bytes, but speeds on digital lines are measured in bits transmitted per second. Bytes stored on computer drives and large servers are stored in digital form.

To summarize, a *byte* is a character made up of 8 *bits*. A bit is an on or off electrical or light pulse.

WIDE AREA NETWORK ACCELERATION AND OPTIMIZATION

Lower-cost Wide Area Network (WAN) services and data lines have made it affordable for midsize and some small organizations to link domestic and international offices with headquarters via high-speed data links. (See Chapter 4, "Carrier Networks," for information on carrier network services.) Previously, these organizations only had access to centralized e-mail.

More recently, organizations have centralized an increasing number of IT functions at their headquarters to reduce or eliminate staffing expenses at remote offices. However, when the ability to access applications and files over the WAN is added, linking their remote offices to their headquarters, they often find that users have to sit and wait while files are downloaded.

This becomes a critical issue as organizations grow, centralize IT services, merge with other companies, or add remote sites to their networks. It's not unusual for enterprises to connect their headquarters with as many as 80 remote sites, including branch offices, small sales offices, and warehouses located in their home country, as well as in international locations.

WAN acceleration and optimization, also referred to as application acceleration, improves the performance of data lines between enterprise locations. It is done by a combination of improved compression and the elimination of delays caused by the most commonly used protocols.

Even with high-speed connections, delays can occur when users access data remotely. Certain protocols are at the root cause for many of the long waits for requested documents and applications to download to personal computers. Downloading delays are referred to as *latency*. TCP, HTTP, and HTML are the most commonly used protocols that contain many error control messages that cause latency. (See the Glossary for definitions of HTTP, HTML, and TCP.)

A number of companies, including Cisco Systems, Riverbed Technology, and software start-up Certeon Inc., offer WAN optimization and acceleration. Gareth Taube, former vice president of Worldwide Marketing at Certeon Inc., refers to the aforementioned protocols as being “chatty”. Examples of “chatty” messages in protocols include “are you ready?” and “did you get those packets?” Error messaging dialogues create delays because documents aren’t downloaded until both ends of the transmission respond to these and other control messages.

Certeon’s software improves transmissions by substituting a proxy that emulates these error messages at the receiving end. The sending end removes most of the error messages. At the receiving end, the proxy performs the error control locally so that transmissions are not delayed by control messages. This technique works effectively on high-quality links such as those made up of fiber-optic cabling.

Because most WAN traffic is identical to previous transactions, Certeon’s patent-pending de-duplication (a type of compression) sends only changes in data exchanges, not the entire file each time. As an example, when two offices collaborate on a Microsoft PowerPoint presentation, the software learns what is in the file the first time it is sent. When a person resends the file with edits, only the changes are transmitted, thus decreasing the file size from perhaps 5 megabytes to 10 kilobytes. The software at the receiving end reassembles the file with the changes included.

In addition to latency elimination and compression, some WAN optimization software can prioritize certain types of data traffic. For example, for a financial institution, it can give priority to customer web transactions over internal communications. This speeds up money transfers to the institution.

Streamlining protocols and using compression increases throughput on enterprise data links and creates more capacity for current and future applications. An important capability makes it possible to utilize an organization’s data links to electronically back up corporate data to other sites. If the main data center is destroyed by fire or a natural disaster, the organization’s data is preserved. This is possible because WAN acceleration software and compression technology free up bandwidth capacity for data backup.

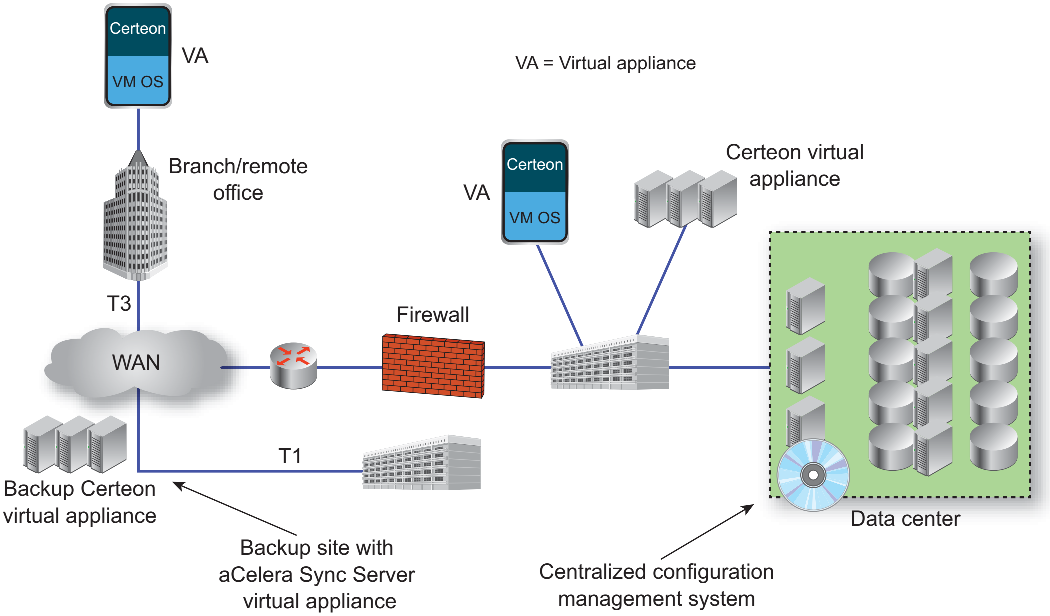


Figure 1-5 Certeon aCelera Virtual Appliance software loaded onto a virtual computer on a physical server at headquarters and at remote branches. Proprietary hardware is not required. (Courtesy Certeon)

WAN acceleration software is often installed on standard computers at the customer's locations. Certeon's software is downloaded onto virtual servers (servers that can run multiple operating systems and applications), in data centers, and at remote locations. (See the section "Single Servers Functioning As Multiple Servers via Virtualization," later in this chapter, for information on virtualization.) Additionally, the software can be downloaded to a desktop computer for remote employees. Figure 1-5 portrays an example of WAN acceleration and optimization software installed at headquarters and branch offices.

USING PROTOCOLS TO ESTABLISH A COMMON SET OF RULES

Protocols enable disparate devices to communicate by establishing a common set of rules for sending and receiving. For example, TCP/IP is the suite of standard protocols used on the Internet with which different types of computers, running a variety of operating systems, can access and browse the Internet. TCP/IP is a prime factor in the Internet's widespread availability.

The fact that protocols used on the Internet are available for free in their basic form and work with a variety of browsers, operating systems, and computer platforms makes them attractive interfaces for enterprises, hosting, and cloud-computing sites that support remote access to services such as Microsoft Office documents. A web-based interface compatible with many types of computers and operating systems enables enterprises to support software at a central site.

Installing software at a central site minimizes support requirements. When an IT department supports applications such as the Office suite that are installed on each user's computer, it must download software and updates to every computer and ensure that each has a compatible hardware platform and operating system. By locating the software at a central site rather than on each user's computer, updates and support are simpler. In addition, fewer IT employees are required to maintain servers with applications on them in remote offices.

However, many of these frequently used protocols are structured in such a way that they add a great deal of overhead traffic to the Internet and enterprise networks. This is because these protocols require numerous short signaling messages between the user and the Internet for functions such as identifying graphics, checking for errors, and ensuring correct delivery and receipt of all the packets.

The following protocols are used on the Internet and on corporate networks that have a web interface to information accessible to local and remote users.

- **Ethernet** This is the most common protocol used in corporate Local Area Networks (LANs). It defines how data is placed on the LAN and how data is retrieved from the network. Wi-Fi wireless networks are based on a different form of Ethernet.
- **Hypertext Markup Language (HTML)** This is the markup language used on the Internet and on enterprise networks. It is often used by employees who write web pages for their organization. HTML commands include instructions to make text bold or italic, or to link to other sites. Instructions, known as tags (not visible on Internet documents), are bracketed by open and closed angle brackets (< and >), otherwise simply known as the less-than and greater-than symbols. Tags indicate how browsers should display the document and images within each web page. For example, <bold> is a command for bolding text. Tags are delivered along with the web page when users browse the Internet and access information through web interfaces at enterprises. They are good examples of overhead bits.
- **Extensible Markup Language (XML)** This is another markup language based on elements surrounded by tags that identify fields requiring user input. The tag <name> is an example of a tagged label; it is not visible to users, but labels the field. Other variable labels might include quantity,

address, age, and so on. Firms can analyze responses provided by visitors to a site who fill out online surveys. Tagged responses can be sorted by fields such as geography or age. XML enables computers to automatically process responses collected online or in specialized applications such as purchasing and ordering functions in businesses. The protocol-related tags and labels identifying fields in XML create the many extra overhead bits transmitted along with documents containing XML commands.

PROTOCOLS AND LAYERS ....

When describing their products' capabilities, organizations often refer to the OSI layers. In the 1970s, the International Organization for Standardization developed the *Open Systems Interconnection* (OSI) architecture, which defines how equipment from multiple vendors should interoperate. *Architecture* refers to the ways that devices in networks are connected to one another.

Although not widely implemented because of its complexity, OSI has had a profound influence on telecommunications. The basic concept underpinning OSI is that of layering. Groups of functions are divided into seven layers, which can be changed and developed without having to change any other layer. (See Table 1-2 in the "Appendix" section at the end of this chapter for a complete list of layers.) LANs, public networks, and the Internet's TCP/IP suite of protocols are based on a layered architecture.

If you have an understanding of the functionality at each layer of the OSI, you will better understand the capability of particular protocols and equipment. Examples of the layers include the following.

- **Layer 2: Switches** This layer corresponds to capabilities in the *Data Link Layer*, functioning as the links to the network. However, Layer 2 devices cannot choose between multiple routes in a network. Layer 2 switches are placed in wiring closets in LANs and route messages to devices within their LAN segment. See Figure 1-6 for an illustration of how this works.
- **Layer 3: Switches and Routers** Layer 3 corresponds to the *Network Layer*. These devices can select an optimal route for each packet. Routers select paths for packets on the Internet and route messages between networks.
- **Layer 5: Encryption Protocols** These are *session layer* protocols that reorder data in packets by using complex mathematical algorithms to keep data private.

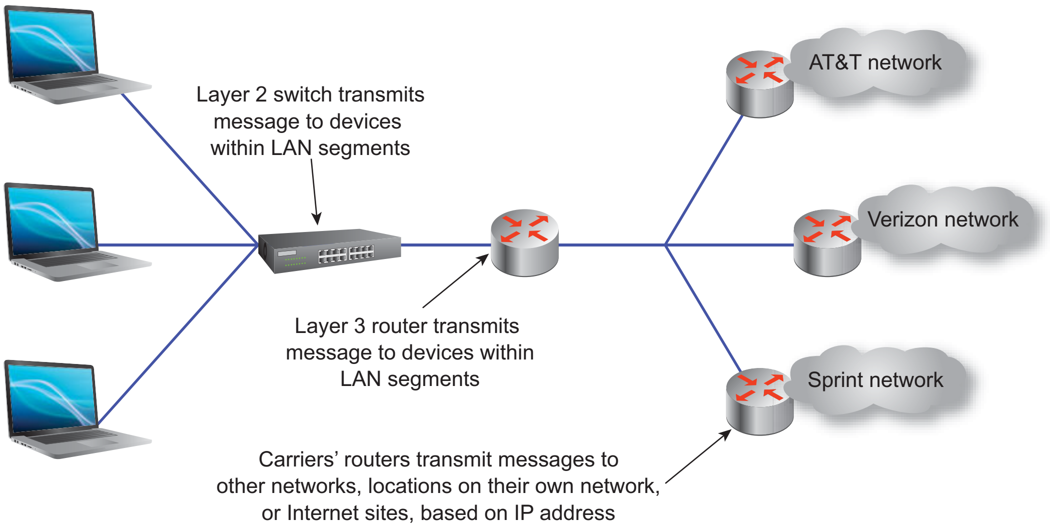


Figure 1-6 *A router at a carrier's site sends traffic to other carriers, based on factors such as destination address and cost of transmitting via particular carriers.*

- **Layer 7: Deep Packet Inspection (DPI)** DPI services include *application layer* capability. It can look into packets to determine the application of the data within them.

Knowing the capabilities in each layer helps in understanding the protocol and equipment capabilities being described.

CLOUD COMPUTING

Cloud computing refers to the paradigm by which computing functions, document storage, software applications, and parts of or all of a data center are located and maintained at an external provider's site.

There are many reason why an organization would want to adopt a cloud-computing strategy. Most of these reasons revolve around the desire to carry out IT functions more cost-effectively. Another reason might be capital outlays. A small startup company, for example, might not have the resources to hire staff and purchase computing hardware. Using a service such as Amazon Web Services or Google Apps (offered by Amazon and Google, respectively) for computing and archiving data saves startup costs with fewer financial risks. If the organization grows, it won't outgrow the hardware that it purchased earlier. Conversely, if the business fails or slows down dramatically, it doesn't have an investment in hardware and software with little resale value or one that might be too sophisticated for its changing needs.

Large enterprises are interested in cloud computing because it can be less costly than hiring additional staff as well as purchasing and supporting hardware and software for new applications. It is also useful in supporting IT in acquired companies and gearing up for spikes in usage. Both large and small organizations look to use cloud computing so that they can maximize their attention and assets on core missions.

Cloud computing customers often use high-speed Internet access to reach applications located at their provider's data centers. This makes cloud computing dependent upon spare capacity on these links. Declining prices have made higher-speed links more affordable. The wider availability of fiber directly to businesses and the greater proximity of fiber to residential customers have made such links more reliable and dependable for accessing applications.

The worldwide recession of 2008 was an enormous impetus toward adopting cloud computing as a cost-cutting measure. Organizations that worried about keeping up with growth suddenly found themselves with fixed expenses for on-site software licenses that could not be lowered. Software licenses are typically 20 percent of the initial fixed fee for the software, and most software companies charge customers a licensing fee per employee who uses their application. However, when staffs shrink, these licensing fees remain fixed at the same high levels they were set at prior to the layoffs. Thus, the more flexible fee structures of cloud computing are attractive because customers can add or delete users, with fees adjusted accordingly.

Large enterprises frequently use a cloud computing provider's data centers and staff to develop and manage new software applications. Adding and supporting new applications requires many hours of staff time to research and develop. Other challenges within data centers include ensuring that key applications don't crash, keeping up with software updates and traffic spikes, and controlling energy costs for electricity and cooling.

Moreover, with staff cutbacks associated with recessions and the emphasis on productivity, IT directors do not always have a sufficient budget to adequately staff their centers for continuous uptime. Even though the cost of running a data center and developing applications is the biggest factors in motivating organizations toward cloud computing, the risks of not keeping critical applications running and the complexity of operating and developing applications are also important considerations.

The Evolution of Cloud Computing

The term "cloud computing" is relatively new, but the trend toward outsourcing computing and programming tasks has been evolving since the late 1980s. During the 1990s, network technologies became robust enough that programmers in developing countries became able to support remote software development for high-tech companies in the United States. Given the time differences, programmers in countries such as India developed software during normal business hours and then sent it back to companies in the United States, where programmers took over during their working hours. This dramatically hastened the introduction of new products, as software was literally being developed day and night.

As IP networks that connected sites worldwide became faster, more reliable, less costly, and widely available, enterprises in Europe and the United States outsourced specific tasks. For example, they contracted with data centers in developing countries such as India and the Philippines, which have lower operational and labor costs. Tasks such as software maintenance and database upgrades became cheaper to perform.

The following factors have enabled the emergence of remote computing and contribute to its cost-effectiveness across a multiplicity of sophisticated data functions:

- Higher-speed, less-costly Internet access
- Multiprocessing computers or servers that are able to support various operating systems and applications simultaneously
- Lower-cost memory
- Vast amounts of spare computing capacity at technology companies such as Amazon and Google

Data storage, remote computer backup, and applications such as e-mail for business and residential customers are examples of cloud computing applications that take advantage of the vast, low-cost computer resources accessible via the Internet.

Links between the Cloud and Customers

The *integration hooks* that link a customer's computers to developers is one reason that security is a critical concern to cloud users.

> NOTE
>
> *Integration hooks* are Application Programming Interfaces (APIs). APIs are used to give disparate computer systems the access and capability to exchange certain data with other computers. These hooks are essentially software translators that interpret commands between dissimilar computer programs. This enables enterprise customers to link their computers to those of the cloud provider and developers, even if they are completely different systems.

It requires a high degree of trust for an organization to grant a vendor access to its data. Security is also a concern because data from multiple customers are on the same servers at the provider's data centers. Although for a higher fee it is possible for an organization to have its data isolated on a single server and not shared with other customers, it is more likely that data from multiple customers will be located on the same servers.

An anonymous IT professional once stated that staff members were adamant in their proclamation, "We're not giving you our data unless we know that the data is secure." Customers need to know that their data is not accessible to other customers and that they are able to audit transactions. When selecting a cloud supplier, industry experts recommend looking at which industry-standard security protocols and *encryption* the supplier uses. Encryption is the use of mathematical algorithms to reorder text so that it is unreadable by anyone without the "key" or a particular algorithm. Some cloud providers might agree to security audits by independent standards organizations rather than by customers themselves.

In addition to evaluating security and service quality, the ability to change suppliers and the difficulty of estimating the total cost of using cloud computing are matters that organizations consider when moving to a cloud model. Large applications might be proprietary, based on software the cloud IT staff created. This locks customers into a developer's platform and requires that customers rebuild the entire application if they change vendors. Possible solutions include using applications that are based on open standards and including an escrow statement in the contract stating the circumstances under which the customer has access to the developer's code. For example, if the developer were to go out of business, the application code would revert to the customer.

Cloud Computing Fees

The pricing structure for most cloud computing providers is typically based on the number of transactions and the number of users for a given application. Customers that contract with providers for e-mail or other data applications pay by the hour or by the gigabyte for CPU (computer processing unit) gigabytes consumed. In addition, cloud providers often charge an implementation fee and might charge developers who use their platform to develop applications for bandwidth consumed on the provider's Internet connections.

The lack of large up-front fees can be a challenge for startup developers creating applications for the cloud. Unlike organizations that sell onsite software platforms, these developers do not receive large fees up front to offset their development costs early on. However, just as publishers depend on ongoing royalties, so too do these developers earn a stream of revenue over a longer period of time.

Subsets of Cloud Computing

There are three generally agreed upon but sometimes overlapping classifications of cloud computing offerings. It's not unusual for providers to offer more than one of these types of services.

The classifications are as follows:

- **Software as a Service (SaaS)** Application developers manage and develop specific applications for enterprises. Enterprise and residential customers pay monthly fees to use these applications, which are generally accessed via a web interface.
- **Platform as a Service (PaaS)**, also called *Application Platform as a Service* A provider makes its hardware and basic application suite available to developers and enterprises that create specialized add-on applications for specific functions.
- **Infrastructure as a Service (IaaS)** Developers create applications on basic computing and storage infrastructure owned and supported by cloud providers.

SaaS

This section begins with an example of an anonymous enterprise exploring the possibility of using an application from a SaaS provider.

A multinational technology consulting organization is considering using a software developer to create and manage an application for applicant tracking. This software will automate tasks associated with sorting the résumés of job seekers, scheduling interviews, and transmitting résumés to the appropriate department.

The consulting organization does not want the tasks of developing and maintaining the new software. Management believes it is more efficient and less costly to hire a developer to host the software application in the developer's data center, on its disk space.

The applicant tracking software being developed will also have the capability to handle and translate résumés as well as associate people with jobs by tracking keywords in résumés. It will keep track of open jobs by means of integration hooks between data on the technology consulting company's computers and the applicant tracking software at the developer's site so that client data such as job requirements can be pulled into the applicant tracking software. Figure 1-7 presents an example of links between a developer's site and a client database.

Other SaaS providers include Salesforce.com and NetSuite. Salesforce.com offers its customer relationship management (CRM) services for managing relationships concerning customers and sales prospects. Its software can be used to automate writing sales proposals. It also profiles and targets customers based on these profiles. NetSuite offers businesses an end-to-end software suite that includes CRM, inventory, and e-commerce applications that integrate web sales with back-office functions such as billing and accounts receivable.

Both Salesforce.com and NetSuite sell directly to business customers and developers. The services to developers are considered PaaS offerings because developers use the Salesforce.com and NetSuite platforms to customize and support software for their own customers. At a 2009 forum held at the Churchill Club in San Jose, California, NetSuite CEO Zach Nelson indicated his belief that developers' customized NetSuite software is compatible with NetSuite's software when it is upgraded. ("The Trade-Off: A New Way to See Your Strategic Plan Without the Use of Psychedelic Drugs," October 9, 2009.) A video of his talk is available on YouTube.

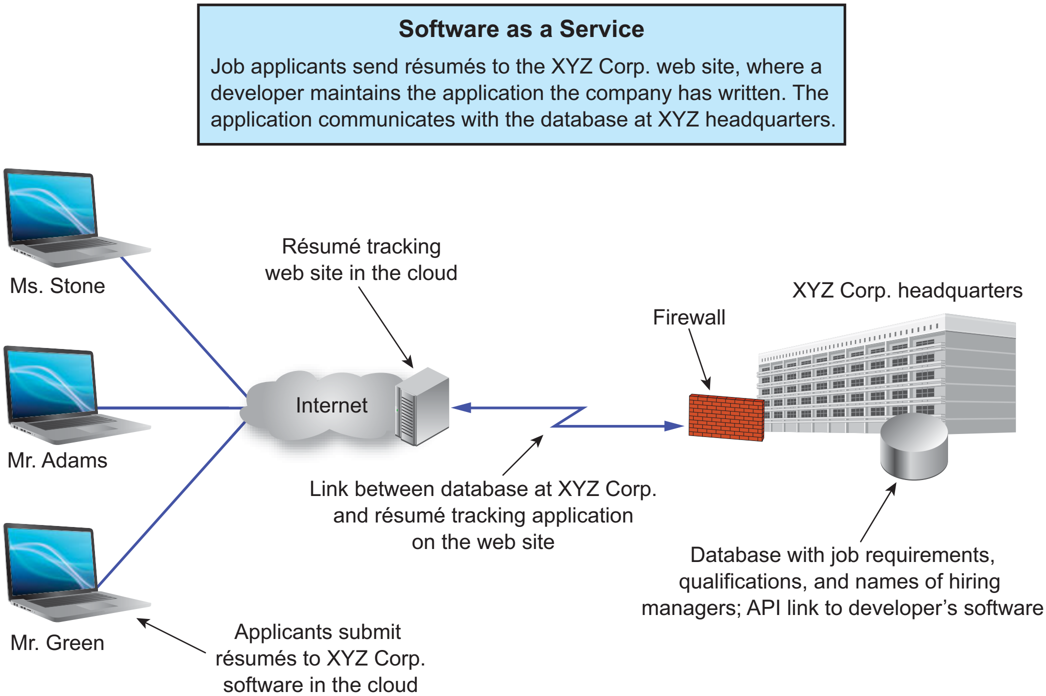


Figure 1-7 *The links between a developer's software in the cloud and a client organization's computer.*

PaaS: Cloud-Based Data Centers with Specialized Software

Platform as a Service (PaaS) providers offer data centers with specialized software to enterprises and application developers. For example, one PaaS provider, Microsoft, currently maintains massive data centers in Chicago, Texas, Dublin, Amersterdam, Singapore, and Hong Kong. The Microsoft Azure platform is available to developers to customize into applications that they in turn offer to their customers.

An enterprise customer can also create applications directly on Azure, or use the standard office software such as word processing and spreadsheet applications as well as productivity applications such as web conferencing and calendaring, and then later port them to Azure. By using applications housed on Azure, organizations eliminate the complexity of supporting in-house applications. Azure also offers storage facilities to developers and enterprise customers. A bank can store a year's worth of records on Azure to which each of its customers and their own staff have access.

Akamai Technologies maintains platforms that are deployed on 950 public networks worldwide, where it hosts web sites for major enterprise customers focused on e-commerce. Web applications located on these servers generate massive amounts of multi-media Internet traffic, such as games, map generation, search, and dealer/store locators. Akamai intercepts this web traffic for its customers and sends it to its destination on the fastest available route. It uses web application acceleration software to remove delays in HTML traffic caused by chatty protocols that its enterprise and major e-commerce customers employ.

Akamai's security services are available at each of the public networks in which its equipment is installed. These services include security that protects sites from distributed Denial of Service (DoS) attacks. Distributed DoS attacks simultaneously send thousands of bogus messages or messages containing viruses to networks in coordinated attacks from computers in multiple locations around the world. If one of its sites does become disabled, Akamai has the ability to run its applications at other locations.

IaaS: Cloud Services Using Third-Party Infrastructure

Providers that develop and sell cloud computing services offer them either on their own data centers or sometimes on another company's large-scale computing infrastructure. Amazon.com's Elastic Compute Cloud (EC2) and Google's Google Apps services sell applications on their computing infrastructure to end users and computing power such as servers and storage to software developers. Developers sell the services they develop on Google's and Amazon's infrastructures to consumer and business customers.

Amazon's 2006 cloud computing offering was the first of its kind and its success brought cloud computing to the forefront of potential competitors' attention. It grew out of Amazon's web-based storefront, Amazon Marketplace, where retailers used the site to sell their merchandise. Once Amazon's IT infrastructure and billing systems were in place for the Marketplace as well as for its own wares, it was a natural progression to offer spare computing and storage resources on its infrastructure to startups and developers. The consumers were then able to start businesses and create new services without investing capital in powerful computers.

Sonian Networks is one of the software developers that uses Amazon's infrastructure for its e-mail archiving services. The service archives customer e-mail messages to searchable, encrypted servers such that Sonian's customers are in compliance with federal and local requirements. Thus, Sonian provides a service to its clients without the burden of managing servers with large numbers of messages and protecting these servers from spam and viruses.

Sonian wrote the software for its archiving services on Amazon's servers by using an Amazon-provided API link. According to chief technology officer and founder Greg Arnette, its business customers' e-mail messages are encrypted before being sent securely across the Internet to the provisioned storage repository at Amazon. Sonian's customers, who typically have 500 to 5,000 employees, are provided with a web interface to access information about their e-mail. In this way, IT managers have access to reports on their company's e-mail traffic, and individual staff members can search for their own messages.

Using Amazon's services, Sonian was able to build its business without establishing redundant data centers across the country. Arnette feels that this kept his own company's costs low and in turn lets him pass the savings on to his customers. Both Sonian and its customers pay for only what they need, and they can take advantage of Amazon's economies of scale. Sonian pays Amazon for the CPUs by the hour, storage by the gigabyte, and bandwidth by the gigabyte. According to Arnette, its Sonian's client e-mail messages are stored on eight of Amazon's data centers throughout the United States. All e-mail messages are archived redundantly in each of these eight data centers.

Akamai's IaaS offering is for content storage. It hosts large enterprise web sites as well as 50 of the top e-commerce sites. Thus, Akamai provides IaaS as well as PaaS.

Computing as a Utility

Cloud computing companies often refer to computing as a utility. In his article "Planet Amazon" (*Wired Magazine*, May 2008, page 92), contributing editor Spencer Reiss quoted Amazon's CEO Jeff Bezos regarding his stance on cloud computing. "'You don't generate your own electricity,' Bezos says. 'Why generate your own computing?'" The phrase "computing as a utility" implies that computing services are not highly differentiated from one another. They are necessary to run a business and stay connected, but the implication is that certain applications are commodities. Thus, companies such as Amazon, Google, IBM, and Microsoft use their resources, economies of scale, and expertise to offer computer services as a "utility" to organizations and individuals.

Cloud Computing for Residential and Small-Business Consumers

Small-business and residential consumers have migrated to cloud computing at a faster pace than larger organizations. A major factor in their adoption is the fact that they have fewer resources with which to maintain their own personal computers, protect their networks from viruses and spam, manage e-mail and office applications, and archive documents.

Small-business and residential consumers use the Internet for low-cost data backup from providers such as Carbonite and Mozy.com (which is owned by EMC Corporation). Backup services sweep customer computers each night and update the files at the provider's location. Moreover, e-mail providers such as Google have expanded their online capabilities to include calendaring and collaboration.

Moving calendaring, collaboration, and office productivity applications online enables customers to access these applications from any device. This way, individuals can use wireless devices, which typically have inherently low storage capacities, to use and share their calendars from any device, at any location that provides Internet access. They've achieved portability by putting files such as calendars and photographs on the Web.

Small businesses that use the cloud maintain their own Local Area Network (LAN) for sharing printers and Internet access. They don't need to invest staff time maintaining office applications, including word processing, e-mail, and spreadsheet software, as well as collaborative tools. With collaboration software, multiple individuals can view and perhaps even change documents such as presentations and spreadsheets. People working remotely can easily collaborate with clients or headquarters staff members with these applications. Microsoft, Amazon, and Google are among the companies that provide these services online. Some cloud providers offer Service-Level Agreements (SLAs) to customers that promise 99.9 percent uptime, which equates to nine hours of downtime, annually.

Moving Applications between Providers and to the Cloud

Often, organizations that consider using the cloud for particular applications are concerned about portability. Cloud computing has generated a great deal of interest in venture capital/financial organizations that have invested in startup cloud providers.

Large, established companies such as Microsoft, IBM, and Hewlett-Packard, as well as ISPs including AT&T, Inc., and Verizon Communications, are also investing in their own cloud initiatives. No one knows which of these companies will be successful. This might lead customers to change providers because of factors such as costs and service, even if the provider is stable, thus enabling them to easily move their data and applications between cloud providers.

Moving applications from data centers to the cloud can involve rewriting them or changing internal processes. For example, operating systems and addressing schemes used by a particular cloud provider might be different from those utilized by its customer. Addressing schemes can include formats such as IP addresses assigned to databases and applications, and Media Access Control (MAC) addresses for individual computers. In addition, compatibility between the two infrastructures is important, because applications that reside on a provider's infrastructure interface might not be compatible with its customers' databases.

CloudSwitch, Inc., a startup located in Burlington, Massachusetts, offers software that affords its customers portability within the cloud and enables them to move applications to the cloud without rewriting them or changing in-place processes. The software is downloaded to the customer's virtual servers for its use. The CloudSwitch software creates compatibility between an application's characteristics and the cloud provider's addressing schemes, methods of packaging memory and storage, and type of network access. Network access refers to how corporations connect to the cloud. For security purposes, CloudSwitch provides Virtual Private Network (VPN) software. (Verizon Communications purchased CloudSwitch in August 2011.)

The VPN creates a secure link between the cloud and the customer by encrypting data and providing a way to securely re-create the data at the receiving end. It also ensures that the data exchanged is formatted so that it is not blocked by firewalls at either end. The software also makes the addressing formats compatible between the cloud's infrastructure and the customer's data center, and vice versa.

Another layer of complexity is that all applications are coded to a particular operating system, and operating systems are dependent on the resident hardware characteristics. Without changes, some applications might not be compatible with hardware located in a provider's data centers. The CloudSwitch software, transparent to customers and cloud providers, creates compatibility between operating systems, hardware, and applications.

John Considine, CloudSwitch founder and chief technology officer, explained the company's philosophy in an interview:

> *We are focused on not forcing the enterprise to abandon the way they do things when they use cloud computing. So when we started CloudSwitch, we focused on what is called hybrid computing: the blending of your IT resources with cloud computing. Another thing we work on is once you bring the application into the cloud, how do you work with it within your existing data center? How do you allow data residing in the cloud*

to work with what's already in your data center? Our software gathers up applications to place in the cloud, configures the storage required, and protects data using security protocols. Security is a big part of what we do.

CloudSwitch accomplishes all of this by using its patent-pending cloud isolation technology. The company endeavors to understand the requirements of providers by maintaining close relationships with major cloud providers, such as Amazon, Microsoft, and Terremark Worldwide, Inc. (now part of Verizon Communications). Other companies that provide software or consulting services to assist clients in moving applications to the cloud include Accenture and AT&T.

SINGLE SERVERS FUNCTIONING AS MULTIPLE SERVERS VIA VIRTUALIZATION

The term "virtual" refers to entities such as networks or servers that provide the functions of the physical devices that they are emulating. Server virtualization refers to single servers performing the functions of multiple servers. To illustrate, multiple *virtual machines* can exist within a single server, with each virtual machine performing the functions of a single server. A virtual machine is software with the functionality of a computer.

NOTE Servers are computers used for specialized tasks such as managing document traffic to printers and storing applications.

Without server virtualization, each server in a data center would support only a single operating system. Virtualization enables each server to run multiple operating systems, with each operating system running multiple applications. Each operating system running multiple applications is a *virtual machine*. This reduction in the number of servers required to support vast numbers of applications made virtualization a key building block for cloud computing.

Technical advances have enabled virtualization to make it possible for large enterprises and cloud computing providers to consolidate servers. Supporting more than one operating system on a single physical server requires large amounts of processing power. However, with the development of powerful multi-core processors, parallel-computing streams can perform multiple computer instructions simultaneously. As of this writing, multi-core processors can contain up to eight core processors.

Virtualization host operating software from companies such as VMware, Inc. (EMC is the majority owner) and Microsoft allocate and manage computer resources such as memory, hard-disk capacity, and computer processing between the operating systems and applications on a server. Virtualization management software simplifies data center operations by providing the ability to allocate more resources in a data center from a single interface.

Scalability and Energy Savings

Carriers, ISPs, enterprises, and developers adopt virtualization as a way to save on energy, computer memory, staffing, and hardware costs. Installing applications on multiple virtual computers on each physical server decreases the number of physical servers required. It also ensures that there is less wasted capacity than on physical servers used for a single application, often using only 10 percent of the physical server's capacity. This makes data centers more scalable. Applications can be installed more easily, without adding extra hardware. Rather, a new virtual machine can be added to a physical computer that has spare capacity until the physical server is at between 70 percent and 80 percent of capacity.

In addition, having fewer computers to run applications results in less space used and lower facility cooling costs. Although individual servers running virtual operating software are more powerful and require more cooling than less-powerful servers, the reduction in the total number of physical devices results in overall energy efficiency.

Virtualization and Cloud Computing

Virtualization is a major enabler of cloud computing. Large cloud providers commonly have multiple data centers that maintain replicated copies of all data. If a data center becomes disabled, another can easily take over its functions. Virtualization makes it less costly and complex for providers to support multiple data centers in different physical locations. This results in a reduction of physical services, less electrical power, and less cooling; thus, lowering providers' energy costs.

Moreover, virtualization enables data centers to support multiple developers by providing a virtual computing platform for each developer while he is logged on to a virtual machine. Multi-core processors enable multiple developers to simultaneously log on to the same physical server. When a developer logs off of his area of the server, computing power is freed up for other uses.

Because of security and privacy concerns, large companies often do not want their applications and files on the same physical servers as those of other organizations. In these instances, they can elect to reserve a group of servers for their own use. Amazon refers to this feature as a Virtual Private Cloud. Other providers offer similar features. Not surprisingly, there is an extra monthly fee associated with this service.

Virtualization as a Green, Efficient Strategy

As of October 1, 2010, the town of Framingham, Massachusetts, had a population of 68,318 people and 8,434 students in 13 schools. According to Adam Seldow, former director of technology for the Framingham Public Schools, there were 40 servers in the school department's data center before they changed over to virtualization technology. There are now four physical servers running VMware virtualization software. Each server boasts much more processing power and RAM than the servers that were replaced. Moreover, they're used more efficiently and require less staff time to maintain.

Additionally, eight applications exist on individual servers because they weren't designed to work on virtual computers. This includes an e-mail server because it is a traffic-intensive application supporting a large volume of e-mail traffic daily. It also includes the Cisco Systems Voice over Internet Protocol (VoIP) telephone system that still requires separate servers for the phone system and voicemail because the available software release was not compatible with VMware at the time of the initial purchase.

In an interview, Seldow stated the following:

> *Virtualization has many advantages for the school department. There are no longer 40 power plugs, 40 devices, as many moving parts, and 40 power supplies that can all fail and must all be maintained. The four servers with VMware act like one physical computer in which memory and processing power can be allocated to different virtual machines in real time. The network manager uses the management software's interface located in the main server to click and slide icons to the left or the right to allocate memory and processing power to applications, on the fly.*

Seldow also stated that the ease of patching and upgrading applications has added efficiency to data center operations. The management interface can be used to point and click to clone (make a copy) an application in need of an upgrade. The cloned application can then be tested before being released to the user community. Once it has been tested, two options exist to change the current setup: One is to upgrade the older version's virtual machine and delete the snapshot, or new version, of the application; the other option is to release the snapshot to end users and delete the old version.

Continued

In addition, virtualization saves time for the network manager, eliminating frequent travel to the school systems' 17 locations to physically manage remote servers. The applications are now centrally located and managed in the virtualized server with the largest-capacity hard drive. This server is referred to as the Storage Area Network (SAN) because it contains the SAN software and stored applications. Three of the VMware servers without applications communicate with end users. All four VMware servers are networked together in the department's central data center and operate as a single computer, with the SAN physical server coordinating interactions with the other three physical servers.

All of the schools and departmental administrative offices are connected to the data center by fiber-optic cabling and treated as a single LAN rather than a Wide Area Network (WAN). RCN Communications, one of the town's cable providers, furnishes the fiber-optic network, which is run on different fiber strands than RCN's cable TV Internet and voice traffic.

Virtualization and Storage

Various state and national regulations mandate that organizations in fields such as banking, healthcare, pharmaceutical, and government retain files for specified lengths of time. In addition to archiving information with cloud providers, organizations often use these providers as a lower-cost emergency backup in the event that their data is destroyed in a natural disaster, fire, or computer hacking incident. Enterprises can store up to a 1 petabyte (PB) of data in servers that are often as large as a refrigerator. These servers consume large amounts of energy and take up a great deal of space.

Computers used for storage are now also able to take advantage of efficiencies attained by virtualization. Data stored in different database formats (for example, Microsoft SQL versus Oracle) can be stored on the same physical computer by using virtualization. Thus, the databases of various customers can be stored on the same storage server, resulting in server consolidation, both for storage and for running applications.

NETWORK CABLING

Improvements in copper cable have made it possible for unshielded, twisted-pair cabling to transmit signals at speeds of 10Gbps in Local Area Networks (LANs). Previously, these speeds were only attainable over fiber-optic cabling. This is important because the interfaces in most computer devices are compatible with unshielded, twisted-pair (UTP) cabling, not fiber-optic cabling. Connecting this gear to fiber requires the cost and labor to install devices that change light signals to electrical signals, and vice versa.

UTP copper and fiber-optic cables are the most common media used in enterprise LANs. Because of improvements in the speeds, capacity, and distances wireless signals can be transmitted, wireless media is replacing copper cabling in some office buildings. Wireless services based on the 802.11 (Wi-Fi) protocols are discussed in Chapter 7.

Characteristics of media have a direct bearing on the distance, speed, and accuracy at which traffic can be carried. For example, thin copper wire carries data shorter distances at lower speeds than thicker, higher-quality copper.

In corporate networks, UTP is the most prevalent medium used to link computers, printers, and servers to wiring closets on the same floor. This is referred to as the horizontal plant.

Fiber is capable of carrying vastly more traffic than copper. However, it is more expensive to install and connect to devices in LANs than UTP, and thus it is generally used in high-traffic connections between the following:

- Wiring closets
- Floors (the risers)
- Buildings on campuses

The key characteristic that makes fiber suitable for these high-traffic areas, is the fact that it's a nonelectric medium. Fiber exhibits superior performance because, unlike copper, it does not transmit electric signals that act like an antenna and pick up noise and interference from nearby electrical devices.

The Disadvantages of Copper Cabling

Signals transmitted via copper react to electrical interference or "noise" on the line. Power lines, lights, and electric machinery can all inject noise into the line in the form of electric energy. This is why interference from signals such as copiers, magnetic sources, manufacturing devices, and even radio stations can introduce noise and static into telephone calls and data transmissions. One way to protect copper cabling from noise and *crosstalk* introduced by nearby wires is to twist each insulated copper wire of a two-wire pair. Noise induced into one wire of the twisted pair cancels an equal amount of noise induced in the other wire of the pair. Crosstalk occurs when electrons that carry the conversations or data along a copper pair cross over, or "leak," on to other nearby wire pairs.

Another electrical property of copper wire is *resistance.* Resistance causes signals to weaken as they are transmitted. This is referred to as *attenuation*. Attenuation is the reason signals on copper cable in the outside network need to be boosted on cable runs of more than approximately 1.5 miles. In contrast, because signals are non-electrical, a signal on a high-performance fiber-optic cabling can travel 80 miles before it needs to be strengthened. Thus, the dual inherent impairments of interference and resistance are the key factors that limit copper's performance.

Using Structured Cabling Standards to Uniformly Support Higher Speeds on Copper Cabling

Cabling standards have been created to support ever-higher speeds, carry multi-media traffic, and ensure that organizations can purchase cabling and connectors from diverse manufacturers without risk of incompatibility. Each cabling standard includes defined tests that should be performed when cables are installed to ensure that it and all of the connectors perform to their specifications.

Every new standard needs to be compatible with all lower standards. This allows applications that operated over lower-category cabling systems to operate on higher categories, as well. The biggest problems organizations face with cabling systems are that they are not always properly installed and tested to meet standards. This results in either lower-than-expected data rates or inconsistent reliability.

Each of the standards specifies not only the cable itself, but all of the connections including jacks (outlets), plugs, and cross-connects in wiring closets. *Cross-connects* provide outlets on each floor where cabling from individual devices is connected. The floor cabling, also referred to as the horizontal plant, is connected to the riser plant, which is the cabling between floors. It is also connected in the building's main wiring closet connected to other buildings within a campus.

Standards also specify the network interface card (NIC) in printers and computers to which a cable connects the device to the jack (outlet). The Telecommunications Industry Association (TIA) rates twisted-pair cabling and connection components used inside buildings.

Unshielded Twisted-Pair Copper Cabling Standards

Category 3 UTP cabling—often referred to as simply "CAT 3"—is rated as suitable for voice transmission, but because it is only suited for older type phone systems, it is rarely used in new installations. Categories 5, 5e, 6, and 6a are the commonly deployed structured cabling system standards for UTP. Organizations often use Category 6a to support 10Gbps speeds in their data centers, and Category 6 for the rest of their facility. Moreover, this same cabling plant is generally used for both voice and data. Category 7 cabling is based on a standard ratified in Europe but not by standards organizations based in the United States. As a result, it is not yet widely installed. The following is a synopsis of the major UTP categories.

- **Category 5** *Supports speeds of up to 100Mbps for 100 meters (328 feet) over UTP.* It was the first ratified standard for megabit Ethernet transmissions. It consists of four pairs of eight unshielded copper wires. Category 5 has been superseded by Category 5e.
- **Category 5e** *Supports 1Gbps speeds at distances of 100 meters (328 feet).* Higher speeds are attainable because the cabling and connectors are manufactured to higher standards. There are more twists per inch in the cabling than that specified for Category 5.
- **Category 6** *Supports 1Gbps speeds at 100 meters (328 feet).* At shorter distances, it handles 10Gbps speeds. A higher twist rate, heavier cabling, and a metallic screen around the entire cable protect it from ambient noise. Insulation material (usually plastic strips) is placed between each of the four pairs to reduce crosstalk between the wires, as shown in Figure 1-8.
- **Category 6a (augmented)** *Supports 10Gbps Ethernet transmissions of up to 55 meters (180 feet).* This is possible because the stricter standards result in less cross talk between adjacent cables. Lower speeds are supported for up to 100 meters (330 feet).
- **Category 7** *Supports 10Gbps speeds of up to 100 meters (330 feet).* High performance at longer distances is possible because there is shielding around each pair of wires and an overall metal foil shield around the entire cable. It

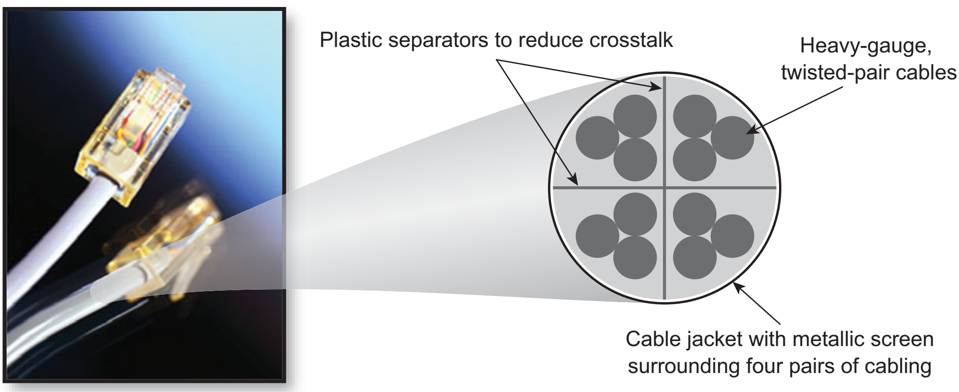


Figure 1-8 *A cross section of a Category 6 cable and a photograph of UTP four-pair data cables with connectors.*

must be installed with different components and connectors than for Categories 5 through 6a to accommodate this shielding. It can also be installed with the same type of connectors specified in earlier standards; however, it will not transmit 10Gbps traffic as far as the 100 meters (330 feet) achieved with the appropriate connectors.

Fiber-Optic Cabling in Commercial Organizations

Because fiber is nonelectric, it can be run in areas without regard to interference from electrical equipment. This is the main reason fiber transmits signals farther than copper before fading. Signals are transmitted along the fiber in the form of on and off light pulses, somewhat similar, in theory, at least, to the operation of signaling lamps that were commonly used in the Navy to transmit Morse code messages.

Although fiber-optic cabling has many advantages for high-traffic areas, the specifications for fiber connections are more exacting, and the fiber itself requires more care in handling and installation. For example, it is less flexible than copper and cannot be bent around tight corners. However, given its greater capacity and cost savings in ongoing maintenance, carriers install fiber in the majority of new apartment buildings and office complexes.

There are two reasons why fiber is typically more expensive than copper to install.

- The electronics (multiplexers and lasers) to convert electrical signals to optical signals, and vice versa, are costly.
- Specialized technicians, paid at higher levels, are required to work with and test fiber cabling.

In addition, the multiplexers and interfaces to copper cabling in the customer's facility requires local power. This adds a point of vulnerability in the event of a power outage.

Fiber-optic cable is made of ultra-pure strands of glass. The narrower the core that carries the signals, the faster and farther a light signal can travel without errors or the need for repeaters. The cladding surrounding the core keeps the light contained to prevent the light signal from dispersing; that is, spreading over time, with wavelengths reaching their destination at different times. Finally, there is a coating that protects the fiber from environmental hazards such as rain, dust, scratches, and snow.

Another benefit of fiber-optic cabling is that eavesdropping is more difficult because the strands have to be physically broken and listening devices spliced into the break. A *splice* is a connection between cables. Splices in fiber-optic cables are easily detected.

Single-Mode versus Multi-Mode Fiber

There are two main types of fiber: single-mode and multi-mode. Single-mode fiber is smaller, is more expensive, and supports higher speeds than multi-mode fiber. Measuring approximately the same diameter of a strand of human hair, it is used mainly in carrier networks and in undersea cabling.

The fact that single-mode fiber carries light pulses faster than multi-mode fiber can be explained by a geometric rule: A straight line is the shortest distance between two points. Light travels faster in a straight line than if it zigzags along a path, which is precisely what happens to light waves if they reflect, or “bounce,” off the inner wall of the fiber strand as they travel. These zigzag paths also cause the signals to attenuate, lose power, and fade over shorter distances. The small core of single-mode fiber keeps the light signal from bouncing across the diameter of the fiber’s core. Thus, the straighter light signal travels faster and has less attenuation than if it had a bouncier ride through the core.

When the light pulses travel in narrower paths, fewer repeaters are needed to boost the signal. Single-mode fiber can be run for 80 miles without regeneration (boosting). In contrast, signals on copper cabling need to be repeated after approximately 1.5 miles. For this reason, telephone companies originally used fiber for outside plant cabling with cable runs longer than 1.24 miles.

The main factor in the increased expense of single-mode fiber is the higher cost to manufacture more exact connectors for patch panels and other devices. The core is so small that connections and splices require much more precise tolerances than with multi-mode fiber. If the connections on single-mode fiber do not match cores exactly, the light will not be transmitted from one fiber to another. It will leak or disperse out of the end of the fiber core at the splice.

Multi-mode fiber has a wider core than single-mode fiber. The wider core means that signals can only travel a short distance before they require amplification. In addition, fewer channels can be carried per fiber pair when it is multiplexed because the signals disperse, spreading more across the fiber core. Multi-mode fiber is used mainly for LAN backbones between campus buildings and between floors of buildings.

Another factor in the expense of installing fiber cabling systems is the lack of connector standardization. Different fiber system manufacturers require specialized tools and proprietary connectors. Two of the main connector types are the Straight Tip (ST) and the Subscriber Connector (SC). Another is the Small Form Factor (SFF) connector. Each type of connector requires specialized tools for installation.

Making Connections between Fiber and Copper

In enterprise networks, when fiber is connected to copper cabling at locations such as entrances to buildings, at wiring closets, or in data centers, equipment converts light pulses to electrical signals, and vice versa. This requires converters called transmitters and receivers. Transmitters also are called light-source transducers. If multiplexing equipment is used on the fiber, each channel of light requires its own receiver and transmitter. Transmitters in fiber-optic systems are either Light-Emitting Diodes (LEDs) or lasers. There are several reasons for this.

- LEDs cost less than lasers. They are commonly used with multi-mode fiber.
- Lasers provide more power. Thus, less regeneration (amplification) is needed over long distances.
- At the receiving end, the light detector transducers (receivers) that change light pulses into electrical signals are either positive intrinsic negatives (PINs) or avalanche photodiodes (APDs).
- LEDs and PINs are used in applications with lower bandwidth and shorter distance requirements.

SUMMARY

Consolidation among corporations that supply equipment, virtualization, and database software has resulted in fewer choices for basic computing functions. While consolidation can decrease innovation, it does reduce the risk of selecting unproven equipment and services. It also makes it less complex to transmit files across networks. Music and TV shows are now easily downloaded or streamed from the Internet to end users because most end users have one of the two or three commonly used types of compression software on their computers. Consequently, software developers can readily create compatibility between these compression standards and the software that they develop for the Internet.

Commonality between hardware and software is making it less complex for cloud providers to build and manage enormous data centers. In addition, the number of highly experienced users running equipment and software developed by leading suppliers ensures a greater percentage of up time. While virtualization has had a big impact on the ability of large data centers to be managed more efficiently, the availability of common database packages, operating systems, and computer hardware has also contributed to this trend.

Cloud computing is changing the ways that consumers, small and midsize businesses, and large conglomerates manage computing resources and store files. However, very large organizations are cautious about which services they move to the cloud. There are concerns about provider security, stability, and loss of control over data that is in the cloud.

In addition, because cloud computing can result in smaller data centers that require fewer people to monitor the systems, IT staff might be resistant to using services that result in job losses and diminished responsibilities. This, combined with natural caution over moving important applications to the cloud, is slowing some organizations' transition to cloud computing.

Legal issues also play a part in the adoption of cloud computing. For example, a provider that archives its customer's e-mail or personnel records needs to be able to access particular records in response to an executed subpoena. Every cloud provider must meet legal requirements for privacy. These requirements can include provisions that certain types of records are stored separately, with no access provided to outside parties. In these instances, customers might opt to store their files separately on dedicated servers that are not shared with other organizations. This is more costly than using a shared service.

Large enterprises are especially concerned about security. With the exception of the largest and most sophisticated enterprises, major cloud providers have more resources and capabilities for implementing strong security than a majority of the concerned organizations. Nevertheless, customers need to be assured about the level of security before placing their data behind someone else's firewall. Security also applies to factors, such as protection from water damage, severe weather, unauthorized entry to data centers, natural disasters, and defense from hackers.

Conversely, using a cloud provider for web-based applications that are intended for public consumption is a prime motivation for using the cloud. This is because institutions either do not need or do not want to add or maintain the necessary resources. This is particularly true with regard to handling traffic spikes that these applications can generate, such as with a retail site during the holiday season. Nonetheless, they need ways to evaluate whether providers have the infrastructure and network bandwidth to keep up with these spikes and that the cloud provider's infrastructure can handle all of the customers that it adds. This requires enough bandwidth for external traffic, adequate storage and servers, and an adequately fast Local Area Network.

Well-thought-out service agreements and contracts that clearly define provisions for security, control over data, uptime, response times, capacity, privacy, and other issues can help to protect customers. Contracts written to address these issues specify penalties if the vendor fails to meet contract terms to further protect vendors and customers.

The more transparent vendors are about their networks, the more attractive their offerings will become to institutions. Vendors can achieve transparency and win customer confidence by sharing their own reports on variables such as network availability and response times. Moreover, customers need to be offered options on items such as real-time reports, summary reports, and departmental-level reporting so that they have as much control as possible over their own data.

APPENDIX

A Comparison between Analog and Digital Signaling

Speed or frequency on analog service is stated in hertz (Hz). A wavelength that oscillates, or swings back and forth between cycles, ten times per second has a speed of 10Hz or cycles per second. A cycle starts at a neutral place in the wavelength, ascends to its highest point, descends to its lowest point, and then goes back to neutral. Lower frequencies are made up of longer wavelengths than higher frequencies.

Analog telephone signals are analogous to water flowing through a pipe. Rushing water loses force as it travels through a pipe. The farther it travels in the pipe, the more force it loses, and the weaker it becomes.

The advantages of digital signals are that they enable the following:

- **Greater capacity** The ability to mix voice, video, photographs, and e-mail on the same transmission enables networks to transmit more data.
- **Higher speeds** It is faster to re-create binary digital ones and zeros than more complex analog wavelengths.
- **Clearer video and audio** In contrast to analog service, noise is clearly different than on and off bits, and therefore can be eliminated rather than boosted along with the signal.
- **Fewer errors** Digital bits are less complex to re-create than analog signals.
- **More reliability** Less equipment is required to boost signals that travel longer distances without weakening. Thus, there is less equipment to maintain.

Table 1-1 Compression Standards and Descriptions

Compression Standard	Description
H.263	An International Telecommunications Union (ITU) standard. It is primarily used for video conferencing on LANs and WANs. It is also used for mobile video on third-generation (3G) networks.
G.726	A family of standards for voice encoding adopted by the ITU. It is used mainly on carrier networks.

Compression Standard	Description
IBOC	*In-band, on-channel* broadcasting uses airwaves within the AM and FM spectrum to broadcast digital programming. IBOC is based on the Perceptual Audio Coder (PAC). There are many sounds that the ear cannot discern because they are masked by louder sounds. PAC discerns and discards these sounds that the ear cannot hear and that are not necessary to retain the observed quality of the transmission. This results in transmission with 15 times fewer bits. PAC was first developed at Bell Labs in the 1930s.
JPEG	*Joint Photographic Experts Group* is a compression standard used mainly for photographs. The International Standards Organization (ISO) and the ITU developed JPEG.
MPEG-1	A *Moving Picture Experts Group* video compression standard that has been largely displaced by the more powerful MPEG-2 and MPEG-3.
MPEG-2	An MPEG standard approved in 1993 for coding and decoding video and television images. MPEG-2 uses past images to predict future images and color. It then transmits only the changed image. For example, the first in a series of frames is sent in a compressed form. The ensuing frames send only the changes. A frame is a group of bits representing a portion of a picture, text, or audio section.
MPEG-3	MPEG-3 is Layer 3 of MPEG-1. MPEG-3, also referred to as MP3, is a compression standard for streaming audio. MPEG-3 is the compression algorithm used to download audio files from the Internet. Some Internet e-commerce sites use MPEG so that potential customers who have applications that use compression software can download samples of music to decide if they want to purchase a particular song.
MPEG-4	MPEG-4 is a standard used mainly for streaming and downloading compressed video and television. It is four times more efficient than MPEG-2.

Table 1-2 OSI Layers

OSI Layer Name and Number	Layer Function
Layer 1: Physical Layer	Layer 1 is the most basic layer. Layer 1 defines the type of media (for instance, copper, wireless, or fiber-optic) and how devices access media. Repeaters used to extend signals over fiber, wireless, and copper networks are Layer 1 devices. Repeaters in cellular networks extend and boost signals inside buildings and in subways so that users can still take advantage of their cellular devices in these otherwise network-inaccessible locations.
Layer 2: Data Link Layer	Ethernet, also known as 802.3, is a Layer 2 protocol. It provides rules for error correction and access to LANs. Layer 2 devices have addressing information analogous to Social Security numbers; they are random but specific to individual locations. Frame Relay is a Layer 2 protocol previously used to access carrier networks from enterprises.
Layer 3: Network Layer	Layer 3 is known as the routing layer. It is responsible for routing traffic between networks that use IP network addresses. Layer 3 has error-control functions. Layer 3 is analogous to a local post office routing an out-of-town letter by ZIP code while not looking at the street address. Once an e-mail message is received at the distant network, a Layer 3 device looks at the specific address and delivers the message.

OSI Layer Name and Number	Layer Function
Layer 4: Transport Layer	Layer 4 protocols enable networks to differentiate between types of content. They are also known as content switches. Layer 4 devices route by content. Video or voice transmissions over data networks might receive a higher priority or quality of service than e-mail, which can tolerate delay. Filters in routers that check for computer viruses by looking at additional bits in packets perform a Layer 4 function. Transmission Control Protocol (TCP) is a Layer 4 protocol.
Layer 5: Session Layer	Layer 5 manages the actual dialog of sessions. Encryption that scrambles signals to ensure privacy occurs in Layer 5. H.323 is a Layer 5 protocol that sends signals in packet networks to set up and tear down, for example, video and audio conferences.
Layer 6: Presentation Layer	Layer 6 controls the format or how the information looks on the user's screen. Hypertext Markup Language (HTML), which is used to format web pages and some e-mail messages, is a Layer 6 standard.
Layer 7: Application Layer	Layer 7 includes the application itself plus specialized services such as file transfers or print services. HTTP is a Layer 7 protocol.

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2 Data Centers and IP Private Branch Exchanges

In this chapter:

INTRODUCTION

The desire to improve staff and computing productivity as well as technological advances motivates enterprises to adopt technologies to increase efficiencies across the organization. Organizations are no longer locked into supporting the majority of IT functions in-house. They can outsource them to cloud providers and hosting services (see Chapter 1, "Computing and Enabling Technologies," for more information about cloud computing), leading to savings in energy, staffing, and space requirements. However, this creates pressure on IT directors to demonstrate that applications in the data center can be run as cost-effectively as those operated by cloud providers. CEOs and chief financial officers are aware that public cloud providers' offerings such as Amazon Web Services, Google Apps, and Rackspace Hosting can potentially save money on in-house computing and increase the speed of developing software applications.

IT directors are often called upon to justify operating or developing certain applications in-house as some large enterprises are reluctant to outsource mission-critical core applications. With these pressures in mind, data center managers are emulating efficiencies such as virtualization and centralization to hold down costs. They are also examining and implementing software packages with which they can automate and simplify tasks cost-effectively. By concentrating usage on fewer software packages, costs can be decreased with simplified application support.

The rising energy costs needed to operate the servers, switches, and cooling systems located in data centers create additional pressure on IT directors. This is also stimulating interest in moving applications to the cloud. Although small and midsize organizations have moved many of their applications to the cloud, larger organizations are more cautious, and are either taking a wait-and-see approach or moving noncritical applications such as benefit systems.

Ironically, storage and server virtualization, which reduce space and energy requirements, increase the criticality of server and network reliability. Each physical server and group of storage devices now holds many more files and applications than they had previously. Physical servers also have the added task of running multiple operating systems and many more applications, whereas they had previously run a single operating system with a few applications. In addition, departments that formerly ran their own applications now share centralized applications. These applications might be accessed over either Local Area Networks (LANs) or Wide Area Networks (WANs). The increased use of virtualization can lead to issues with potential downtime: If one server crashes, many more employees lose service; if applications are not available, many more employees are affected. This creates added pressure for reliable, high-speed internal networks and WANs.

These same high-speed LANs and WANs also transmit Voice over Internet Protocol (VoIP) telephone and messaging system traffic. An increasing number of small and mid-sized organizations are moving to cloud-based, hosted telephone systems. The VoIP provider leases telephones to users, but maintains the telephony main processor and adjunct services such as voicemail and conferencing services at external sites. It also hands off voice traffic to carriers that route outgoing and incoming local and long-distance traffic.

After years of stalled adoption, Unified Communications (UC) is now commonly implemented when organizations purchase new IP telephone systems. UC applications integrates with desktop e-mail and other functions such as calendaring and address book applications. This gives users the ability to access voicemail, e-mail, instant messaging, collaboration software, and conferencing from a single interface on their computers. Because IP telephone systems are part of an organization's LAN, integration is simpler than when older-style systems had to be adapted for LAN connections.

The impetus for saving money on travel and technological improvements in desktop videoconferencing has also created interest in and growing use of desktop and group videoconferencing. (Group videoconferencing systems, also referred to as room-type videoconferencing, are commonly deployed in conference rooms.) In addition, the cost to use desktop videoconferencing has dropped, more computers are equipped with video cameras, and the quality has improved. Moreover, including desktop videoconferencing in UC has increased its availability. The fact that video is often transmitted over data networks is a major factor in its convenience and lower usage costs.

NEXT-GENERATION DATA CENTERS: VIRTUALIZATION AND GIGABIT SPEEDS ....

A *data center* is a physical location where an organization's data and voice telephony applications such as e-mail and accounting applications reside. Most data centers have special accommodations for cooling, fire alarms, secure entry, and duplicate power sources. Data centers are located in private and public organizations, at cloud facilities, and in carrier networks.

Next-generation data centers support:

- Gigabit-speed communications between devices
- Virtualization to decrease the number of physical servers required to store files and run applications

Private Clouds within Data Centers

Enterprise and commercial organizations are cautious about moving their data center functions to the cloud. As detailed in Chapter 1, concerns about security, portability, and loss of control over data are the primary factors in their caution. However, IT directors are under pressure from CEOs and CFOs to operate their data centers as efficiently and cost-effectively as cloud providers. For example, when IT departments request money for staff, software, or equipment, top management will likely ask how much cheaper it would be to use a cloud provider. In addition, economic downturns have made organizations careful about spending money. All of these factors, together with technological improvements, are leading the drive to improve operational efficiencies in onsite data centers.

These streamlined data center operations are often termed *private clouds*. One of the best ways for an organization to realize efficiencies is to consolidate into central data centers functions that were previously located in numerous remote offices and department. Centralization and streamlined data center operations are enabled in large part by storage, server, and switch virtualization. Increased speed in data networks is another key impetus to creating private clouds.

Virtualization has made it more cost-effective to centralize applications and storage rather than installing complex applications and their attendant support requirements in individual departments or remote sales and branch offices. High-speed networks utilizing WAN and application acceleration software ensure that people accessing applications remotely from branch offices do not experience delays. Refer to Chapter 1 for an explanation of WAN acceleration and virtualization.

Thus, the term "private cloud" refers to efforts by private companies to provide services to end users in a similar fashion as cloud providers. Their goals, in addition to lowering costs, are to make applications as easy to use as Google's Gmail, for example, and to standardize as much as possible on applications, based on open standards so that user training and support costs are minimized. In addition, by trying to ensure that everyone uses the same version of each software package, all support personnel are "on the same page" and learn only the latest software version. This is now done by Salesforce.com, a web-based application that automates and tracks sales processes. Salesforce.com is owned by Oracle.

Along with standardization and simplification, efforts are underway to automate as many functions as possible. Some software packages streamline help-desk functions by automatically identifying problems. In addition, reducing the number of applications supported improves efficiency because it requires fewer staff members to support a smaller number of applications. Self-service is a key concept in data center automation. When someone requests more computing power or an additional service, chargeback software can charge the employee's department directly upon the employee providing a department or authorization code.

Ramifications of the Private Cloud Model and Unified Entities

Virtualization and efforts to manage data centers as a unified entity have led organizations to seek solutions from vendors whose equipment and software interoperate with computing, switching, and storage systems. To provide this, many of the largest manufacturers are forming alliances with other manufacturers and purchasing companies that offer complementary products.

The use of equipment from the same manufacturers or from manufacturers with collaboration agreements is often referred to as providing a *unified fabric*. Using these services provides a way to manage and diagnose capacity and usage levels, resolve problems, and easily move virtual machines between physical host servers by using a uniform software package. It hopefully also eliminates some of the finger pointing in problem diagnostics, for which technicians are not certain if the problem is in the network or in equipment or software.

Some examples include the following.

- Cisco Systems, Inc., EMC Corporation, and VMware, Inc. (which is owned by EMC) have created a coalition to collaborate on networking, virtualization, and storage equipment.
- Hewlett-Packard (HP) purchased 3Com to expand its switching line. HP also purchased LeftHand to offer customers its virtualized storage arrays, aimed at small and midsize organizations.
- Juniper Networks, Inc., has original equipment manufacturer (OEM) partnerships with Dell and IBM Corporation. An OEM agreement enables vendors to put their own brand name on equipment developed by another manufacturer.

Using Storage Area Networks for Backing Up Computer Files

Storage Area Networks (SANs) are used by organizations to archive backup copies of computer files and databases on specialized computers. The files and databases are stored locally, usually at another one of the organization's sites, or at a site managed by a third party. Thus, in the event of a computer failure or natural disaster, files can be recovered.

Frequently, only the changes in files are backed up nightly by using spare capacity in data lines. As LANs and WANs became more powerful, SANs began using *disk mirroring* to back up files in real time. Disk mirroring is the process of simultaneously writing data to backup and primary servers so that all recent changes are saved and up-to-date, in the event of a failure.

SANs in Data Centers

Additionally, SANs are an integral part of the day-to-day data center operations. Hard drives used for storage have become smaller and more powerful, and are arranged in denser configurations. Small disk drives can be networked together in arrays so that they appear as one disk to the network. These arrays are referred to as Redundant Array of Independent Disks (RAID). The advantage of arrays working together as one device is that if a drive is on the verge of failing, its contents are automatically moved to a functioning drive in the array.

The small size of hard drives has made it possible for organizations to store enormous amounts of data in less space. In data centers, switches connect storage systems to computing systems (applications). In large organizations, a specialized, centralized staff manages the storage.

These SANs communicate with physical servers that run operating systems, which in turn run applications. Virtualization is implemented to decrease server sprawl. (See Chapter 1 for an explanation of virtualization.) In virtualized host physical servers, operating systems are configured to act like SANs that store and run applications rather than databases.

A piece of software called a *hypervisor* allocates server memory, disk space, central processors, and network connections to the applications running on the physical computer. In data centers with only one physical server running applications on virtual machines, the physical server itself is referred to as the SAN.

Switches connected to virtualized physical servers manage communications between the following:

- Applications on physical servers and users that access them
- Physical servers in the data center
- Applications on virtual machines and software applications used to manage and troubleshoot problems within data centers

Switches also run security operations to protect applications from attacks by unauthorized users. There are more switches than physical servers because of the high frequency of communications between physical servers and other devices.

NOTE

In data communications parlance, a *port* is an interface into which a cable is plugged for linking a computer to another device (a laptop to a display), or to link devices to networks.

Storage Capacity on Commodity Servers: A Lower-Cost Approach

An alternative to separate SANs is the use of hard drives on commodity servers to store databases and other files. Storage on commodity servers was pioneered by Google for its cloud offering. It involves the use of sophisticated software to keep track of and identify files stored on the servers. The software applies a unique identifier to each file, which it transmits to the application so that it can be accessed. Because of its cost savings, other cloud providers, including Amazon, use this lower-cost storage method rather than traditional SANs.

Protocols for Communications in LANs

All devices connected to LANs use network protocols to access them and to reach other devices and applications, which might be located on the same floor, on another floor, in another building, or even on another continent. By providing a uniform way to communicate, they simplify the process of linking devices, applications, and networks together. Ethernet and TCP/IP are the most common of these protocols. Fibre Channel is used in SANs.

The Ethernet Open Standard for Network Access

Ethernet is an 802.3 open-standard protocol, approved by the Institute of Electrical and Electronics Engineers (IEEE), a non-profit standards body. Devices such as personal computers and printers use it to access the LAN and to retrieve packets from wired and wireless LANs. Each device on an Ethernet LAN has an address, referred to as its Media Access Control (MAC) address. Switches use the MAC address to send messages to LAN-attached devices.

Ethernet is the first LAN access scheme that was widely adopted. Because it is based on an open standard, it is broadly available to different manufacturers. In the 1980s, departments within companies began to use Ethernet to link their computers together over coaxial cables to share software applications, such as accounting and financial tracking packages as well as printers. The use of the lighter-weight, lower-cost unshielded, twisted-pair (UTP) cabling occurred following the 1990 adoption of new UTP cable standards on LANs. This greatly simplified installing and moving computers on LANs because of the lighter weight and flexibility of UTP cabling.

Ethernet is an *asynchronous* protocol. Asynchronous protocols do not specify a specific start and stop time for each packet of data. All devices connected to the network attempt to send whenever they're ready.

Ethernet's simplicity makes it straightforward to connect equipment to networks. All that's required are computers with Ethernet interfaces (ports) for an Ethernet cable and Ethernet software to link devices to switches in wiring closets. Because of the uncertainty of traffic volume at any given point in time, Ethernet networks are often configured to run at no more than half of their capacity.

Using TCP/IP as a Linking Protocol

Whereas Ethernet is a way for individual packets to access LANs and for computers to retrieve packets from local networks, TCP/IP is used to tie LANs together and to route packets between networks as well as to and from the Internet. As the need arose to tie LANs together for e-mail and file sharing, compatibility between LANs from different manufacturers became a problem. The TCP/IP suite of protocols became a popular choice for overcoming these incompatibilities and for managing the flow of information on LANs.

Routers were developed to send data between individual LANs, and between LANs and the Internet. Routers send packets to individual networks based on their IP address. IP addresses are assigned to individual networks and servers that run software applications.

Fibre Channel in Storage Area Networks

Fibre Channel is a group of open protocols approved by the American National Standards Institute (ANSI). The protocol was designed for the heavy traffic generated in data-intensive networks such as SANs. It is a point-to-point protocol, wherein data is transferred directly from one point (a computer) to another point (perhaps disk storage). Because of its capability to transfer large amounts of data at high speeds, Fibre Channel has traditionally been used in the majority of SANs.

Switches connected to physical servers use Ethernet-dedicated ports that are adapted for Fibre Channel to communicate with SANs. Thus, the physical servers running applications that need access to data and the storage disks containing the organizations' databases can communicate with one another.

Server and Storage Virtualization

Accounts receivable applications are examples of applications that access databases. These applications might need to retrieve vendor-addressing information from a centralized database. However, because the SAN in which the database resides is likely running Fibre Channel, a translation device called a *gateway* is required to translate between the Ethernet switches and the SAN.

The following example demonstrates the chain of communications between applications on virtual machines, SANs, and end-user computers.

1. An enterprise employee issues a request over the Ethernet LAN from his computer to view a training video.
2. The request is sent to a video application on a virtual machine in a physical server.
3. The application issues a request for the video, which is in a database in the data center's SAN.
4. The switch connected to the server on which the application resides forwards the request to the disk in the SAN over one of its Fibre Channel–adapted ports.
5. Once it receives the video, the switch sends it via an Ethernet port to the computer that requested it and connects the employee's computer to the video application.

In the preceding scenario, data centers support and pay for two sets of interfaces: Ethernet, and Fibre Channel ports on each switch and on each server, plus the associated circuit cards and cables for each interface. This is illustrated in Figure 2-1.

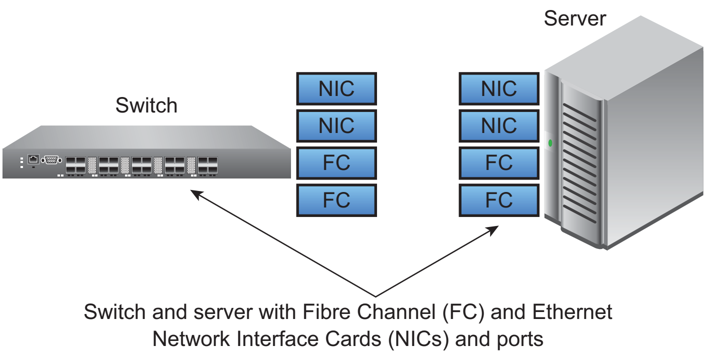

Figure 2-1 Fibre Channel and Ethernet ports in servers and switches.

Virtual Switches Installed on Physical Servers

Virtual switches can be installed as software within host physical servers rather than as stand-alone hardware. This offers the advantage of more tightly integrating applications running on virtual machines with the rest of the data center. With virtual switches, management software identifies each application in the physical server as a separate entity. Thus, it is less complex to troubleshoot problems. The physical server is equipped with Ethernet interfaces for communicating with other Ethernet-connected devices as well as ports adapted to communicate with Fibre Channel interfaces (ports) in SANs.

NOTE *Frames* serve the same function as packets. They surround user data with addressing, error checking, and other protocol-related bits. The term "frame" is used in lower-level protocols, such as Ethernet, which is used for communicating within LANs connected to the same switch in the wiring closet. *Packets* refer to data configured for transmission between LANs and on the Internet by using TCP/IP.

Fibre Channel over Ethernet

The Fibre Channel over Ethernet (FCoE) protocol is an open standard that was approved by ANSI in 2009. It was developed so that Fibre Channel SANs could communicate with 10Gbps Ethernet networks without translating between Ethernet and Fibre Channel protocols. The goal is to simplify structures and communications in data centers. In FCoE, the Ethernet protocol is enhanced with techniques to avoid packet loss in the event of congestion. FCoE currently supports 10Gbps speeds, and higher speeds are planned for the future. Interfaces with FCoE are referred to as Converged Network Adapters (CNAs), which you can see illustrated in Figure 2-2.

FCoE encapsulates the Fibre Channel frame into the Ethernet frame. Ethernet bits surround the beginning and end of the Fibre Channel frame, which is encapsulated within the Ethernet protocol. Ethernet headers are added before the Fibre Channel header; Ethernet end-of-frame and error-checking bits are used at the end of each frame.

The goal in implementing FCoE is to create less complex networks with fewer types of ports to support as well as improve on the utilization of ports. It is hoped that this will be a step toward decreasing the complexity of networks within organizations. If implemented in conjunction with virtual switches and physical servers, it can reduce space, power, and cooling requirements because the same network interfaces (ports) can be used for communications between Ethernet and SANs.

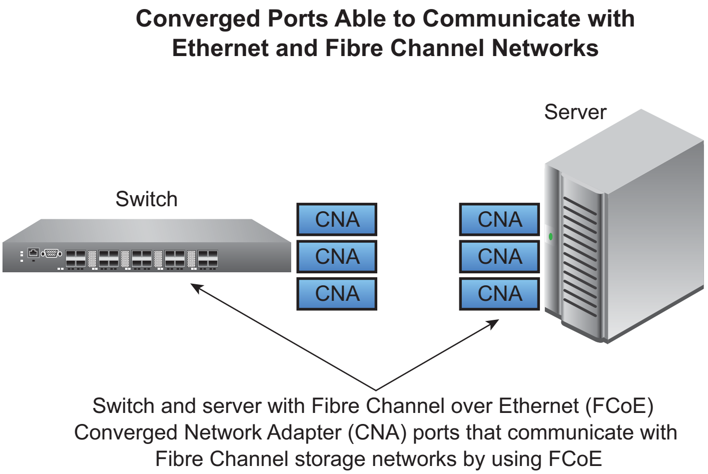

Figure 2-2 *Switches and servers with converged network adapters.*

The Costs and Operational Issues of FCoE

FCoE is in the early stages of implementation, and although it has advantages—particularly for large enterprises—there are organizational and cost issues as well as benefits. As is common with early stages of product introductions, prices are high. In addition, older switches are not always compatible with the protocol, so implementing the protocol might require new hardware.

Moreover, there is a learning curve for staff members. In large data centers, separate groups specialize in and manage storage, and a different group manages and has expertise in networking. However, when FCoE is implemented, the functions of the networking and storage groups overlap, requiring that the groups work together in understanding, implementing, and managing the FCoE services.

Network Operating Systems

LAN Network Operating System (NOS) software is located on specialized computers called file servers in the LAN. A NOS—also referred to simply as the operating system (OS)—defines consistent ways for software to use LAN hardware and for software on computers to interoperate with the LAN. LAN operating system client software is located on each device connected to the LAN. Most operating systems in use today are built on the client-server model.

Clients (PCs) request access to services such as printers, e-mail, and sales applications located on servers. Examples of NOSs include Windows Server 2003, Windows Server 2008, Sun Solaris 10, and Linux. Client software installed on PCs includes Windows XP, Windows 7, and Windows 8.

The Impact of Virtualized Hardware Failure

Because multiple software applications run on each physical server, virtualization increases each physical server's criticality. If one server fails, multiple applications and business processes are disrupted. Moreover, both server and storage virtualization result in the need to centralize more applications, such as collaboration, video and audio conferencing, and accounts payable and accounts receivable software within data centers rather than located in remote departments. Thus, in multi-site organizations, failures affect multiple sites and departments.

Redundancy is a key consideration in organizations where computing is critical for operations. *Hot standby* is one option for redundancy. Hot standby refers to the capability of one piece of equipment to automatically take over the function of a failed unit, without human intervention. One way to achieve this is to cable servers to more than one switch so that if a switch crashes, the server automatically fails over to the backup switch. Another option is to use replication software, which is used in virtualized servers to back up all files to a hot standby location that can handle all computing if the main site crashes, as shown in Figure 2-3. Critical applications can also be run on duplicate physical servers, wherein the redundant server automatically takes over in the event of a failure.

Uptime and continuous operations depend on outside networks as well as internal servers and switches. If a cable to the Internet is cut, service to remote or hosted sites is lost. For this reason, organizations might lease Internet access from more than one carrier with each carrier running its service into a different part of the building to prevent total loss of network access if cables in the same conduit are cut. Alternatively, an organization can lease a wireless broadband access connection to prevent service interruption in the event of a cable failure. (For more information, see Chapter 7, "Mobile and Wi-Fi Networks.")

Environmental Controls in Data Centers

Virtualization has decreased the number of physical servers needed in data centers. However, each physical server requires more cooling due to its more powerful, quad processors that generate more heat than dual or single processors. In addition, electricity costs needed for cooling are increasing dramatically.

Designing cooling, power, and Uninterrupted Power Supply (UPS) systems that distribute power are so complex that organizations often hire consultants to design

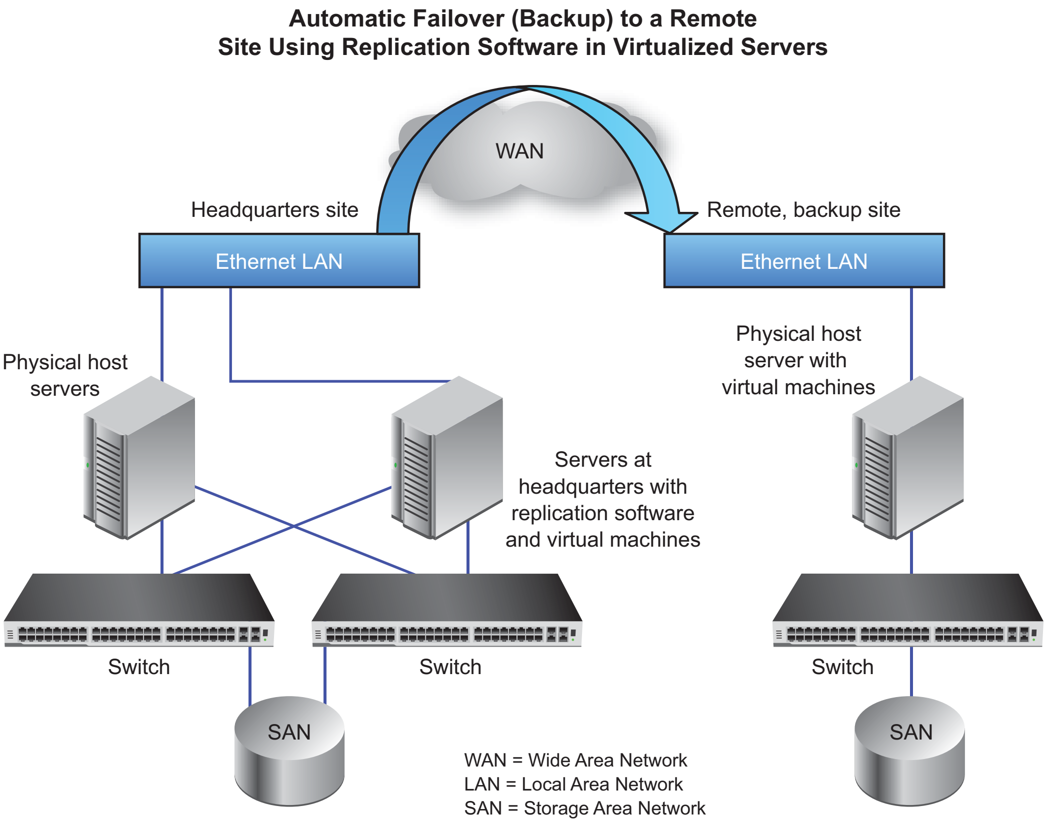

Figure 2-3 *Automatic failover to a remote site.*

cost-effective environmental controls. The number of people in the data center will further impact cooling needs. In addition, there are different cooling requirements for equipment located at the bottom of racks versus equipment located at the top. The type and amount of lighting will also impact cooling requirements. IBM, EMC, and HP are among the companies that offer energy consulting services aimed at designing cost-effective energy and power systems for data centers.

A key task in designing data centers is determining which devices or elements represent single points of failure that have the potential to put the entire data center out of service. Power cuts and interruptions, fire, and natural disasters such as hurricanes all have the potential to shut down computer operations. Human error can also cause failures.

Thus, in addition to saving energy costs, enterprises and carriers with mission-critical data centers must decide where to spend money on redundancy and protection from catastrophic failures. Because loss of a UPS can bring down a data center, many organizations consider redundant UPS service, as well. This can mean two UPS devices connected to the same electrical feed or the more costly option of two electrical feeds, each with its own UPS device. If one electrical cable is cut, the data center will fail over to the other one.

Taking Steps to Ensure Adequate, Lower-Cost Power

In an effort to save money on electricity, some large enterprises have applied for and received permission from the United States Federal Energy Regulatory Commission (FERC) to become wholesale providers of electricity. By doing so, they can purchase bulk supplies of power at low rates. In addition to saving money on power purchases, this ensures that they have an adequate supply of electricity for their own power needs. Examples of companies that have been approved by FERC include Google, Safeway, Inc., Kimberly-Clark Corporation, Alcoa, and Wal-Mart. None of these companies have stated an interest in reselling electricity on a retail basis.

While it's not expected that smaller organizations will follow this route, this does point out the efforts that large, multisite firms will take to ensure an adequate supply of electricity at the lowest possible rates. To further ensure a steady supply of power, companies also purchase power from multiple power generating companies over different power feeds. In addition, electric rates and adequate sources of power often factor into decisions of where to locate data centers.

Taking Advantage of Modular Construction for Data Center Structures

Although the criticality of data centers has increased, some data centers have shrunk in physical size. Virtualization, miniaturization of the hard drives used in storage devices, and the use of cloud and hosting services have resulted in uncertainty about the future floor and rack space requirements of internal data centers. Because small and mid-size organizations have moved applications to the cloud and hosting services, it's not unusual for data centers located in these organizations to have half-empty racks that formerly housed physical servers.

Not only are floor space requirements uncertain, but power requirements are, as well. Thus, data centers that have the potential to grow, but are only equipped for a two- or three-year period, not only save current capital but also have the flexibility to add power or floor space as needed. Modularly constructed data centers have room to expand but only expand for two- to three-year periods. If a number of applications have been outsourced to the cloud during that time, or if the organization shrinks, the organization will not have purchased unneeded services and equipment for its data center.

Managing Users' Computers via Desktop Virtualization

For IT staff members, installing and managing new computers, troubleshooting software, and upgrading software on computers occupies a considerable amount of time. Moreover, ensuring that desktop and laptop computers don't contaminate networks with viruses is a complex and time-consuming task. End users who install unknown programs or inadvertently open e-mail attachments that contain viruses can unwittingly bring computer networks to their knees.

All of these factors plus improvements in desktop virtualization are pushing an interest in desktop virtualization by large enterprises. With desktop virtualization, users have a screen, keyboard, and small connector box in their offices rather than a complete computer. The connector box is tied to a centralized server that runs desktop virtualization software. User desktops are hosted in the central server. When a user turns on his screen, he sees an image of his desktop, complete with icons. This is referred to as thin-client technology because very little intelligence is located at the end user's device. The user's equipment is referred to as the client. Organizations such as Citrix Systems, Inc., Microsoft, and VMware supply desktop virtualization software.

In the past, when desktop virtualization was tested, most organizations that installed it experienced unacceptable delays in accessing centralized files and applications. Improvements have eliminated these delays. However, initial costs for the centralized server and software and end-user devices are inhibiting factors. This is particularly true if laptops or desktop computers are new and not fully depreciated. Another factor inhibiting implementation is the fear that if a remote user wants to work on centralized files, and she is not somewhere with an available broadband connection, productivity gains in centralizing applications and any modifications to the files will be lost.

MANAGING VIRTUALIZATION

Organizations can take advantage of many benefits by implementing virtualization capability in servers and storage networks. They also take on challenges managing them in complex environments.

Managing Memory, CPUs, and Storage in Virtualized Data Centers

Server and storage virtualization have many benefits, including saving money on electricity, heating, and cooling. However, there are challenges in large data centers. One such challenge is managing memory in the host physical servers. Operating systems installed on host servers now have more code and require more memory to operate. IT staff members allocate memory to applications on virtual machines by using VMware's Hypervisor software. Staff members need to monitor applications' memory usage so that servers can be upgraded or applications moved to other hosts if memory in the current host is not adequate. If this isn't done, applications will run slowly and response times on individual user computers will be degraded.

New servers are equipped with quad CPUs—quite literally, four CPU chips on a single host server. However, as the amount of processing needed to run programs grows, even this is not always adequate for the virtual machines installed on them. Programs that have sound and video are "fatter," with more code, which requires additional CPU overhead. It's difficult to estimate under these conditions the amount of CPU power that's required for applications running on virtual machines.

In addition, disk storage is being used up at a faster rate. Users now routinely store MP3 files in their e-mail inboxes. In data centers where user files and e-mail messages are archived, this can deplete spare storage in Storage Area Networks (SANs) at a faster rate than planned. Thus, storage, memory, and processing requirements should be monitored. In large, complex data centers, it can sometimes be easier to monitor and manage single physical servers rather than virtual machines and storage.

In small organizations, managing memory, storage, and CPU usage is not as complex. With only one or two physical servers, it's not as difficult to track and manage resource allocation.

Server Sprawl

Server sprawl is the unchecked proliferation of virtual machines on physical host servers. (Virtual machines are also referred to as *images*.) Managing server sprawl in large data centers is a major challenge. Because it's easier to install applications on virtualized servers, the number of applications can escalate rapidly. Data centers that previously had 1,000 servers with a 1,000 applications can potentially now have eight images per physical server and 8,000 applications to manage. Another cause of server sprawl occurs when an application is upgraded. To test the application before it's upgraded, management creates an image of the application, upgrades the image, and then tests the upgrade on a small group of users before making the upgrade available to all users. However, often the original and the upgraded application are left on the physical server, which further contributes to sprawl. To complicate matters further, if either the original or the upgraded version is moved to a different physical server, it can be difficult to determine that there is a duplicate.

Software to Monitor Virtualized Data Centers

Small data centers with only one or two physical computers holding virtual computers are generally easier to manage than the same data centers with perhaps 20 applications installed on 20 physical servers. However, there is a learning curve for managing numerous physical servers, each running multiple operating systems and applications on virtual computers. It involves keeping track of which physical server each image resides on as well as the application's address. For large data centers, it is often easier to manage physical servers, where each one can be physically observed, than to manage an array of applications on virtual computers.

To do this properly, a good suite of management tools is required. Moreover, because problems can occur in switches, servers, and storage, the best management suites are those that are capable of diagnosing and monitoring all of these areas. Visibility across these three sectors is complicated by the fact that in many data centers, different manufacturers supply the switches, servers, and storage. One solution is to use third-party suites of management software that are capable of monitoring equipment supplied by more than one manufacturer.

However, in economic downturns, organizations are often reluctant to invest in this type of software. New applications critical to operating an organization's core operations have a priority in resource allocation.

A Nonprofit's Experiences with the Cloud

A non-profit organization that works with developing countries has offices in the United States and remote sites around the world. The company's vision is to move as many applications as possible to either hosted sites or cloud providers. With hosting, the customer's own servers are located at the host sites. Several applications including budgeting and payroll have already been outsourced to cloud or hosting sites.

The company is now moving its accounting packages to a hosting facility. These packages will be located on the nonprofit's own server at a hosting site. A software developer will manage the applications. The nonprofit still has in-house applications, including e-mail, and IP phone and voicemail systems. It hasn't moved the phone system and voicemail because it owns the hardware on which these systems reside and has multiyear commitments for the software licenses.

When the organization first moved its budget application to the cloud, there were many snags. Users had problems logging in, they couldn't see department charge codes, and some managers couldn't charge items to their own departments. The application still does not work satisfactorily.

Continued

A major problem is that not all of these remote applications are compatible with their current browser. The non-profit would like to see more standardization in this area. When it moves applications off-site, it moves the database associated with each, as well. Management feels that this creates a simpler configuration than moving just the application.

The IT director feels that the cloud works well for testing and developing new applications, but that it needs to improve. He has heard that many other non-profits are also using cloud-based applications, particularly e-mail. And although the IT department might shrink, it will continue to be needed to manage the switches on the Ethernet LAN. The LAN is critical for accessing and transmitting data on cloud-based applications.

The non-profit uses Cisco's WebEx, which is a web-based audio and video conferencing service that it accesses from user desktops and camera-equipped laptops. Because it is Internet-based, remote staff members can easily access it. However, the IT director would like WebEx to be easier to use and plans to integrate it with the organization's Microsoft Office applications on users' desktops. The WebEx service is also used for collaboration and conferencing, where participants are able to write comments on a "whiteboard."

This is part of its concept of an office without walls, wherein people easily work with staff members in other locations. As part of this concept, more employees, such as new mothers, now work from home and access their files remotely.

LAN Traffic

The volume of LAN traffic has grown exponentially due to powerful computers that are able to handle multimedia traffic. This traffic has a longer duration and shorter pauses between packets for other devices to transmit. This is true whether applications are on desktops, centralized in data centers, or in the cloud, because at some point, data is still transmitted over the LAN to the user. The following are examples.

- Large graphics file attachments such as PowerPoint files.
- Daily backups to databases of entire corporate files.
- Web downloads of long, continuous streams of images, audio, and video files.
- Growth of audio and video conferencing conducted over LANs.
- Voicemail, call center, and voice traffic.

- Access by remote and local employees to applications and personal files on centralized servers and storage devices.
- Web access, during which users typically have four or more pages open concurrently. Each open web page is a *session*, an open communication with packets traveling between the user and the Internet.

BACKBONE AND INDIVIDUAL LOCAL AREA NETWORK STRUCTURES

Most Local Area Networks (LANs) are made up of the *backbone*, which connects wiring closets to the data centers and to other buildings on a campus. It also connects individual LANs on each floor and a data center with centralized applications and equipment for Internet access.

Layer 2 Switches

Devices on LANs, such as PCs, workstations, IP telephones, and printers, are connected to Layer 2 switches, which are typically located in the wiring closet on each floor. Layer 2 switches have a dedicated port for each device connected to them. As a result, they support higher speeds per port than early devices for which each device shared the cable that was run to the wiring closet. Because each device has its own port, messages are not broadcast to all users.

These are considered Layer 2 because they send packets to devices based on their Media Access Control (MAC) address. In contrast, Layer 3 switches and routers send packets to networks and servers based on their IP address. Each device connected to a LAN has a MAC address. Layer 2 switches typically support 1Gbps speeds. The disadvantage is that they represent a single point of failure to the devices connected to them. If the switch crashes, all of the devices connected to them are out of service.

Many Layer 2 switches are an industry-standard 19 inches wide for rack mounting and are typically housed in free-standing equipment racks with horizontally positioned blades. Circuit boards are often referred to as *blades* when they are dense, such as when they have many ports. Switches can be wall-mounted in wiring closets that don't contain other equipment.

Layer 3 Switches (Switching Routers)

Layer 3 switches are faster and more complex to install and maintain than Layer 2 switches. A Layer 3 switch has connections to multiple Layer 2 switches and each port has routing capability. If a link to one switch is down, the Layer 3 switch can send traffic via another link. Layer 3 switches generally are located in wiring closets (connecting hundreds of users) or LAN data centers (connecting many wiring closets or buildings together). Most enterprises use Layer 3 switches to connect traffic on the LAN or campus backbone.

40/100Gbps Ethernet Switches

The Institute of Electrical and Electronics Engineers (IEEE) has approved a 40/100Gbps standard for switches. Manufacturers have made these high-speed devices available. Older Layer 3 switches typically support 10Gbps speeds. However, for organizations that support the very largest web sites, this is actually too slow. To support that level of web site traffic, they network together 10Gbps Ethernet switches or purchase the higher-speed Ethernet switches.

LAN Backbones in Heavy Traffic Areas

LAN backbones are the portions of an organization's internal networks that carry the heaviest amount of traffic. This includes the copper or fiber-optic cabling run between buildings on a campus and the fiber-optic cabling that typically runs between floors within buildings. In multistory buildings, backbone cabling connects switches in wiring closets to Layer 3 backbone switches located in data centers.

The devices that connect internal networks to a carrier's public networks are considered *edge devices*. Routers are defined as edge devices because they connect sites to the Internet via dedicated links, such as T1, T3, and Carrier Gigabit Ethernet services. For more on T1, T3, and Carrier Gigabit Ethernet, see Chapter 5, "Broadband and Wide Area Network Services." In carrier networks, cell phones and smartphones are edge devices that connect users to either the Internet or other mobile devices.

Switch Redundancy in the Backbone

If a backbone switch crashes, it will cause many LAN segments to lose service, not just a single department. Organizations consider a variety of levels of redundancy for Layer 3 switches, including the following.

- Purchase of a separate, duplicate switch that can take over if one fails.
- Installation of redundant power supplies in the switch. (A power supply converts AC power to the low-voltage DC power required by computers.) Switches are inoperable if the power supply fails.

- Installation of redundant CPUs within the switch.
- Installation of redundant blades in the switch.

Using Virtual Local Area Networks for Specialized Treatment

A Virtual Local Area Network (VLAN) comprises devices such as personal computers, physical servers, IP phones, and wireless telephones whose addresses are programmed as a group in switches to give them higher capacity or special privileges, or to segregate them from the rest of the corporate network for higher security. Although they are programmed as a separate LAN and treated like a separate LAN in terms of privileges, they are not necessarily connected to the same switches. Some computers are put into VLANs so that they can access secure files such as healthcare records.

IP telephones that send voice data as packets over networks and wireless LAN devices are often programmed into their own VLANs. These devices allow only certain types of equipment, such as other telephones, to communicate with them.

Access to the Internet via Routers

Routers connect enterprise networks to the Internet, a carrier's network, and other corporate sites, based on the IP address stored in the router's memory. If a LAN-connected device such as a printer or PC is moved from one LAN to another, the router table must be updated or messages will not reach that device. The fact that routers transmit packets by IP networks rather than individual device addresses is one reason they are considered Layer 3 devices. Routers are critical. If they fail, all access to the Internet and other sites is lost. Because of this criticality, organizations typically purchase backup routers. They can balance the traffic between the two routers or keep a backup router on hand, which can be installed quickly in the event of a primary-device failure.

Additional Router Functionality

Beyond simply acting as a connection point to the Internet, routers can provide other functionality, including the following.

- **Firewall** Routers can screen incoming and outgoing traffic.
- **Deep Packet Inspection (DPI)** You can use DPI to manage internal traffic. See Chapter 1 for more information about DPI.

- **Encryption protocols** Routers employ IPsec and other protocols for sending packets over the Internet securely.
- **T1 and T3 multiplexers** See Chapter 5 for more information about T1 and T3.
- **Video Digital Signal Processor (DSP)** This is used for conferencing services.
- **Wi-Fi** An increasingly popular capability for branch and small offices, this allows users to connect wirelessly to the router for Internet access.
- **Session Initiation Protocol (SIP)** SIP support permits trunking for Unified Communications (UC) functions such as presence and instant messaging with other sites and VoIP calls.
- **Quality of Service (QoS)** This prioritizes voice and video in the WAN. Voice and video are assigned tags that classify them with a higher priority than data bits.

These services are located on specialized circuit boards, or *blades*, within the router. In new routers, multiple services can be located on the same blade, which can have more than one processor.

NOTE *Blade servers* hold blades that are arranged vertically and housed in racks in data centers. In contrast to horizontal circuit boards, vertical arrangements such as this conserve space and can share power supplies, fans, and cabling, thus consuming less energy. In addition, applications can be added or removed without taking the server out of service.

IP PRIVATE BRANCH EXCHANGE SYSTEMS FOR INTERNAL USE

IP phone systems operate on servers that use industry-standard operating systems and often open-standardized protocols. They don't require a great deal of space and are considered another application in the data center.

IP for New Systems

When organizations purchase new phone systems, they buy IP-based systems for a number of reasons. Voice services are not as critical for communications because many users rely mostly on electronic messaging. Today, most employees conduct their day-to-day communications by using e-mail and instant messaging. Thus, there is not the level of concern regarding the use of one network (the Local Area Network [LAN]) for both voice and data in the event of a crash. For the most part, voice is used for discussions about complex topics and audio and video conferences. It is also used for time-sensitive purposes such as reporting fires and other emergencies. These outgoing calls can be made on mobile phones.

Whereas some customers still maintain older, traditional-style phone systems, new systems are IP-based. These systems are easier to maintain and can be more easily integrated with all types of conferencing, contact centers, and Unified Communications (UC) systems. Moreover, IP technology has improved and the quality of voice carried on LANs is generally quite good. This is also due to improvements in LAN speeds. In addition, LAN reliability is such that downtime is no longer a concern of any substance.

While the initial cost of many IP telephone systems is no less expensive than older-style phone systems, ongoing support costs are lower. In addition, sharing centralized applications such as voice messaging and contact center services with remote offices is less complex than it was in older systems.

Makers of voice telephone systems such as Avaya, Inc. and Mitel Networks Corporation once dominated the market for telephone systems. However, the advent of IP telephony, wherein voice and data are carried on the same network, presented an opportunity to companies such as Cisco Systems and Microsoft that previously sold only data equipment and software.

Cisco Systems, which had relationships with IT directors and known expertise in data switching, used these assets as leverage to position its IP telephony products. Because IP telephones plug into switches, and IP telephones require Quality of Service (QoS) enabled partly by switches, customers had confidence that the switches and telephones could be made to work together for the QoS levels needed for voice. Prior to Avaya's acquisition of Nortel, Cisco was the leading manufacturer of new IP systems, based upon number of systems sold.

Microsoft is another example of an organization that took advantage of its data offerings and reputation by introducing a Voice over Internet Protocol (VoIP) service. Microsoft's VoIP product, Lync, integrates with its Outlook desktop software. Outlook manages e-mail, address book, and calendar applications so that users can access all of them from a single desktop application. If a user has Lync, she will see telephone icons in Outlook for making, receiving, and managing calls.

Manufacturers of IP-based telephone systems include the following:

- Aastra
- Alcatel-Lucent
- Avaya Communications
- Cisco Systems, Inc.
- Microsoft
- Mitel Networks
- NEC
- Polycom
- ShoreTel, Inc.
- Siemens ICN
- Vertical

Direct and Indirect Channels and Managed Services

Most office telephone systems are sold through distributors and value-added resellers, not by manufacturers directly. However, there are manufacturers that use both direct and indirect sales channels. These manufacturers often have sales personnel that sell directly to large universities and multinational organizations. Distributors are used as an indirect channel for their smaller customers. Distributors include carriers and value-added resellers who, in addition to IP Private Branch Exchanges (PBXs), offer products and services such as data equipment, consulting on data networks, and managed services. Managed services include maintenance and consulting on IP telephone systems and peripherals, Wi-Fi wireless networking equipment, and data networks. Some distributors also act as agents for telephone companies. They place orders for data and voice services with carriers, audit telephone bills for customers, and coordinate resolution of repair problems with carriers. This is attractive to customers who want an organization that can recognize and separate outside network issues from telephone system issues.

A value-added reseller might sell an IP telephony system at below its own cost in anticipation of profits from managed services, ongoing fees for maintenance contracts, and add-on voice and data peripherals such Wi-Fi and videoconferencing systems.

THE TECHNOLOGY BEHIND IP TELEPHONY...........

Converged phone systems use IP technology to convert analog voice signals to digital bits, compress that data, and then bundle the compressed, digitized bits into packets. Data, voice, and video packets often share the same Local-Area Network (LAN) infrastructure as that used for normal data traffic. However, voice and video are not like regular data. They need to be sent in real time. Impairments such as delay and packet loss caused by network congestion are often not noticeable with data traffic. However, these problems noticeably degrade voice and video quality.

Thus, network capacity is critical for sustaining voice quality. Greater LAN capacity and faster Digital Signal Processors (DSPs) as well as protocols for Quality of Service (QoS) enable data networks to carry high-quality voice and video. Even though voice quality is generally good in IP systems, the aforementioned problems can occur. Therefore, packets with voice and video are given priority over packets containing bits that are less time-sensitive, such as e-mail.

Voice QoS and Security

Keeping networks secure is a difficult, ongoing challenge. Security needs to be installed in IP telephony system servers, and in all of the Layer 2 and Layer 3 switches, the routers, and the firewalls. In particular, many IP systems use common protocols. These protocols are wide open in the sense that many hackers know how they work and put a great deal of effort into finding their vulnerabilities.

Organizations use the following to ensure voice quality and security.

- **Adequate capacity** If there is congestion due to inadequate capacity, the network will discard packets and voice quality will be degraded.
- **QoS solutions** Solutions that mark and prioritize voice are important to ensure minimal delays for acceptable voice quality. See the upcoming sections “Assessing Network Quality by Using Voice Quality Measurements” and “Prioritizing Voice and Video on a VLAN” for information about voice quality measurements and Virtual LANs (VLANs).
- **Compression** Compressing and digitizing voice signals impacts quality. For example, the recently developed compression algorithm, Adaptive Multi-Rate Wideband (AMR-WB), based on the G.722.2 standard, is able to compress 16,000 samples of voice per second to lower rates, including 12.65 kilobits per second. At this rate, each voice session uses only 12.65KB of bandwidth, but provides better audio than earlier compression standards,

including G.711, which required more capacity. G.722.2 provides high-definition (HD) voice and is used for some mobile voice traffic.

- **Security against viruses, worms, and distributed Denial of Service (DoS)** Worms are malicious programs that attempt to disrupt normal computer and network operation by duplicating themselves on multiple computers. Worms, which are also known as *bots*, are like viruses except that they are programmed to start infecting computers or other devices on networks at a predetermined future date. In distributed DoS attacks, hackers send millions of simultaneous messages to networks in attempts to disrupt their capability to cope with that level of traffic.
- **Security Monitoring Services** Organizations subscribe to security monitoring services to receive patches that prevent attacks from newly discovered viruses, worms, and distributed DoS attacks.

In addition to the preceding, proxy servers authenticate callers to verify that they are who they say they are before being sent to their destination. *Proxy servers*, located in gateways and firewalls, serve as intermediaries between callers and applications or endpoints, telephones, and other devices connected to the LAN. They are commonly used with Session Initiation Protocol (SIP) for audio and video conferencing. See the section "Session Initiation Protocol in UC" for an explanation of SIP.

Assessing Network Quality by Using Voice Quality Measurements

IT staff members can manage VoIP by using software management tools to assess voice and video quality to analyze the following.

- **Packet loss** This refers to the packets that are dropped when there is network congestion. Packet loss results in uneven voice quality. Voice conversations "break up" when packet loss is too high.
- **Latency** This term refers to delays (in milliseconds) that are incurred when voice packets traverse the network. Latency results in long pauses within conversations, and clipped words.
- **Jitter** Jitter is uneven latency and packet loss, which results in noisy calls that contain pops and clicks or crackling sounds.

- **Echo** This is the annoying effect of hearing your voice repeated, an issue with which so many of us are familiar. It is often caused when voice data is translated from a circuit-switched format to the IP format. This is usually corrected during installation by special echo-canceling software.

Prioritizing Voice and Video on a Virtual Local Area Network

Organizations can program voice telephony as a separate Virtual Local Area Network (VLAN). These "virtual" networks act as separate LANs. Voice systems use components that are programmed together to decrease delay. These components use common protocols and control types of devices that are able to communicate with IP telephones and hold audio and video conferences.

VLANs perform the following special treatment for IP endpoints.

- 802.1P protocols tag voice and multimedia packets to prioritize them for improved availability with less delay. The tag distinguishes voice and video packets. In addition to multimedia, tagging protocols such as 802.1P are used for conferencing services, as well.
- VLANs shield endpoints from hackers by allowing only certain types of packets through firewalls to reach them. This is accomplished by means of policies for firewall logical ports that are dedicated to voice and video traffic. Logical firewall ports are defined in software rather than actual physical ports.

IP PRIVATE BRANCH EXCHANGE ARCHITECTURE....

Internet Protocol Private Branch Exchange (IP PBX) architecture varies somewhat among different manufacturers, but the servers for call processing and gateway functionality are common to all. The gateway converts Voice over Internet Protocol (VoIP) signals to those compatible with the Public Switched Telephone Network (PSTN). These are located in a separate gateway or in a router (see Figure 2-4). In addition, Layer 2 switches transmit calls to other devices connected to the switch and backbone switches.

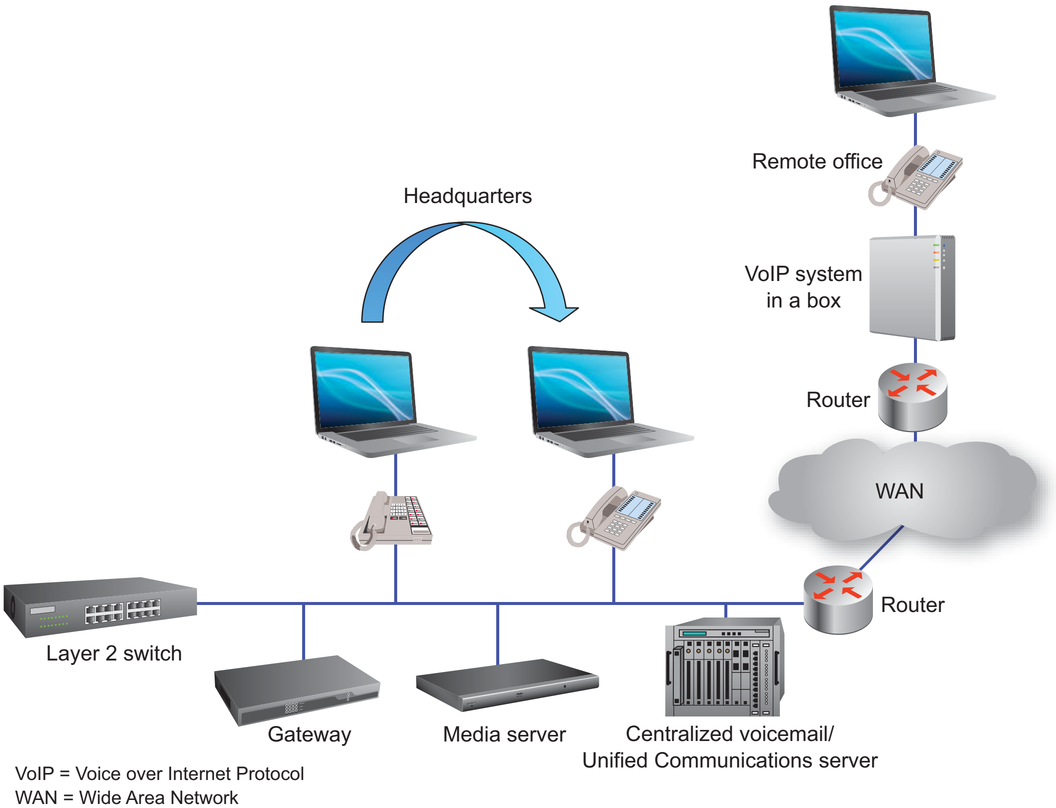

Figure 2-4 An overview of the IP PBX architecture.

Communications Servers and Voice as an Application on the LAN

Communications servers perform call processing, sending instructions on how to set up calls. They send instructions for features such as three-party conferencing, speed dial, and transfer. Communications servers host the software for the system, trunking, and station features. These servers specify the trunks over which international, local, and interstate calls should be routed. They also have lists of user profiles with extension numbers and permissions. Permissions include specifying who is allowed to use particular features such as video conferencing and placing calls to international locations.

Most IP servers run on UNIX, Linux, or Microsoft's Windows operating systems. These operating systems control basic operations, including how information gets on and off the network, how it's organized in memory, and the administrative interface for staff members to monitor and maintain the system. System administration and programming is performed via a computer logged in to the communications server.

In addition to basic voice features and call processing, some communications servers also hold software for specialized applications, such as audio and video conferencing, speech recognition, contact centers, voicemail, and Unified Communications (UC) systems. In other instances, these applications might be on separate application servers. Whether they reside on separate servers or in the communications server, any device connected to the corporate LAN—even those at remote locations—can be given permission in the communications server to access these applications.

Redundant Communications Servers for Backup

Many IP phone systems are equipped with two communications servers for redundancy, in case the main server crashes. If the primary server goes down, the system will automatically fail over to the backup and continue to process calls. In addition, communications servers at different sites can provide mutual redundancy. If the server at one site fails, traffic is sent over the data network to the backup site. This assumes that the link to the remote site has adequate capacity to support the additional traffic. If the entire network fails at one site, the telephone company would have to be notified to forward calls to the backup location.

Media Gateways, Protocol Translation, and Signaling

Media gateways contain Digital Signal Processors (DSPs) that compress voice data to make it smaller and more efficient to transmit. DSPs also convert analog voice signals to digital, and vice versa. They then bundle the digital voice signals into packets compatible with LANs. In addition, media gateways include circuit packs with ports for connections to traditional circuit-switched analog and T1 trunks.

Media gateways are responsible for managing some security, monitoring call quality, detecting and transmitting off-hook conditions, and handling touch-tone, dial tone, busy signal, and ring-no-answer conditions. Media gateways transmit signals for VoIP such as ringing, call setup, and touch-tone in separate channels from voice calls.

Analog Ports and Connections to the PSTN in Media Gateways

Media gateways also contain ports for analog telephones. Analog telephones, which have similar electronics as older home telephones, are not compatible with IP networks.

Analog ports are usually used for two functions: fax machines, and backup in the event of a failure. Some organizations have a backup analog phone for their central operator. If the LAN or the IP telephone systems fail, the organization will still be able to receive incoming calls.

NOTE In IP telephone systems, the gateways are connected to the public telephone network and the DSPs perform the IP-to-circuit-switched conversions to make IP telephone system calls compatible with the PSTN. This conversion is not required for calls that bypass the public network and are transmitted over data networks.

Connecting IP Telephones to Layer 2 Switches

On IP-based systems, multifeatured IP telephones are connected to ports in Layer 2 switches on LANs. Computers and phones often share the same jack and cabling with the Layer 2 switch. In this configuration, the user's personal computer is plugged into a data outlet on the back of the telephone, and the telephone is plugged into the nearest RJ45 data jack. (IP telephones are often referred to as endpoints, a term for items such as PCs and printers connected to LANs.)

NOTE RJ45 is the designation for a type of jack into which data devices plug to connect to networks.

For greater redundancy and to create a dedicated path to the Layer 2 switch, the PC and telephone can each use a separate RJ45 jack, cabling, and port on the Layer 2 switch. This requires additional hardware in the switch and an extra cable run from the telephone to the switch. In either case, voice, video, and data share the fiber-optic cabling and ports on Layer 3 switches that transmit traffic between floors and buildings. This is the enterprise backbone.

Central Power Distribution and Backup via Power over Ethernet

Every IP telephone needs its own source of electrical power, unless it's connected to a PC's USB port. To avoid the expense and labor of providing local electricity to each phone at installation, organizations can power them via the Layer 2 switch to which the they are connected. This ensures that all phones are connected to a UPS to survive power surges and interruptions. Common power sources and backup also avoid the problem of ensuring that each phone is near an electrical outlet, is plugged in, and has an electrical cord.

To bring power to groups of endpoints, organizations use 802.3af, the IEEE standard known as Power over Ethernet (PoE) that defines how power can be carried from the Layer 2 switch to the IP telephone by using the same cabling that transmits voice and data. Battery backups and generators are deployed in wiring closets where switches support mission-critical telephones or attendant consoles. PoE is also used to power corporate wireless Wi-Fi antennas and base stations. (See Chapter 7 for more information about corporate wireless networks.)

IP Telephones Connected to USB Ports on PCs

In addition to connecting IP devices to RJ45 ports, another option is to connect them to USB interfaces on PCs. There are now IP phones on the market that connect directly to USB ports. One of the benefits of this is that the IP phone uses the PC's electric power. Thus, if the computer has backup power, in the event of a power outage the VoIP device is also backed up. Separate power in the form of either a local outlet or PoE is not required.

Connecting to Branch Offices in a Centralized Services Environment

The ability to connect IP telephone systems to one another over existing data networks is a major motivating purchasing factor. In addition to carrying packetized voice, these networks carry signals for centralized voicemail, UC systems, and contact center applications. Contact center signals might indicate that all agents are busy and that calls should be sent to another site. Signals can also indicate the level of traffic at sites so that calls are distributed to alternate sites based on traffic volumes or the number of agents logged in to the system.

Often, customers with private lines or Multi-Protocol Label Switching (MPLS) networks between their locations use these connections for IP voice and video as well as data. (MPLS networks connect locations together via carriers' private data networks; for more information, see Chapter 5.) Customer calls answered in a central location can be transferred over these data links along with data traffic.

The most important issue in extending IP and video between sites is ensuring that the links between locations are engineered with enough capacity to support voice and video and that Quality of Service (QoS) is implemented. The data connections are often upgraded for more capacity to handle voice traffic. The upgrade is less costly than separate per-site links for voice and individual voicemail and contact center systems.

Combining voice, video, and data traffic between sites has resulted in cost savings on long-distance fees. This is particularly true for organizations with international locations because data lines and calling rates are higher between intercontinental sites. Worldwide headquarters might be located in London, whereas regional headquarters are in the United States. They usually use managed network services such as MPLS, which can provide QoS for voice. These MPLS services are also used to carry videoconferencing signals between sites. Small and midsize organizations might use lower cost options such as Skype for international voice and video calls.

IP Telephony for Small Organizations and Branch Offices: A System in a Box

IP telephone systems designed for small to midsize businesses have almost all of the features and functionality of their large-enterprise cousins, including provisions for redundant key components. However, because they support fewer users, in many systems, the server and gateway components fit into a single rack-mountable device or small cabinet. Cisco Systems' diminutive IP PBX fits inside a router.

When IP telephone systems are installed in small branch offices, the branch sometimes routes all of its outgoing calls through headquarters by using a Wide Area Network (WAN) link and receives incoming calls through its own local phone lines. In addition, voicemail, contact center, and UC software are usually located at the headquarters site.

The remote system site often has backup outgoing lines in case the link to headquarters is down. If this occurs, the system will automatically fail over to local telephone lines for outgoing calls. If there is no local backup, callers will need to depend on their mobile phones.

Softphones and Portability

A *softphone* is software with which people can use their computer to make telephone calls (see Figure 2-5). For privacy and noise abatement, they usually use headsets. Features such as hold buttons, caller ID, and message waiting alerts appear on their PC screen. Savings on telephone hardware and increased mobility for users are among the advantages of softphones. If the softphone is on a laptop, staff members can use the softphone anywhere on the corporate network or remotely if remote access is enabled. Mobile employees such as salespeople often use hardware-based phones at the office and softphones when they work from hotels or home offices.

Many manufacturers integrate softphones with office software such as Microsoft Outlook so that they have access to collaboration software, instant messaging,

Figure 2-5 *An Avaya integrated tablet computer for video and audio conferencing, Internet browsing, email, instant messaging, VoIP phone calls, and collaboration. (Courtesy Avaya)*

calendars, address books, and presence indicators from the same interface. Instant messaging is the ability to exchange e-mail in near-real time without typing in an address. Users merely select an icon representing the individual within the community of users to whom the message is intended, type a message, and then click a submit button. Presence indicators let users know when someone within their community is available for real-time or near-real-time messaging. Users can click icons in their e-mail software to indicate their availability.

With collaborative software, users can all look at the same file on their individual PC or tablet screens while on an audio conference call or simply speaking together on the telephone. The softphone can also contain or link to corporate directories.

Mobility and Single-Number Service

Many telephone systems offer a feature by which calls to desk phones also ring cell phones so that employees can receive workplace calls, even when they are out of the office. In essence, the mobile devices become an extension of the telephone system. Using this feature, callers can reach staff members—perhaps a sales representative who is out on the road—by dialing the same number as the office phone. They don't have to try two numbers or know when the person is out of the office. When the desk phone is called, both the cell phone and the desk phone ring. The displays on the cell phone and the desk phone show the phone number and name of the calling party, if that service is available from the carrier. If the person to whom the call is directed does not answer, the call is forwarded to the telephone system's voicemail.

Session Initiation Protocol–Compatible Trunks

Session Initiation Protocol (SIP) signaling is a key protocol for connecting IP networks together. It is also used to connect enterprise locations with data networks for voice calling. Signaling systems used in office phone systems need to be compatible with signals used in a carrier's network if voice calls are to be sent over data links. This is so that the equipment can interpret addressing signals, ringing signals, and busy signals sent by office IP PBXs, and vice versa.

Without this compatibility, organizations with IP telephone systems need to support two different sets of trunks, one set for voice and another set for data. Or they can use a gateway to translate their IP non-SIP calls to SIP. (Trunks are used to carry voice and data on public networks.) Without SIP there are extra costs and long-distance fees for gateways, and voice quality is impaired. The signal's quality is impaired when converting VoIP to formats compatible with SIP data networks when they are sent, and converting them back to VoIP when they are received. Impairment results because compression does not re-create voice in exactly the same format when it's decompressed, and vice versa. Thus, its quality is degraded every time voice data is converted.

Because not all IP telephone systems are SIP compatible, they are not all able to share data links for voice traffic without using gateways. In addition, the telephone company that carries the traffic must use SIP-compatible signaling, as well. Most providers now offer SIP-compatible trunks.

The Demarcation Point at Which Telephone Companies Wire Trunks

The local telephone company brings telephone lines into buildings and wires them to interfaces. The interface is called a *jack* or a *punch-down block*. Each outside line is punched down (wired) to the connecting block. *RJ11c* jacks connect one line. The RJ stands for *registered jack*. These are the jacks found in most homes. The *RJ21x*, which holds 25 lines, is the interface to which local telephone companies wire multiple, outside lines in businesses. The RJ21x jack is a point from which telephone lines and trunks can be tested. For instance, if there is a question with regard to where a problem lies, the telephone company can test its trunk to the RJ21x jack, and the equipment vendor can test service between the equipment or router and the interface. The RJ21x jack is the demarcation point between the telephone company line and the inside wiring. Figure 2-6 illustrates a demarcation point.

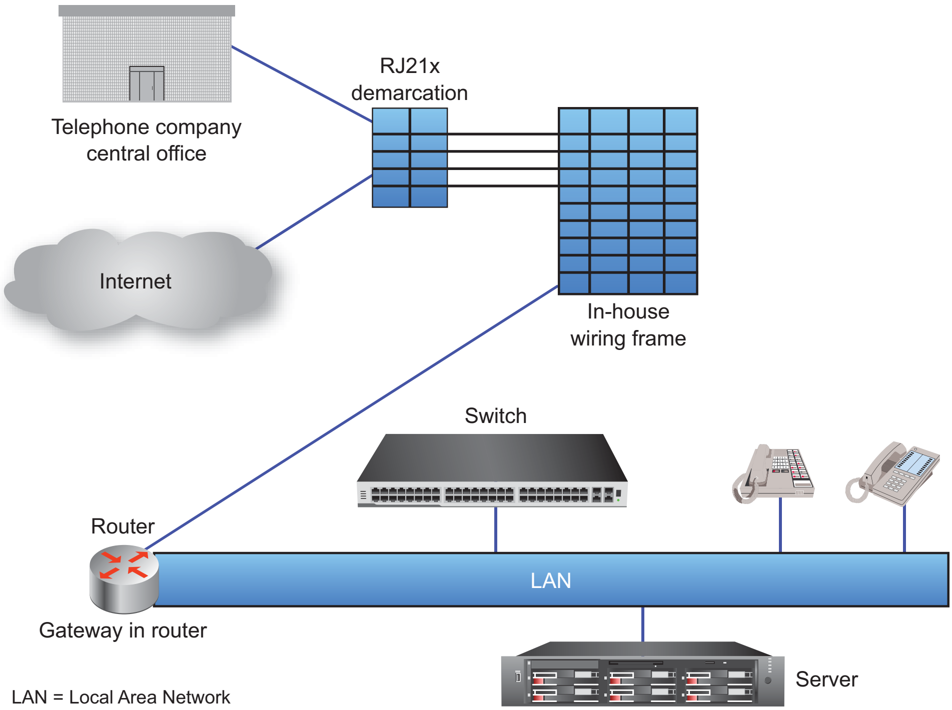

Figure 2-6 *The demarcation point to which outside trunks are wired.*

Individual T1 lines terminate at data jacks (RJ48 jacks), and T3 lines terminate on 75 ohm connectors. These are both at the customer premises, and they are the points at which telephone companies test the T1 and T3 lines if there is an outage. T1 is a high-speed line capable of carrying 24 switched voice lines or a mix of voice and data traffic. A T3 line is equivalent to 48 T1 trunks: 672 voice channels or a mix of voice and data.

Direct Inward Dialing

Direct Inward Dialing (DID) is a feature that routes incoming calls directly to a telephone system extension without operator intervention. DID traffic can be carried on existing T1 trunks used for incoming and outgoing voice calls and on SIP-type trunks carrying voice and data traffic.

As Figure 2-7 illustrates, DID service is made up of "software" telephone numbers. Each number is not assigned a specific trunk; rather, a few hundred DID numbers

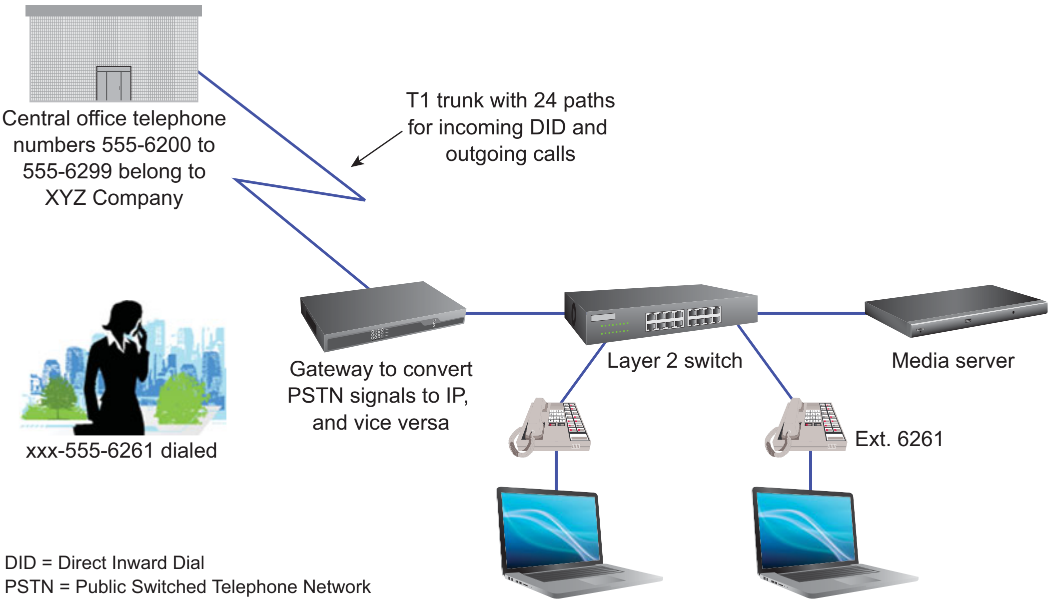

Figure 2-7 *DID soft numbers pointed to an organization's circuits.*

are able to share 24 T1 slots (paths). When DID calls reach a specific slot, the carrier's switching equipment in the central office looks at the digits dialed and identifies the call as belonging to a particular organization. The central office passes the last three or four digits of the dialed number to the organization's telephone system. The onsite telephone system reads the digits and sends the call directly to the correct telephone.

In the case of a T1 failure, calls can be routed on backup individual analog or T1 lines.

Circuit-Switched Proprietary PBXs

A PBX is an older-type telephone system that uses circuit switching. They are also referred to as proprietary PBXs. *Circuit switching* saves a path for each voice conversation. Although these types of systems are no longer manufactured, many are still in use. Each PBX manufacturer uses proprietary signaling to link telephone and trunk lines to the CPU. Features and peripherals such as contact center software also operate on proprietary signaling. In PBXs that support a single building, the components are generally housed in one cabinet. The main components of a proprietary PBX are the CPU and circuit packs for dial tone, touch-tone, and other signals. Other ports connect to trunks, individual telephones, and voicemail.

VALUE-ADDED APPLICATIONS FOR TELEPHONE SYSTEMS ....

The following value-added services add functionality to telephone systems. Unified Communications (UC) adds efficiency by combining voicemail, e-mail, instant messaging, audio and desktop video conferencing, and presence to a single mailbox. Contact centers manage large numbers of incoming and outgoing telephone calls, faxes, and e-mail messages. Voice response units enable callers to enter and access computer information. UC applications are available on IP-wired phones as well as mobile devices.

Integrating Conferencing, Voicemail, Instant Messaging, and E-Mail through UC

UC systems are optional features of voicemail systems. They provide the capability to retrieve e-mail and voicemail messages from a single device such as a PC or a touch-tone telephone. Additionally, they contain presence indicators that show the availability of people in their group. Figure 2-8 depicts a UC inbox that is part of Microsoft Lync. Many UC systems offer audio and video conferencing capability from users' computers.

An important advantage of UC systems is the ability of people who travel to have the convenience of checking only one source for messages and sharing information with others via audio and video conferencing. Retrieving messages from PCs, tablets,

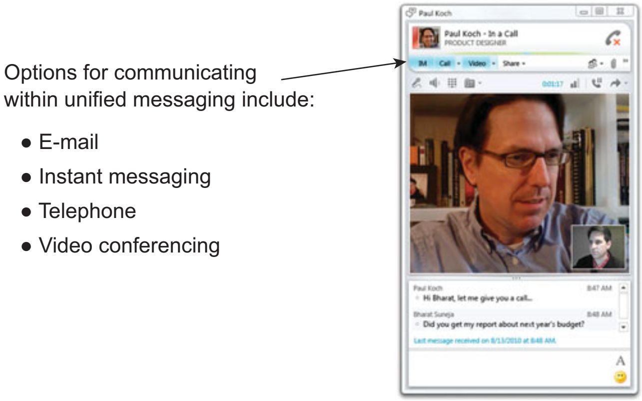

Figure 2-8 *An example of a Unified Communications (UC) system application. (Used with permission of Microsoft.)*

and smartphones also affords users the ability to prioritize messages and listen to the most important ones first. It eliminates the need to hear all voicemail messages before getting to the critical ones.

When users access messages from a touch-tone phone, text-to-speech software converts e-mail to speech for callers and reads their e-mail messages to them. Employees access messages through e-mail software on their PCs or remotely on their mobile devices. UC systems need to be compatible with e-mail programs such as Microsoft Exchange and Lotus Notes. Systems typically also support e-mail retrieval from within browsers so that remote workers can retrieve messages from their PC and listen to them through the PC's speaker. IP PBX providers supply the majority of UC systems. This gives customers single-source support for their phone and messaging systems.

The Declining Use and Criticality of Voicemail

Voicemail use is declining. This is due in large part to increasing dependence on e-mail and instant messaging and faster responses to e-mail as a result of its integration on tablet computers and smartphones such as the BlackBerry and Apple iPhone. Voicemail for mobile services is also declining because more people use text messaging. Most large systems that support multiple locations are on stand-alone or virtual servers. However, small systems are sometimes integrated as cards in a telephone system or on the same server as the VoIP system.

Using Automated Attendants to Answer Phones

Automated attendants are used as adjuncts to—or in some cases substitutes for—company operators. An automated attendant is programmed to answer all calls, certain calls to particular telephone lines or departments, or after-hours calls. Here is a classic example:

> *Thank you for calling ABC Company. If you know your party's extension, you may dial it now. For sales, press 1. For customer service, press 2.*

Automated attendants are now standard software features of voicemail systems. However, they were first used in the 1980s, before the advent of voicemail. Automated attendants were an important first step in automating the ability of callers to reach high-traffic departments. They also provided a way for callers to reach people outside of normal business hours, or when a live operator was not available.

Poorly scripted, confusing, and overly long automated attendants tend to be a source of frustration for callers. Another source is the inability in some organizations to speak with a live operator. In these organizations, when callers press 0, their call is sent to a "general delivery mailbox," and any messages left often result in no return call. In some other instances, pressing 0 does nothing except trigger the initial confusing menu to be replayed.

Remote and Desktop Audio and Video Conferencing

Many Unified Communications (UC) packages include desktop video and audio conferencing capabilities. These require software clients on each personal computer and a server for the software. The software can be either in the communications server used for the main telephone system or in a separate server along with the UC applications. Often, as is the case with Microsoft and Cisco, the application itself is located on the Internet. Participants in audio conferences with access to collaboration software can also illustrate ideas by using PowerPoint or other types of documents. They can edit as well as view the documents, jointly.

As opposed to room-type video conferencing, which is intended for group meetings that must be planned and scheduled ahead of time, desktop-enabled video conferencing can be spontaneous because the meeting is often between two people. Those included in a voice call can enable video, on the spur of the moment. Figure 2-9 presents an example of video conferencing on a personal computer.

Using video conferencing capabilities such as this, co-workers with video cameras and UC-licensed PCs can work together on a more personal level. Another advantage is that staff members who have camera-equipped laptops can take advantage of the same communications capability away from the office as they do in their office.

In addition to the use of licensed video conferencing software, companies now routinely use Skype for audio and video conferencing because of its low cost (or often no cost) and ubiquity. Universal availability is an important characteristic when you're attempting to use video conferencing with people outside of your own organization.

The following is a quote from an anonymous consultant based in the United States:

> *So, now instead of me having to fly to Thailand for a two-hour meeting with my development team, or having to travel to Newcastle, England, in order to have a three-hour requirements review session, my office's network is powerful enough to let me do all of this from my desk via a high-resolution and low-latency video conference using WebEx or Skype, for basically no cost above the cost my company already pays for its network. I can tell you that this has allowed me to do great work quicker and more effectively.*

Desktop Video Conferencing in Unified Communications

Users access a single Unified Communications application that includes the following:

- Telephony features
- Instant messaging
- Employee directories with presence indicators
- Video communications
- Unified messaging with e-mail and voicemail in the same inbox
- conferencing and collaboration with desktop files sharing
- Microsoft Outlook integration with presence indicators

Figure 2-9 Video conferencing and other capabilities in Unified Communications (UC). (Courtesy ShoreTel)

> *In the past, I would have to set aside three days to fly to Europe simply for the purposes of conducting a single meeting that I couldn't conduct over the phone, because it required mine and my client's visual aids in order to effectively communicate the subject matter. Now, I'm able to conduct these meetings without the additional travel time, as if the person were sitting right next to me, saving me money and time—two of my favorite things!*

These desktop video capabilities are now integrated in UC services in many telephone systems.

Session Initiation Protocol in UC

Session Initiation Protocol (SIP) is a signaling standard made up of a number of protocols that define a uniform way to connect IP telephone systems to data networks, set up phone calls, audio and video conferences, and configure features on phones so that telephones from different manufacturers interact as designed.

SIP is also important in UC because it recognizes signals from devices, indicating their state. It can detect whether a user is on a telephone call or whether she is logged in to e-mail. SIP uses these presence indicators to tie these applications together. A presence indicator informs a sender as to whether the person she wishes to contact is available, busy, or not available, before she sends an e-mail or instant message.

Group Video Conferencing in Private and Public Conference Rooms

Room-size video conferencing systems have long been touted as a way to cut down on travel and improve communication between remote offices, business partners, and customers. However, not all room-size systems have been adopted successfully.

Impediments to Room-Size Video Acceptance

Sometimes, acceptance and use of room-sized systems can probably best be described as disappointing. These less-than-successful implementations are examples of how technology alone does not guarantee adoption. Also vital are ease of use and training.

The following are some other reasons for low usage.

- Lack of Quality of Service (QoS) in the network, resulting in poor video and audio quality.
- Insufficient bandwidth (capacity), also resulting in poor-quality video.
- A combination of inadequate user training and video systems that are difficult to set up. Participants often do not know how to set up the conference or share documents or graphics with remote participants.
- Poor camera use, such that the distant participants' heads are indistinguishable from one another or whose expressions are not clearly visible.

The Growing Interest in Group Video Conferencing

Newer video equipment that is easier to use, provides higher-quality resolution, and operates on IP networks has resolved some of these problems. The use of public rooms and carriers' managed services for video conferences can also lessen problems. Moreover, improved wide area networks (WANs) and specially designed conference rooms, in combination with economic factors, together with technological improvements in video, have sparked renewed interest in all types of conferencing.

A number of additional factors are raising the interest of many organizations in using group video conferencing for meetings. These include saving money on travel; speeding up projects and decision making by making it easier for groups to discuss issues in real time; interactive modes; and people's positive experiences with residential desktop video services, such as those offered by Google and Skype. When employees travel with camera-equipped laptops, they often take advantage of formerly residential video offerings and are aware of their benefits. Lastly, the possibility of worldwide epidemics has increased the desire among organizations to use alternative ways to conduct business with distant customers and offices, without the need to travel.

Telepresence: Video Conferencing in High Definition

The term “telepresence” refers to group video conferencing systems that transmit high-definition video signals. Rooms designed specifically for telepresence contain furniture and have specially configured lighting to enhance the video experience for users. Seating at the conference table might be arranged so that all of the chairs face the video screens. In addition, rather than just containing one video monitor, these rooms have a wall of either three large, flat-panel monitors or, less often, an entire wall-size monitor. Viewing life-size images of remote co-workers, customers, or business partners in high resolution imparts the feeling of actually being in the same room with them.

New telepresence systems often are integrated with UC systems such as Microsoft Office Communications Server. They make it easier to integrate collaboration capabilities, such that people in the meeting view the same documents and can edit them, as well. Systems on the IP LAN often have lower transmission costs and, more important, if they use a common signaling protocol such as SIP and H.323, they can hold conferences with organizations outside of their own company, with colleagues who might be using another manufacturer’s system. Other capabilities in H.264 can overcome some deficiencies in IP networks, assuring a higher quality of video.

Organizations that want to try telepresence before purchasing a system or use it without investing in hardware have the option of renting public systems by the hour. These public facilities are located in certain hotel chains and executive office suites in managed office buildings that rent out furnished office space. Additionally, organizations with a large network of telepresence systems can hire outside firms to manage the systems for them. Manufacturers of telepresence systems include Polycom, Inc., Tandberg (part of Cisco Systems), and Vidyo, Inc.

Using Hosted-IP PBX Services

As its name suggests, hosted-IP PBX services relieve an organization of the burden of maintaining the hardware and software for a phone system and Unified Communications (UC) and moves it all instead to either a carrier’s or provider’s site. This solution is more attractive to small and midsize organizations that do not want to commit to purchasing and maintaining VoIP hardware. Some hosted IP providers also provide e-mail and Internet access.

Customers that use a hosted IP PBX service are connected to their system via high-speed network connections. These network connections also transmit busy signals and ring tones between the provider and the customer's handsets. The connection also supports Internet access and e-mail traffic.

Depending on their provider, IP telephones are either installed by the provider's technicians or shipped to customers. Remote employees access the service from their PC or mobile handset. In addition, users have PC-based graphical web interfaces for UC and other features, including the following:

- Audio conferencing activated from the PC
- Integrated mailboxes on PCs with access to voicemail, e-mail, and fax messages
- Instant messaging with graphical indications of users' availability
- Collaboration for working jointly with employees on shared documents
- Contact center software
- Offsite call forwarding to mobile devices

As with onsite telephone systems, voice security and protection from hackers depend on LAN capabilities. These capabilities include data-grade cabling, switches, and routers capable of prioritizing voice and proper security precautions.

Hosted VoIP systems are attractive to smaller companies that might not have in-house expertise to manage e-mail, UC, and IP telephony. These companies might also be uncertain about their future growth. In addition, hosted systems provide disaster recovery and portability. If the customer loses electricity or their LAN crashes, they can access their e-mail and telephony functions remotely.

VoIP hosting providers include 8x8, Inc., PingTone, and MegaPath, as well as telephone companies and cable providers such as Cablevision Systems and Cox Communications.

Managing Customer Relationships by Using Contact Centers

Contact centers are groups of agents created to handle incoming and outgoing sales, web queries, credit and collections, and customer service queries. Contact centers consist of software on servers that is used to manage incoming and outgoing communications with agents, particularly when there are more calls and other messages than there are people to respond to them. Importantly, contact centers provide statistics on utilization of agents, telecommunications lines, and numbers of e-mail and chats.

The main theory behind grouping agents into "pools" is that large groups of agents can handle more calls than the same number of agents organized into small groups, without overflow of calls between groups. This is analogous to the practice of the United States Post Office of using one long line for postal clerks rather than an individual line for each. With one line for all postal workers, a clerk will be available more quickly from the pool and the same number of clerks will help more people within a given amount of time than by forming separate lines for each clerk.

Contact centers route incoming calls to the agent that has been idle the longest within the appropriate agent group, based on the telephone number dialed or by the customer's account or telephone number. If all agents are busy, the contact center shunts the call to a queue, routes the call to an alternate group of agents, or gives the caller the option to leave a voicemail message.

Callers to contact centers can recognize when they reach one if they hear a message such as the following:

Please hold, and the next available agent will take your call.

Virtual and Dispersed Contact Centers

Agents using the same contact center software can be located in other cities or countries. The software distributes calls based on criteria such as time of day or level of traffic. In addition, agents can work from home via their broadband connection and remotely log in to the contact center system, which then routes calls and messages to them. These are called *virtual call centers*. Many firms establish virtual call centers to save on real estate, furniture, and utility expenses.

Contact center systems are offered by almost all VoIP manufacturers as well as providers such as software developer Aspect which offers it independently of the telephone system.

Contact Center Staffing and Self-Service Transactions

Contact centers are under increasing pressure to increase staff productivity, justify the number of agents hired, and improve the quality of customer service to attract and retain customers. Initially companies in the United States and Europe outsourced their centers to Latin America, India, the Philippines, and other countries with lower labor rates. Many of these companies have now closed or cut back on staffing levels in these remote areas, as well. It's a particular challenge to improve customer service when cutting labor expenses by using fewer agents.

To respond to customers without adding staff members, companies are deploying technologies, such as automatic and written responses to e-mail, speech recognition, web-based sales, online forums, and chats. The practice of customers completing transactions without speaking with an agent is referred to as *self-service*. Some companies operate their sales function almost entirely on the Web. And, of course, Amazon and Dell built their entire business models around the Web.

Many of these web-based businesses are well regarded for their customer service, even though they don't actually involve any human contact. Moreover, many consumers prefer self-service on the Web over having to listening to long, automated menus and waiting in phone queues.

Others conduct business mainly on the Web but do have provisions for live help. For example, direct sales of Google's Android-based Nexus One phone was initially handled entirely on the Web. However, the company formed a live contact center after numerous complaints began to appear in its online forum.

Contact Center Statistics

Reports on the real-time status of calls and electronic messages are the lifeblood of a contact center and are closely monitored by management. Management then uses these statistics to plan network design and analyze staffing requirements. Statistics are also used as an aid in improving web site design by alerting organizations to the most frequently asked questions. These issues can then be more fully clarified on the web site or via automated e-mail messages designed to explain common procedures for fixing or analyzing software issues.

Statistics are organized into reports that provide real-time and historical data on incoming and outgoing calls and agents' usage on individual trunks so that managers will know if they have the correct number of lines. Reports also indicate the number of calls and web hits associated with each toll-free number and web advertisement so that response rates generated by ad campaigns can be analyzed. They additionally alert supervisors to unusually high or low call volumes so that staffing can be adjusted accordingly.

Making Information Accessible by Using Customer Relationship Management

Customer relationship management (CRM) is a customer-centric strategy that aims to make information such as customers' transaction histories accessible across the entire organization. CRM can comprise many elements including sales automation with automated proposals and brochures available to representatives. CRM also includes marketing tools that track the impact of direct mail, e-mail, and Internet-based campaigns. In addition, customer service with links to billing, payment status, purchase histories, open issues, and universal queues are considered part of CRM. The largest providers of CRM software are Oracle, SAP, and Siebel Systems.

Managing E-mail, Chat, and Inbound and Outbound Telephone Calls via Universal Queues

Universal queues provide contact centers with one integrated queue and management report as well as the ability to respond to and manage customer contacts in the form of e-mail, telephone calls, and chat. Figure 2-10 illustrates a configuration that uses queue management software linked to e-mail servers and contact centers. Using UC and contact center software from one vendor allows enterprises to manage and analyze service levels by using one set of reports. Real-time and historical reports monitor and track both calling and response times. If they are integrated with back-office CRM systems, they can track revenue per transaction.

It also enables contact center agents to use presence indicators to locate available experts working outside of the contact center. In a telephone interview, Bernard Gutnick, senior director of Product Marketing for ShoreTel, states:

> *We're seeing more deployments where contact center agents are able to leverage presence indicators for staff outside of the contact center, to address customer concerns in less time. For example, an agent can see if a subject-matter expert on a certain topic is available, send an instant message with a specific question, and respond to the customer's inquiry quickly and accurately.*

E-mail Response Management Software

E-mail response management software is another tool for increasing self-service. It can be used independently or as part of universal queue software. E-mail response management software installed on an organization's servers routes e-mail messages to agents by topic, subject, and content. If appropriate, the software can automatically respond to the e-mail. Natural language software for written language is capable of interpreting and extracting concepts in e-mail messages. It can link phrases in a meaningful way. E-mail response management systems also create reports based on the number of messages received, by message subject, date, and content. This provides management with information on which web sections need to be improved.

E-mail response management software pulls out messages to managed mailboxes such as those addressed to generic functions such as info@company.com, techsupport@company.com, and sales@company.com. They route them to groups of agents or respond to them with an automatic reply, based on subject, message, and content.

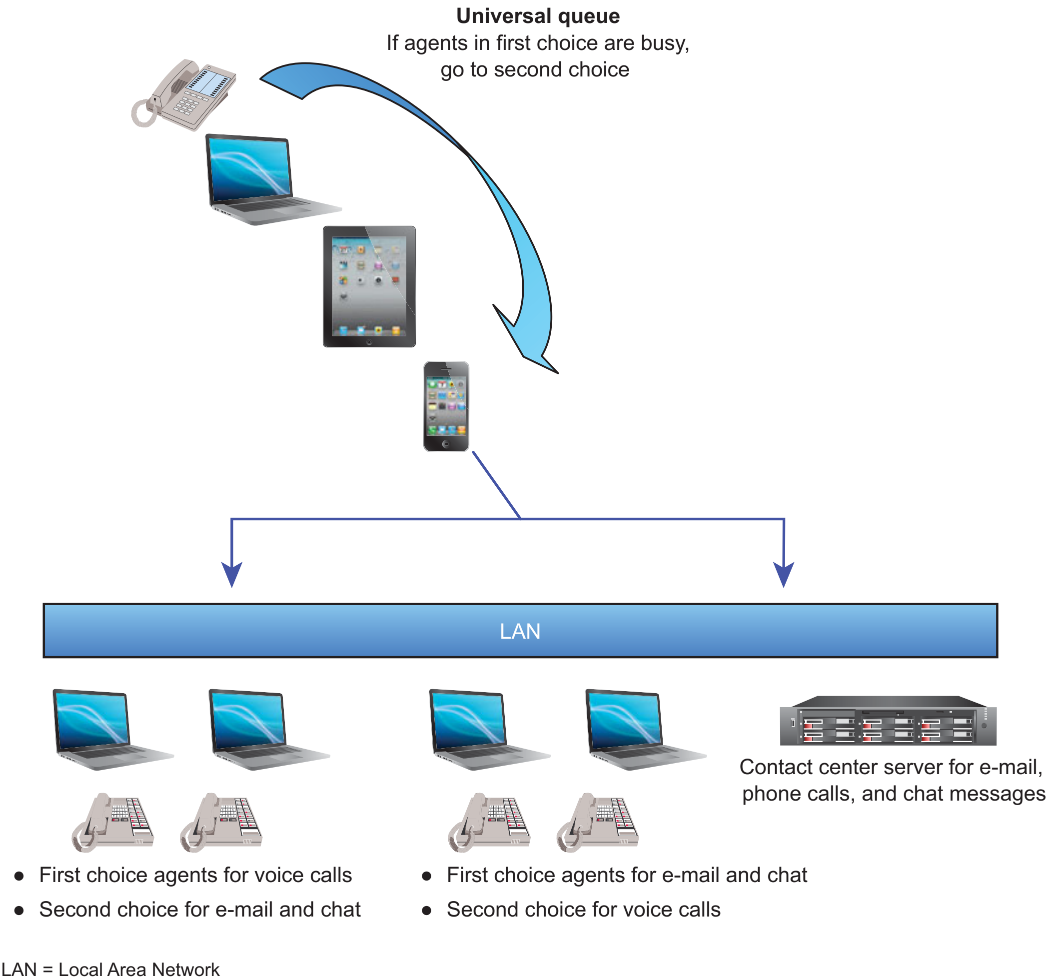

Figure 2-10 *A universal queue in a contact center.*

In a similar manner, web chat software pulls messages sent by people who clicked a Contact Me Now button on the organization's web site. Software like this uses the same protocol to pull the messages as that on the e-mail server. With both the e-mail and web chat software, a gateway interface provides information on agent availability and skill level to handle the chat session or e-mail message.

An Organization That Lauds Its Live Service

In the midst of cutting back on the use of live agents, some web-based organizations make a special point of advertising how easy it is to reach their live help to assist in ordering or returning merchandise. One such organization is Zappos, a subsidiary of Amazon.com. A March 5, 2010 *New York Times* article by Stuart Elliott, titled "Tireless Employees Get Their Tribute, Even If It's in Felt and Polyester," described Zappos' new advertising campaign.

In the advertising campaign, Zappos' customer service agents, represented by puppets, are depicted during phone calls with customers. In the article, Aaron Magness, director for Brand Marketing and Business Development at Zappos, had this to say:

> *Our customer loyalty team is not scripted and is not measured on time of calls. The goal is when you see the ads and TV, print or digital, you'll say, "That's the Zappos I know," or "That's a company I want to do business with." Zappos refers to its customer service representatives as the customer loyalty team.*

These ads are an example of promoting the ability to easily speak with a live person to get help with a purchase or to return merchandise. With staff cutbacks in many other organizations, it's a striking example of trying to maintain a competitive advantage by promoting interactions with live agents. It's a contrast to Zappos' parent company, Amazon.com, which pioneered the self-service web site with the click-to-buy ease of completing purchases, complete information about its products, and customer rating system, all designed to make it easy to select and purchase merchandise.

Using Voice Response Units for Routing and Information via Touch-Tone or Speech

Voice Response Units (VRUs) provide information to callers based on touch-tone signals or spoken commands. Customers can call their bank or credit card company to ascertain their balance or learn if a payment has been received. They enter their account number and PIN when prompted by an electronic voice. The VRU repeats the requested information, in spoken word.

The use of voice response technology is decreasing due to the increasing use of the Web to access information. However, to handle traffic from callers, companies justify the expense of speech recognition and VRUs because they need fewer people to speak with live agents. (The terms “integrated voice response” and “voice response” are used interchangeably.)

The following are examples of VRU applications.

- Newspapers subscribers can use it to stop and start delivery before and after vacations, or report nondelivery of newspapers.
- Airlines can give flight information.
- Prescription drug benefit programs enable people to order drug refills.

Using Speech Recognition to Expand Self-Service

Many call centers add speech recognition to their integrated voice response platforms to make them more user-friendly and faster to navigate. Toll-free directory services ask callers to speak the name of the company for which they require a toll-free number without operator assistance. Local telephone companies use speech recognition so that customers can easily obtain billing information without speaking with a billing representative.

How Speech Recognition Works

Speech recognition works by first detecting and then capturing parts of spoken words (utterances). After removing background noise, it converts the captured utterances to a digital representation. Capturing the speech and digitally representing it is done by Digital Signal Processors (DSPs) on high-speed specialized computer chips. The speech recognition software then breaks the sounds into small chunks and compares various properties of the chunks of sound to large amounts of previously captured data contained in a database.

High-speed computer processors perform the digitization and comparisons in milliseconds. They also take into account gender differences and regional accents. Systems contain different databases of expected responses based on the application. A corporate directory has a different speech database than one for airline scheduling or lost-luggage applications.

SUMMARY

Virtualization and VoIP systems have helped increase efficiency in data centers and in IT functions. Virtualization offers data centers the ability to reduce capital spent on servers and to use less space. Because they operate over the same cabling as data applications, IP telephone systems eliminate the requirement for two sets of cabling, one for voice and one for data. Both of these innovations require that IT staff members learn new ways to manage servers with multiple applications and operating systems, as well as VoIP technology, which is markedly different from older-style telephone systems.

Applications that an enterprise feels can be moved to hosting centers and cloud providers are likely to be those that are commoditized or not critical for an organization's core business. Thus, in many organizations the applications remaining in data centers are often customized, complex, and core critical.

Moreover, applications centralized in data centers at main and regional headquarters require high network availability as more staff members depend on access. Centralization of applications in data centers also requires networks with higher speeds and more capacity to carry ever-increasing amounts of computer data.

In summary, streamlined data centers, cloud computing, and virtualization have created more pressure on IT staff members to operate data centers with around-the-clock availability, and networks with ever-increasing capacity. They also require more complex skills on the part of IT personnel.

APPENDIX

Table 2-1 *Protocols and VoIP Terms*

Protocols and Terms for VoIP Service	Description
802.1pq	802.1pq is used to tag certain Virtual LAN traffic to indicate that it is part of a special group. It might tag voice packets to segregate them for special treatment and monitoring. It also contains bits that identify the packet's priority level.
CoS	Class of Service provides priority to particular types of traffic. Voice or video can be designated with a higher priority than voicemail.
DoS	Denial-of-Service attacks occur when hackers attempt to disrupt communications by bombarding endpoints or proxies with packets.

Protocols and Terms for VoIP Service	Description
G.711	G.711 is used to compress voice signals at 64,000 bits per second plus a 6- to 21-kilobit header for VoIP services. It produces good voice quality but uses more network capacity than other compression techniques. This technique requires 60 milliseconds to process and "look ahead" (check the route).
G.723.1	G.723.1 is a compression protocol that uses small packets with 6.3Kbps compression. Small packets are more efficient than large ones, in terms of bandwidth use. With the header, total bandwidth is about 16Kbps.
G.729	G.729 is a voice compression standard used in VoIP. It compresses voice signals from 64,000 bits per seconds to 8,000 bits per second. The header brings the total bandwidth to about 18,000 bits per second.
H.323	H.323 is a family of signaling standards for multimedia transmissions over packet networks adopted by the International Telecommunications Union (ITU). Microsoft Corporation and Intel Corporation adopted the standard in 1996 for sending voice over packet networks. H.323 includes standards for compressing calls and for signaling. It has higher overhead than the newer signaling protocol, SIP.
Presence theft	This refers to the impersonation of a legitimate IP telephone or other device by a hacker.
Proxy server	A proxy server screens communications between endpoints to verify that the called and calling parties are who they say they are and that no virus will be sent. A proxy server might sit between a VoIP server and external devices that request an audio conference or videoconference session. This is referred to as intermediating sessions. Proxy servers are also used between IP telephones and the Internet.
RTP	Real-time Transport Protocol is an Internet Engineering Task Force (IETF) standardized protocol for transmitting multimedia in IP networks. RTP is used for the "bearer" channels—the actual voice, video, and image content. SIP is commonly used for the signaling to set up and tear down sessions.
SCCP	Skinny Client Control Protocol is a Cisco proprietary signaling protocol for sending signals between devices in Cisco telephone systems. It is also referred to as "Cisco Skinny."

Table 2-1 *(Continued)*

Protocols and Terms for VoIP Service	Description
SIP	Session Initiation Protocol establishes sessions over IP networks, such as those for telephone calls, audio conferencing, click-to-dial from the Web, and instant messaging exchanges between devices. It is also used to link IP telephones from different manufacturers to SIP-compatible IP telephone systems. It is used in landline and mobile networks.
QoS	Quality of Service guarantees a particular level of service. To meet these guarantees, service providers or IT staff members allocate bandwidth for certain types of traffic.

Table 2-2 *LAN Protocols, Devices, and Terms*

Protocol, Service, or Device	Description
Backbone	The wiring running from floor to floor in single buildings and from building to building within a campus. A backbone connects switches in different wiring closets to one another. Backbones support high concentrations of traffic in carrier and enterprise networks.
Blade server	Blade servers are computers packaged on individual boards—blades—that plug into slots in a chassis. A chassis is the metal frame on which components fit, similar to a custom cabinet with slots for specific items. In high density, chassis blades are arranged vertically. In low density, three- or four-blade servers, they are arranged horizontally. Chassis are placed on racks in data centers. Vertical arrangements conserve space and can share power supplies, fans, and cabling. In addition, blades can be easily added.
Bridge	Bridges originally connected LANs using the same type of protocol. They had limited intelligence and generally only connected a few LANs together. Bridges are now used in LAN switches that support VLANs. The bridge connects devices (PCs, VoIP phones) together into VLANs for special treatment needed for services such as VoIP and conferencing services.

Protocol, Service, or Device	Description
File server	A specialized computer with a large hard drive. File servers provide users with access to documents and applications in central locations in LANs.
Hub	The wiring center to which all devices, printers, scanners, PCs, and so forth were formerly connected to within a segment of a LAN. Hubs enable LANs to be connected to twisted-pair cabling instead of coaxial cable. Only one device at a time can transmit via a hub. Higher-speed switches have replaced hubs in wiring closets.
Load balancing	The capability of equipment to balance traffic between networks and devices so that one network or device is not overloaded while others carry little or no traffic.
Local Area Network (LAN)	A group of devices such as computers, printers, and scanners that can communicate with one another within a limited geographic area, such as a floor, department, or small cluster of buildings.
Layer 2 switch (also called a switching hub)	A switch located in a wiring closet that allows multiple simultaneous transmissions within a single LAN. Layer 2 switches provide a dedicated connection during an entire transmission.
Layer 3 switch (also known as a routing switch)	A switch that routes traffic across the LAN backbone based on IP (network) addresses. They are more complex to manage than Layer 2 switches, but they can use alternate paths if one path is out of service. They are located in data centers and link wiring closets and buildings within a campus.
Layer 4 switch (also known as a content switch)	A switch located at hosting sites and corporate and government sites that host their own web pages. Layer 4 switches connect web traffic to the desired web pages by looking at the URL, the web address from which each packet was transferred to the site.
Metropolitan Area Network (MAN)	Networks that can communicate with one another within a city or a large campus area covering many city blocks.
Router	Routers carry traffic between LANs, from enterprises to the Internet, and across the Internet. They are more complex than switches because they have routing tables with addresses and perform other functions. Routers select the best available path over which to send data.

Table 2-2 *(Continued)*

Protocol, Service, or Device	Description
Server	A centrally located computer with common departmental or organizational files such as personnel records, e-mails, sales data, price lists, student information, and medical records. Servers are connected to Layer 2 or Layer 3 switches. Access to servers can be restricted to authorized users only.
Virtual Local Area Network (VLAN)	A virtual local area network is made up of devices, usually personal computers or VoIP devices, whose addresses are programmed as a group in Layer 2 switches. This segregates them from the rest of the corporate network so that all devices in the same VLAN can be given a higher priority or level of security. They are programmed as a separate LAN but are physically connected to the same switch as other devices.
Wide Area Network (WAN)	A group of data devices, usually LANs, that communicate with one another between multiple cities.

Part II

Industry Overview

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3 Competition, Industry Structures, and Regulations

In this chapter:

INTRODUCTION

Mobile networks have had a growing impact on business and residential life as their capacities and speed have improved. Until the early 2000s, mobile networks carried mainly voice; now, they support a growing volume of instant messages, e-mail, and applications, as well as Internet access. Business people and consumers alike are able to easily carry around their most important voice and data communications information in lightweight smartphones and tablet computers. Today, staff members can create proposals, check on orders, and conduct most business functions from within their office building, while away on a business trip, or from a home office.

For carriers, most of which have experienced large losses in home telephone services, mobile services are a growing percentage of revenue. However, their success in attracting customers who transmit large amounts of data has increased pressure to upgrade networks to carry more data on finite amounts of *spectrum*. Spectrum, as the word is used with respect to the telecommunications industry, is the range of all radio frequency signals (invisible electromagnetic waves) upon which wireless traffic is transmitted.

Because of past acquisitions and mergers, the largest carriers maintain the greatest control over how the majority of customers in the United States access these services. The mobile and wireline infrastructure owned by AT&T, Inc., and Verizon Corporation provides nationwide coverage. These companies also have the resources to upgrade their wireless networks to new-generation, high-capacity protocols. Their wireline networks are global in scope and support enterprise customers around the world.

Competitive carriers such as EarthLink, Inc., Level 3 Communications, and Windstream Communications provide Internet access and a variety of other services to business customers. Windstream offers service to both residential and business customers. These and other carriers have grown by acquiring competitors and expanding their offerings. Many of them cover multiple regions of the country, but none of them have facilities across the entire country. They compete with the wireline divisions of AT&T and Verizon, cable TV operators, and others. Like AT&T, Verizon, and CenturyLink, Inc., competitive carriers have merged with other carriers, resulting in fewer competitors and less pressure to offer rock-bottom prices.

Carriers such as Windstream, large incumbents such as CenturyLink, AT&T, and Verizon, as well as cable TV operators such as Cox Communications concentrate their wireline business customer sales efforts on cloud and *managed services*, which are seen as more lucrative than broadband data communications services. Managed services are those that carriers offer as adjuncts to broadband links. Examples include managing routers, multiplexers, or security. It's unclear if the market can support all of these services plus the many cloud computing and managed service offerings from other types of companies.

Another source of competition for telephone companies and Multiple System Operators (MSOs) such as Comcast, Time Warner Cable, Verizon, and AT&T that provide cable TV comes from over-the-top providers such as Hulu, YouTube, and Netflix. Over-the-top providers transmit TV shows and movies to consumers over cable and telephone company broadband networks. These services attract customers in part because of their lower costs compared to subscriptions to traditional pay-TV services. While most subscribers keep some cable TV service, many have dropped premium services in favor of lower-cost options. Netflix is now the largest provider of pay-TV service in the United States. To counter this competition, cable TV and telephone companies are developing the ability to transmit the content subscribers pay for to laptop and tablet computers.

Although none of the major cable operators own mobile networks, they do resell mobile services. This mobile traffic is carried on other carriers' networks. At one time, the majority of cable operators' mobile offerings were carried on Sprint Nextel and Clearwire's networks. Operators that resell mobile services rely on the availability of spare capacity on wireless networks and the financial health of these mobile carriers. Comcast and other MSOs invested in Clearwire to cement their relationship with them. However, as of the second quarter of 2011, Clearwire was operating at a loss and the cable companies had sold very little mobile services. Time Warner Cable and Comcast both decided to end their agreement to sell services on the Clearwire network. They instead made an agreement to sell their spectrum to Verizon and resell service on the Verizon Wireless network. The spectrum sale requires regulatory approval.

Cox Cable started to build its own mobile network, but shut it down in 2011. Building a mobile network is a costly endeavor that requires vast resources. It's not unusual for organizations to underestimate the cost and complexity of building a mobile network. When it shut down its network, Cox announced that it would resell mobile services.

Internet-based companies including Apple, Google, Amazon, and Microsoft have had an enormous impact on the industry. Many of these relatively new companies have achieved astonishing success; much of their success can be attributed to the drive and vision of the entrepreneurs that founded them. Apple, Netflix, Amazon, Google, and Microsoft are examples of former startups that became hugely successful and had profound influences on the industry.

However, as technology advances, these now-mature companies are faced with many of the same issues as the more established cable TV and telephone companies. They all face the need to continue to innovate in order to develop new sources of revenue. This is often difficult; none of these companies are as nimble as they were when they got started. Now, being large companies themselves, it takes longer to make decisions and develop products, with more layers of management needed to approve new projects. Moreover, when companies become public, short-term profit requirements often interfere with long-term projects that might not produce results right away.

The rise of Internet giants with huge customer bases was made possible by improvements in the Internet and mobile networks. These improvements have enabled these companies to provide less costly services than cable TV operators, mobile providers, and telephone companies. However, broadband and mobile providers have their own advantage: their extensive broadband mobile and wired networks that connect directly to residential and business customers.

Government regulations play a critical role in telecommunications. Important regulatory issues revolve around how to ensure that no single carrier is allowed to block competition and innovation by slowing down competitors' traffic. Doing this without hampering the ability and motivation of the carriers to invest in costly upgrades to keep up with traffic growth is not a simple task. In the United States, the Federal Communications Commission (FCC) must balance pressure from large incumbent telephone companies and cable TV operators against the interests of consumer groups and other competing companies.

Large businesses that are dominant in the market often push back against regulations that are intended to foster competition. These organizations understandably see regulations as potentially costing them market share or impinging on their operations in other ways. Regulatory rules are critical factors in the success or failure of carriers. They impact pricing, billing practices, and decisions as to whether to build or lease network infrastructure. The following quote from the 2003 annual report of BellSouth (now a part of AT&T) is still relevant:

> *Our future operations and financial results will be substantially influenced by developments in a number of federal and state regulatory proceedings. Adverse results in these proceedings could materially affect our revenues, expenses, and ability to compete effectively against other telecommunications carriers.*

THE 1984 BREAKUP OF AT&T ....

Prior to 1984, the Bell system consisted of 22 local Bell telephone companies that were owned by AT&T Corporation.

NOTE The Bell telephone system was named after Alexander Graham Bell, who is credited with having invented the telephone.

Customers had one point of contact for all of their telecommunications requirements. The former AT&T did all of the following:

- Sold local, interstate, and international long-distance telephone services
- Manufactured and sold central-office switches, customer-premises telephone systems, electronics, and consumer telephones
- Conducted research and development
- Published yellow and white-pages telephone directories

This changed in 1984 when the Unites States Justice Department forced the company to divest itself of major assets and services, split off the 22 local Bell telephone companies, and constrained it to sell only local services, and yellow and white-pages directories. Divestiture was instituted because it was felt that AT&T's 22 local companies created artificial hurdles when long-distance competitors required access to local switches in order to sell long-distance service to their subscribers.

As part of the divestiture ruling, AT&T kept the long-distance portion of its organization, which it viewed as more lucrative than local calling. It also retained the right to manufacture and sell telephone and central-office systems and to sell interstate and international long-distance phone service. AT&T kept Western Electric, its engineering and manufacturing arm, and Bell Labs, its research facility. *The goal of divestiture was to encourage competition for long-distance services*. The 22 local telephone companies were organized into the following seven Regional Bell Operating Companies (RBOCs):

- Ameritech (now part of the new AT&T)
- BellSouth (now part of the new AT&T)
- Pacific Telesis (now part of the new AT&T)
- SBC (Southwestern Bell Communications; now part of the new AT&T)
- Bell Atlantic (Verizon Communications)
- NYNEX (now part of Verizon Communications)
- US West (changed its name to Qwest Communications; now a part of CenturyLink)

Following divestiture, the RBOCs each operated extensive mobile networks on spectrum granted to them at no charge by the FCC. They later expanded their mobile services by purchasing additional spectrum at FCC auctions. In addition, some of them purchased other mobile operators.

The Creation of Verizon Communications and the Post-2005 AT&T

Two of the RBOCs, SBC and Bell Atlantic, began purchasing their largest rivals. In 2006, SBC changed its name to AT&T Incorporated. It had previously purchased the diminished former AT&T Corporation and other local phone companies. Bell Atlantic had changed its name to Verizon Communications. It also purchased other phone and mobile companies.

Verizon Communications and the new AT&T, Inc., are now nationwide powerhouses that, between them, count 58 percent of mobile subscribers in the United States as their customers. They are additionally the dominant suppliers of voice and data services to the largest businesses and commercial organizations in the United States.

As a result of multiple mergers, by 2011 the seven RBOCs had been reorganized into three organizations: Verizon Communications, AT&T, Inc., and CenturyLink.

Table 3-1 presents the time line of the decline of AT&T Corporation.

Table 3-1 The Demise of the Former AT&T Corporation

Name of Organization	Purchased or Spun-Off Entity: Year	Details
AT&T Corporation	Lucent Technologies: 1996	Spun off Lucent Technologies, its telephone system and carrier equipment sales, and manufacturing businesses. Lucent kept its research and development arm, Bell Labs.
Lucent	Avaya Inc.: 2000	Spun off its customer-premises business to newly formed Avaya, Inc. Lucent kept carrier sales, manufacturing, and Bell Labs.
Alcatel	Lucent: 2006	French company Alcatel purchased Lucent and changed its name to Alcatel-Lucent.

Name of Organization	Purchased or Spun-Off Entity: Year	Details
AT&T Corporation	Teleport: 1998	Purchased Teleport, which owned fiber-optic networks in 63 cities. At the time, it was the largest local competitor to the Bells.
	McCaw Cellular: 1994	Purchased the largest cellular provider in the United States from Craig McCaw.
	TCI: 1999	Purchased the largest cable TV provider in the United States at a premium price.
	MediaOne: 2000	Purchased cable TV operator MediaOne. AT&T had envisioned using its cable assets for bundled TV, Internet access, and telephone service. However, the combined costs of upgrades and purchases for these investments—$115 billion by 2000—resulted in huge losses.
	AT&T Wireless: 2001	Spun off AT&T Wireless to raise capital for its other ventures. It was the largest mobile operator in the United States.
Comcast	AT&T Broadband: 2002	As a result of its losses, the former AT&T sold its cable properties, AT&T Broadband, to Comcast for $41 billion plus the assumption by Comcast of $25 billion of debt.
Cingular Wireless	AT&T Wireless: 2004	Cingular purchased AT&T Wireless, which was operating at a loss. At the time, Cingular was a mobile provider, jointly owned by RBOCs BellSouth and SBC.

Table 3-2 lists the purchases that enabled SBC to become a nationwide provider of mobile, broadband, and business services. In 2005, it purchased the old AT&T. In 2006, following its purchase of BellSouth, SBC changed its name to AT&T, Inc.

Table 3-2 Purchases That Fueled SBC's Transformation to AT&T, Inc.

Acquired Company: Year	*Details of Purchased Organization*
Pacific Telesis Group: 1997	Regional Bell Operating Company (RBOC) in California and Nevada
Southern New England Telephone Company: 1998	Incumbent telephone company in Connecticut
Ameritech: 1999	RBOC in Michigan, Indiana, Illinois, Ohio, and Wisconsin
The former AT&T Corp: 2005	SBC purchased the former AT&T's long-distance, and global network, which was operating at a loss due to customer defections to lower-priced competitive services and lower prices on its own services. This gave SBC a large global network.
BellSouth: 2006	With the purchase of RBOC BellSouth, SBC gained total control of Cingular Wireless. Previously, Cingular Wireless had been jointly owned with BellSouth. SBC changed its name to AT&T, Inc., because of AT&T's greater name recognition.

In a similar fashion to SBC, Bell Atlantic pursued a strategy of mergers to become a dominant force in broadband, mobile, and business services. Table 3-3 lists the major acquisitions that resulted in Bell Atlantic's transformation from an RBOC to nationwide operator, Verizon Communications. In addition to these mergers, Verizon purchased mobile carriers including the majority of Alltel Corporation, which had service in 34 states, and Rural Cellular Corporation, which had been one of the largest rural cellular operators in the United States.

Table 3-3 *The Post-1996 Evolution of Bell Atlantic to Verizon Communications*

Purchased Entity: Year	Details
NYNEX: 1997	Bell Atlantic purchased NYNEX, the former RBOC in New England. Prior to the merger, Bell Atlantic's territory covered Pennsylvania, New Jersey, Maryland, Washington DC, Delaware, Virginia, and West Virginia.
GTE: 2000	At the time of its purchase, GTE was the largest non-Bell local telephone company. Following the purchase, Bell Atlantic changed its name to Verizon Communications. Verizon later sold off most of GTE's rural landline properties to Frontier Communications and FairPoint Communications in order to focus on its mobile offerings and services to business customers. It kept GTE's wireless assets as well as the former GTE landline properties in Florida, Texas, California, and Pennsylvania.
Vodafone AirTouch: 2000	Verizon formed a joint venture with Vodafone, called Verizon Wireless. Vodafone had previously purchased the cellular assets of Pacific Telesis (now part of AT&T, Inc.) and US West (now part of CenturyLink). Vodafone owns 45 percent of Verizon Wireless, and Verizon owns 55 percent.
MCI: 2006	MCI was the second largest independent long-distance company with fiber to business premises in many metropolitan areas and a data network with operations in 200 countries. MCI had been previously purchased by WorldCom, which changed its name to MCI after WorldCom's bankruptcy.
Terremark: 2011	Terremark was the largest co-location provider worldwide. Co-location sites provide secure facilities for carriers to connect their networks to one another to exchange traffic. Terremark also provided managed services, cloud computing, and hosting services to carriers, government agencies, and enterprises. Verizon and the United States Department of Defense were among its customers.

CenturyLink: The Journey from 75 Customers in 1930 to the Third-Largest Telephone Company in the United States

CenturyLink was founded in 1930 when William Clarke Williams purchased a 75-customer telephone company in Louisiana for $500. At that time, the switchboard was operated in the Williams' parlor, and the owner's son delivered bills by bicycle. After World War II, the company (then called Central Telephone and Electronics) began expanding into other states, and in 1968, CenturyLink was incorporated. Descendents of the founders ran the company until 2002, when the grandson of the founders, Clarke M. Williams, died in his mid-40s.

CenturyLink went public in 1978, after acquiring additional rural phone lines. Many of these properties were purchased from incumbent telephone companies Verizon and the former Ameritech, which is now part of AT&T. Verizon and Ameritech sold rural assets to concentrate on mobile services and services to enterprise customers.

When CenturyLink acquired EMBARQ in 2008, it began to shift from all rural properties to a mix of rural and metropolitan markets such as Las Vegas and Orlando. EMBARQ was a landline telephone company that Sprint had previously spun off to concentrate on its own wireless services.

The purchase of Qwest Communications in 2011 doubled CenturyLink's size, adding services to additional metropolitan areas such as Denver, Seattle, Minneapolis, Phoenix, and Salt Lake City. Qwest was the incumbent telephone company in 14 states in the western United States. Its territory was more sparsely populated than those of AT&T and Verizon and included difficult-to-cable mountainous regions. This made it challenging to profitably upgrade its networks due to the lower number of customers per square mile. A unit of Qwest offered long-distance service throughout the United States, mainly to small and mid-sized business and commercial customers.

Qwest's recently upgraded 100-gigabit nationwide fiber network is a valuable addition to CenturyLink's midwestern regional fiber network that it purchased from Level 3 Communications in 2003. Owning interstate fiber networks saves on costs for its local companies to connect to the Internet and is an opportunity for leasing backhaul service to mobile companies. Backhaul networks carry mobile traffic from antennas at base stations to carriers' centralized data centers.

Continued

In 2011, CenturyLink also acquired Savvis. The combination of Savvis and Qwest increases CenturyLink's offerings for enterprise customers. Savvis offers hosting, cloud computing, and managed computing at its data centers in the United States and Canada as well as those in the United Kingdom, Singapore, and Japan. It also has networks in South Africa, Australia, China, the Middle East, and Europe. Qwest offered hosting and data center services to business customers in the United States. The Savvis acquisition further broadens Century-Link's offerings to enterprises with national and international branch offices.

CenturyLink now has 47,500 employees and is the third largest phone company by telephone lines in the United States. Its territory now includes 37 states. However, much of its territory is still in rural areas with mainly residential customers. Moreover, CenturyLink, along with other incumbent telephone companies, is losing home telephone customers as residential subscribers continue to drop home phones for mobile service.

Neither the former Qwest nor CenturyLink owned a mobile network. They both resold wireless services on Verizon Mobile's network. Profit margins on resale are lower than those on direct sales. Moreover, there are fewer managed service offerings available on resale for mobile devices geared to larger, more profitable enterprise customers. CenturyLink has not announced intentions to purchase or develop a mobile network. It does have a more robust offering for enterprise customers as the result of its purchases of Qwest and Savvis. CenturyLink has been profitable throughout its history, despite its declining number of landlines. Fees generated by intercarrier compensation have aided earnings. It's unknown how future reductions in these fees will impact CenturyLink or if it will recoup some of these declines through federal subsidies for broadband.

REGULATORY ISSUES

A major issue facing United States government regulators is how to cost-effectively support broadband services in rural, low-income, and hard-to-cable areas. Currently, subsidies support only voice, not broadband. Regulators are reviewing ways to promote universal broadband services that carry voice and Internet connections as IP packets in these areas.

Universal Service and Guaranteed Rate of Return

In 1913, when the former AT&T was given a monopoly in telecommunications service in the United States, it made a commitment to offer reasonably priced universal services everywhere in its territories. In exchange, the government guaranteed that AT&T could earn a specific rate of return on its telecommunications services. This marked the beginning of the concepts of universal service and rate of return guarantees. In the absence of competition between 1913 and its 1984 split-up, AT&T used artificially high long-distance rates to subsidize local services.

While rate of return guarantees did not encourage efficient operations, they did enable the company to invest in research and development through its Bell Labs division. AT&T inventions included touch-tone service, integrated circuits, and laser technologies. These innovations were freely available without patent fees, were adopted worldwide, and are one of the reasons that global networks are compatible with one another today.

In the late 1970s, the introduction of competition from lower-cost long-distance providers such as MCI and Sprint made it untenable for AT&T to continue charging high fees for its own long-distance calling. Gradually, AT&T lowered its long-distance fees and increased its local service rates to compensate. To make up for local service subsidies, regulators set fees for carriers to pay one another for connecting calls to one another's customers. These are known as Intercarrier Compensation (ICC) fees, and they marked the beginning of the imposition of access charges.

Voice over Internet Protocol Regulations—Information versus Telephone Service

In February 2004, the Federal Communications Commission (FCC) ruled that computer-to-computer IP telephony is an information service; thus, it is not subject to most FCC regulations. Voice over Internet Protocol (VoIP) PC-to-PC calls are those between subscribers of the same service such as Skype. An *information service* is one that stores, processes, or transforms information. However, VoIP calls from personal computers to telephones on the Public Switched Telephone Network (PSTN) are considered telecommunications services and are subject to federal and state telecommunications regulations and fees. An example of a VoIP call to the PSTN is one where a Skype customer calls someone's mobile or home telephone number.

Continued

In November 2004, the FCC further ruled that VoIP traffic should be regulated as an interstate service at the national, not the state, level because it's not always clear where calls originate or terminate. This makes it less cumbersome for VoIP providers such as Vonage and Skype because they are not required to obtain state-by-state approval to offer service. The FCC did state that VoIP providers are required to provide emergency 911 services equivalent to those provided by landline-based, traditional telephone companies.

ICC Payments for Connecting Traffic

Currently, there are federally mandated fees for interstate calls and state-mandated fees for intrastate calls. When a college student calls his parents who live in another telephone company's territory, the student's phone company pays an ICC fee to the other telephone company for connecting the call. Currently, ICC for traditional voice is done via access fees.

There are two types of access fees: *originating access fees* and *terminating access fees*. They apply to mobile, wireline, and interconnected VoIP traffic. Interconnected VoIP calls are those made to people on the PSTN.

The following are examples of originating terminating and access fees.

- Originating access fees are paid by phone companies whose customers lease toll-free numbers.
  - A subscriber on a different carrier's network calls a toll-free (800-888) number that belongs to another carrier's subscriber.
  - A person places a VoIP call to a toll-free number connected to someone on the PSTN.
- Terminating access fees.
  - A person whose phone is connected to the PSTN calls someone on another carrier's network.
  - A person places a VoIP call to someone on the PSTN.

Access fees paid to carriers in rural, high-cost areas are set higher than those in urban areas. Moreover, intrastate access fees, which are set by states, are generally higher than interstate access fees. Access fee rates for local calls are minimal. Most large carriers don't bill one another for local calls. They use a *bill and keep* method so that administrative billing efforts are eliminated. Instead, they assume that any differences are made up by revenue from subscribers.

Disputes Involving ICC Fees

Despite rules governing access fee rates, telephone companies employ entire departments to analyze and settle access fee disputes. The primary cause of disagreements is that it is often difficult to determine where traffic originated and how it should be rated, solely based on call records. The increased use of VoIP applications such as Skype on cell phones compounds these complexities. There are no agreements as to whether VoIP calls to people on the PSTN should be rated as interstate, intrastate, or local, because VoIP calls do not carry location-identifying information.

A major point of contention is traffic from providers of free conference services, chat lines, and adult entertainment services. Companies that provide these services often game the system through schemes known as *traffic pumping* and *access stimulation*. These providers often install telephone switches in rural or hard-to-cable areas with high access fees. They register as telephone companies to earn revenue from high access fees paid by carriers whose customers make free conference calls. Some carriers refuse to pay access fees to known traffic pumpers.

If the parties to an ICC dispute can't settle through negotiations, the next step is costly litigation in court. Individual disagreements over access fees run the gamut from $500,000 to $30 million in disputed fees.

The Universal Service Fund

The Telecommunications Act of 1996 codified universal service by establishing the Universal Service Fund (USF), which subsidizes costs in rural and high-cost (for example, mountainous) areas. The USF is paid for by contributions from long-distance, paging, and mobile carriers. Contributions are based on a percentage of revenue from these services. Carriers that mix voice and data on transmission lines that carry traffic to the Internet and to long-distance switches also contribute based on revenue from these lines. The USF additionally subsidizes services to healthcare facilities, libraries, schools, and people living below the poverty level. Every carrier, cell phone company, and paging company is required to pay a percentage of its interstate and international revenues to the fund, as are providers of interconnected VoIP traffic, which are VoIP calls to landline phones.

The goal is to enable providers in rural and high-cost areas to offer services at reasonably comparable rates for similar services in urban areas. The portion of the USF that applies to schools and libraries is known as the *E-rate*. The E-rate subsidizes Internet access and infrastructure costs needed for high-speed Internet access. In 2000, subsidies were extended to Native American reservations. End-user line charges listed as subscriber line charges on home phone bills help subsidize the E-rate.

However, with the exception of the E-rate and subsidies to rural healthcare providers and schools, the USF covers only basic mobile and landline services, not broadband. The FCC is changing the rules, such that broadband will be classified as a universal service, eligible for subsidies.

Changes to Access Fees and the USF

In February 2011, the FCC issued a Notice of Proposed Rule Making (NPRM) that recommended support for broadband services. An NPRM contains proposed changes to FCC rules and seeks comments from the public related to these changes. The proposed ruling essentially expands universal service and ICC from voice only to broadband. It states that it envisions voice being provided more efficiently over IP networks rather than over separate circuit-switched facilities. The proposed rule would gradually eliminate access fees and replace the USF with the Connect America Fund. These changes would be phased in over a period of time and completed by 2020, with intermediate steps taken in the interim.

The overall goals are to eliminate waste and provide affordable broadband. In its proposed rulemaking, the FCC suggested universal availability of broadband with 4Mbps *downstream* and 1Mbps *upstream* from the customer to the provider. Downstream refers to speeds from carriers to customers. Upstream refers to speed from the customer to the carrier. Unlike the USF, the Connect America Fund would try to grant money and subsidies only to mobile and landline carriers in areas where there are no other providers. These funds would support new projects and maintenance of existing broadband. According to the NPRM, competition from wireless and cable companies now exists in many areas where telephone companies receive subsidies.

The NPRM recommended eliminating use of rate of return to determine grant and subsidy amounts. The FCC stated that a guaranteed rate of return removes the incentive to operate efficiently. Rather, the rulemaking proposes using competitive *reverse auctions*, also referred to as *purchase auctions*, for granting money for nonserved areas. With reverse auctions, organizations win grants for low bids rather than high bids.

Access Fee Exemptions

Access fees for toll traffic do not currently apply to VoIP calls that originate and terminate on the Internet. Nor do access fee regulations apply to wireless carriers. Rather, wireless carriers pay indirectly. They negotiate contracts with each carrier to which they connect so that the wireline carrier is able to cover its costs for transmitting calls between wireless networks and the PSTN.

Transition to Reforms and Reverse Auctions

In its February 8, 2011 NPRM, the FCC laid out a transition period (also referred to as a *glide path*) to move from the USF and the current ICC system to reverse auctions and a Connect America Fund. The rulemaking specified a transition period toward meeting its end goals of evolving to intercarrier compensation suitable for IP networks and subsidization of universal broadband.

One immediate reform is the creation of a Mobility Fund for building out mobile wireless networks for broadband in areas where there are currently no next-generation mobile networks. The Mobility Fund was previously proposed in an October 2010 NPRM.

The NPRM also elucidated the short-term goals of eliminating loopholes in existing rules that enable inflated access fees, lead to costly legal disputes, and discourage carrier efficiency. As first steps in lowering access fees, payments for traffic pumping, access stimulation, and another scheme called *phantom traffic* will be eliminated and intrastate and interstate access fees will be equalized. Phantom traffic is traffic that does not contain carrier or calling number identifying information. The FCC will additionally take steps to remove support for duplicate carriers in the same area.

In the short term, the FCC will also take public comments regarding the development of a framework for long-term intercarrier compensation for VoIP and rules for compensation for VoIP traffic. The FCC is also seeking comments on contribution mechanisms and obligations to recipients of the Connect America Fund.

Finally, the FCC proposes conducting competitive bidding auctions in the short term, where providers will compete for funds to build broadband networks. Recipients will be subject to requirements to build out their broadband facilities within a specific period of time and to make these services available for a defined period of years.

By the year 2020, the FCC envisions access fees reduced to zero and compensation between carriers closer to the arrangements between carriers at *peering locations* on the Internet. These arrangements are based on charges for the amount of traffic exchanged, not minutes of traffic. Peering locations are data centers that house routers and switches that belong to multiple carriers. Carriers use these facilities to connect with one another to exchange traffic destined for locations outside of their coverage areas.

In addition, support for carriers in rural and hard-to-cable areas will be replaced by the Connect America Fund, which will support ongoing maintenance and operations of broadband wireline and wireless networks. Moreover, these carriers will no longer receive funding based on rate of return analysis. Rather, price cap systems will be instituted so that carriers will have incentives to operate efficiently rather than guaranteed revenues. With price caps, carriers agree to impose an upper limit on their rates and keep them at an agreed-upon level for a specific number of years.

ICC Reform

The FCC's final NPRM, issued in October 2011, finalized rules to reform ICC. It adopted rules to stop access stimulation, traffic pumping, and phantom calls. It additionally adopted a framework for bill and keep as well as rules for gradually setting the same rates for intrastate and interstate intercarrier compensation.

FCC Approval of Funding for Universal Broadband

In October 2011, the FCC finalized rules to include affordable broadband in universal service for rural and other underserved areas. Unlike the previous universal service fund, the new fund will support wireline and mobile broadband as well as voice. The FCC defined broadband as 4Mbps downstream (from the provider to the customer) and 1Mbps upstream (from the customer to the provider). Currently, 18 million households in the United States do not have broadband access.

The funding plan is intended to support broadband for business and residential consumers. Providers in areas where competitors already provide broadband services will not be eligible for funds. As part of the plan, the amount of money to be collected in USF is capped at the amount collected in 2011.

The following funds were established to promote universal broadband.

- The Connect America Fund establishes a fund for supporting broadband and packetized voice (VoIP). The FCC authorized new fees—Access Recovery Charges (ARCs)—on wireline phone bills to help fund the broadband efforts. Funds will be distributed to providers through the aformentioned reverse auctions.
- The Mobility Fund established a one-time payment of $300 million for building mobile broadband infrastructure followed by a $500 million annual Mobility Fund for ongoing support. The one-time allocation will be awarded based on reverse auctions. Some carriers might receive funding from ARC fees as well as from the Mobility Fund in areas without mobile broadband.

- The Remote Areas Fund was established to fund mobile broadband for Americans living in the most remote areas of the United States. Carriers who apply for these funds will be allowed to offer services through lower-cost wireless technologies such as satellite and new forms of Wi-Fi. See Chapter 7, "Mobile and Wi-Fi Networks," for information on unlicensed spectrum for Wi-Fi service.
- Price cap carriers were allocated $300 million. Price cap carriers are previously highly regulated local carriers. In exchange for less regulation in earlier years, they agreed to not raise their local rates by more than the rate of inflation. The FCC stated that more than 83 percent of Americans without broadband are in these carriers' service areas. Examples of price cap carriers are the larger incumbent telephone companies, including Verizon Communications, CenturyLink, and Windstream. In return for this money, carriers are required to build broadband facilities statewide, throughout their territories.

The Response of Rural Carriers to Universal Service Fund and Intercarrier Compensation Proposed Reforms

The reforms proposed by the Federal Communications Commission (FCC) might adversely impact the more than 1,100 small rural carriers that depend on universal service fees and Intercarrier Compensation (ICC) for a large percentage of their annual revenue. ICC alone accounts for an average of approximately 30 percent of annual revenue, according to the National Exchange Carriers Association (NECA). NECA prepares interstate access tariffs and administers pools of access fees for small carriers in high-cost, mainly rural areas.

Rural carriers agree that there are inefficiencies in both the Universal Service Fund (USF) and ICC. They support regulations to curb traffic pumping schemes, and they also support subsidies for broadband. However, they feel that there should be a longer transition between supports for public switched telephone services and supporting only broadband services.

Although the FCC's February 2011 Notice of Proposed Rule Making (NPRM) mentions supporting *middle-mile networks*, it is concerned that these subsidies will not be sufficient to adequately support broadband and mobile networks. Middle-mile networks transport traffic from a local phone company's territory to the Internet. Lack of robust, affordable connections to middle-mile networks is a key factor inhibiting broadband capacity. See Chapter 4, "Carrier Networks," for more information on middle-mile networks.

Rural carriers would also like to keep rate of return regulations so that they will have sufficient funding to repay loans for capital upgrades. They fear that they will not be able to adequately maintain and upgrade their networks. They are also concerned that without subsidies based on rate of return, their broadband prices will not be affordable for their subscribers.

Although it's more cost effective to support both voice and data on a single IP network, the rulings' unfortunate consequence is that the transition will likely result in business losses for many of the more than 1,100 small rural providers. It's likely that larger providers will have the resources to bid lower amounts in reverse auctions. Many of these networks will be based on wireless technologies. Continued oversight will be required to ensure that rates in these areas remain on a par with those in more urban locales. The presence of only one provider precludes incentives for carriers that win grants to keep prices low, operate efficiently, or offer new services.

The Telecommunications Act of 1996

The goal of the Telecommunications Act of 1996 was to spur innovation by fostering competition for local services. Local incumbent telephone companies along with the former AT&T Corporation (now part of AT&T, Inc.) lobbied for an act that would allow them to expand their offerings. The act laid out provisions that allowed incumbent local telephone companies to sell the out-of-region long-distance service that the 1984 divestiture had barred them from offering.

The act also decreed that for the first time, cable TV operators, electric utilities, broadcasters, interexchange carriers, and competitive local exchange providers could sell local calling, toll calling, and related services. This provision allowed the former AT&T, which was then an interexchange carrier, to resume selling local services.

To encourage competition for local services, the act prescribed rules enabling competitors to connect to the central offices of incumbent phone companies at mandated discounted rates. However, most of these connectivity rules were gradually rescinded when large incumbents such as the former Regional Bell Operating Companies (RBOCs) challenged the rules in court and won. For a list of these rulings, see Table 3-11 in the "Appendix" section at the end of this chapter.

Telecommunications Act of 1996 Mandated Fees

When the Telecommunications Act of 1996 was enacted, the United States Congress felt that it was not economically feasible for rivals of the RBOCs to build all their own local facilities. It therefore mandated that incumbents such as the then SBC (now AT&T, Inc.) make their local networks available at replacement cost plus a reasonable profit to competitors such as the former MCI (now part of Verizon) at Unbundled

Network Element (UNE) rates. UNE refers to the services and switching equipment that belong to individual local telephone companies that are leased to competitors. These assets included the following:

- The local copper loop from the incumbent's equipment to the customer
- High-speed lines between the Competitive Local Exchange Carrier (CLEC) switch and the incumbent's central office
- RBOC local central office switch ports for connections to local loops
- Operator services
- Signaling services to link central offices to systems, including billing

Many CLECs including MCI (now part of Verizon) and Sprint leased entire platforms of incumbents' facilities at a discounted rate to offer service without building their own infrastructure. These platforms are referred to as Unbundled Network Element Platform (UNE-P). Some competitors used this strategy primarily for residential service; others built their whole business around the resale of UNE-P. Other competitors built their own facilities in areas where they had concentrations of business customers and used an incumbent's entire platforms (UNE-P) in other areas.

Court Rulings on Access to an Incumbent's Equipment and Fiber

In a March 2004 ruling, the United States Court of Appeals for the District of Columbia struck down state authority to set discounts for competitors to connect to an incumbent's facilities, such as central office switch ports, local loops, and high-capacity T1 (1.54Mbps) and T3 (44Mbps) links.

The circuit court's ruling ended most of the deep discounts available to competitors in metropolitan areas under the UNE pricing. The FCC spelled out a limited number of conditions under which eliminating these pricing rules impairs competition.

In another blow to competitors, the courts ruled that incumbent telephone companies are not obligated to share fiber facilities built within 500 feet of customers with competitors. As a result, where fiber replaces copper or is within 500 feet of customers, local loops might not be available to competitors.

Analog local loops have not been impacted by FCC rulings. However, as RBOCs build out fiber closer to customers, the number of analog loops has decreased. In major cities, there are fiber connections to most midsize and large organizations. Fiber is often additionally connected to suburban office buildings and business parks. Larger providers, such as Level 3, which provides retail service to commercial organizations, lay their own fiber to the business customers that they serve.

The Impact of Higher Leasing Rates on Competitors

As a result of these court decisions, costs for carriers that don't have their own local central office switches, fiber networks, and local lines increased dramatically. Thus, many of the incumbent telephone companies' competitors decreased the range of their offerings or ceased operations entirely. Ultimately, regional competitors such as Paetec (now part of Windstream) in the Northeast were purchased by or purchased competitors with services in other parts of the country. They also purchased rivals in their own territory to consolidate their coverage within their footprint. Before it was acquired by Windstream, Paetec purchased.

- US LEC in the South
- McLeodUSA, which had service in the Midwest, Texas, and the Northwest
- Cavalier Telephone Corporation in the East

These consolidations lowered overall administrative costs, enhanced purchasing power, and enabled competitors to increase the scope of their offerings to business customers with branch offices.

The Impact of the Telecommunications Act of 1996

The Telecommunications Act initially spurred new investment in equipment and services. However, capital investments decreased after 2001, and many providers went out of business due to the high cost of building network infrastructure, the cost and delays associated with connecting to incumbent facilities, unfavorable regulatory rulings, and low retail prices offered in response to competitive bids. Growth and innovation in mobile services, which in turn is attracting increased investment capital, is reversing this trend.

A major impact of the Telecommunications Act is the push of cable TV operators into telecommunications services and telephone companies into cable TV services. Although, in recent years AT&T and Verizon have suspended their residential cable TV build-outs.

A second achievement is the mandate that local number portability be implemented. Consumers now take for granted that they can keep their telephone number when they change mobile carriers, drop their home phone service for mobile service, and keep their business number when they move or change providers. However, this was not the case prior to 1996.

Moreover, small and midsize businesses have benefited from increased competition, which triggered widespread affordable, high-speed Internet access. These organizations have more choices than larger enterprises.

Large enterprises for the most part still rely mainly on AT&T and Verizon because of their global networks. However, they still use competitive carriers such as Level 3 and tw telecom (formerly part of Time Warner Cable) to supplement their network connections in the event of a major network outage at their primary carrier. Large organizations are also more likely to use AT&T and Verizon for mobile services because they are the only providers with close to nationwide mobile networks.

Unfortunately for most consumers, the choice for Internet access is often limited to the local cable TV provider. However, initial build-outs of telephone company broadband facilities did provide some impetus for cable Multiple System Operators (MSOs) to upgrade their own broadband facilities. Broadband speeds are low and prices remain high compared to Asia and Europe.

Legislation to Protect the Privacy of Minors

Privacy is different from security. *Security lapse* refers to access by unauthorized people or organizations to personally identifiable information. The 2011 hacking attack that gained access to 70 million Sony game network subscribers is an example of a security lapse. *Privacy*, however, refers to control over personal information, the ability to make decisions regarding how people want information accessed, and which information they want available. Privacy settings on social networks such as Facebook are an example of how users control what information is available.

Currently, the only legislation in the United States that protects privacy is the 1998 *Children's Online Privacy Protection Act* (COPPA). This law grants parents of children 12 years old and younger the ability to control what information web sites collect about them. It does not apply to adults or teenagers younger than 18. Furthermore, it makes no mention of privacy on mobile networks or online apps (applications).

In 2011, Representatives Joe Burton and Edward Markey jointly filed legislation to update COPPA. The *Do Not Track Kids Act of 2011* updated COPPA in the following three ways.

1. It extends COPPA rules to sites accessed by mobile services and includes online apps.
2. It adds privacy safeguards to teenagers between the ages of 13 and 17 by which teenagers can control what information web sites are allowed to collect about them. For example, if the legislation is passed, teenagers will be able to control whether geolocation services can track and keep information concerning their whereabouts.
3. It mandates that, where technically feasible, web sites accessed by mobile handsets, computers using wired broadband, and online apps have an *eraser button*. Teenagers could use the eraser button to delete any personal information that was gathered.

This act has not yet been passed. Nor have any laws governing adult privacy been passed. Industry organizations oppose the Do Not Track Kids Act of 2011 on the grounds that it is unduly onerous. In addition, they stated that it would weaken privacy because web sites would collect information about web surfers' ages. They also argue that it discourages sites from directing content to teenagers because of the difficulty of complying with the act, thus limiting services to teenagers.

At present, individuals concerned about deleting untruthful or damaging information about minors must hire private services such as Reputation.com to attempt to correct or delete this information. These efforts are not always successful. Thus, young people, who often don't have the maturity to understand the damage that can be caused by careless web hosts, have little legal protection. It's also unclear, if a similar privacy act is passed, whether teenagers would understand the implications of allowing geolocation services to track and keep information about their location.

Efforts to Influence Regulations

Because telecommunications is so heavily regulated, all large mobile, cable TV, and landline providers spend sizeable amounts of money on court cases and on lobbyists to attempt to influence lawmakers and regulatory agencies.

Legal Challenges to FCC Rulings

Since the mid-1990s, providers have taken the FCC to court over rulings that they felt had the potential to negatively affect them. The courts have handed down significant judgments blocking many of these FCC rulings. For example, Comcast appealed the FCC fine imposed against it for blocking customers' access to a peer-to-peer site. In April 2010 the courts sided with Comcast and struck down FCC rules prohibiting broadband providers from slowing or delaying Internet traffic.

The courts also sided with large telephone companies in the following cases.

- The United States Court of Appeals for the District of Columbia struck down an FCC rule in March 2004 that made it possible for competitors to connect to an incumbent's switches and other equipment in central offices at deeply discounted rates. (Central offices contain the equipment used to send traffic to and from locations within cities.)
- They ruled that carriers are not required to provide access to their fiber-optic connections to customers.

These last two rulings were major blows to CLECs. More recently, in 2011, Verizon appealed to the courts, objecting to the FCC's December 2010 network neutrality rules that require broadband providers to allow customers access to the services of other providers. Verizon's position is that the FCC has no authority over broadband and Internet services. In the past, the FCC has regulated only voice services. As of this writing, the court has not ruled on the case. For more information on network neutrality, read Chapter 6, "The Internet."

Lobbying to Shape Government Regulations

Government regulations impact all phases of telecommunications, which is why almost all large and midsize providers such as Comcast, Verizon, and AT&T spend money on lobbyists every year. Moreover, lobbying expenditures spike when there are issues they consider critical. For example, in 2010 Comcast increased its lobbying spending when it needed the approval of the FCC and the Justice Department for its merger with NBCU. In the first quarter of 2011, when AT&T required approval to purchase T-Mobile USA, it spent $6.8 million on lobbyists, a 15 percent increase over the first quarter of 2010. In response to the AT&T planned merger, Sprint's lobbyists pushed legislators to impose rules that would have required the merged AT&T organization to divest itself of as much spectrum and as many cell sites as possible if regulatory approval were granted. This would enable other mobile operators to increase the footprint of their network coverage.

Over-the-Top Connections to Cable TV and Telco Broadband Customers

Companies such as Netflix provide services that compete with cable TV and telephone company cable TV services. For example, it streams movies and TV shows to customers. Other companies stream sporting events. These competitors, known as over-the-top (OTT) companies, require access to broadband providers' customers via cable and Digital Subscriber Line (DSL) networks. Their services ride "over the top" of the broadband provided by cable TV and telephone companies.

Beginning in 2010, there have been sharp increases in high-bandwidth streamed movies and TV shows that have added large amounts of traffic to last-mile networks. Users can stream content to view movies and hear music in real time, without storing the content on their tablets or computers.

Continued

Large telephone companies and Multiple System Operators (MSOs) control the majority of broadband last-mile networks. Comcast alone controls 22 percent of the cable TV connection market. However, entertainment-streaming applications compete with cable TV and telephone companies' own video-on-demand and television services.

Because Netflix does not have its own networks, when customers place a request to stream a movie, that movie is transmitted from a Netflix server to a *tier 1* broadband backbone provider, such as Level 3 Communications. Tier 1 providers own fiber-optic networks that transmit data between large cities. The broadband provider transmits the Netflix movie to the cable provider's data center that is closest to the subscriber. From there, the cable provider transmits the movie to the subscriber over its own network.

Until recently, cable TV and telephone companies did not charge tier 1 network operators for connections to their local networks. However, this changed when the amount of streaming content spiked. In late 2010, Level 3 Communications, one of the tier 1 carriers Netflix uses to carry its streaming traffic, informed Comcast that it needed extra connectivity capacity for streaming traffic at Comcast's local interconnection sites. Comcast attempted to collect monthly fees for this connectivity. After a series of discussions, Level 3 paid these fees but protested in letters to the FCC and the Justice Department. Level 3 stated that the Netflix service competed with Comcast's services, and Comcast's actions were anticompetitive.

In response, Comcast has stated that there is a great deal of competition with its services from providers such as Boxee, Amazon, and Apple, as well as satellite TV operators. Comcast further maintained that it provides interconnections for entertainment and media companies that stream services over its broadband network. In addition, Comcast stated that Level 3's requests were for peering connections. Peering sites are locations in backbone networks, where carriers exchange traffic addressed to locations on others' networks. In these instances, carriers that transmit many more IP packets over greater distances have traditionally paid to transmit IP traffic to carriers to which they connect.

Level 3 contends that the billing dispute with Comcast is not about peering traffic in the backbone portion of networks. Rather, this traffic is essentially localized traffic for connection to Comcast's customers. Level 3 further contends that the FCC's 2010 Notice of Proposed Rule Making (NPRM) explicitly forbade broadband carriers from charging competitors for access to their last-mile customers. This is because access is required to reach these customers, and it is not economically feasible for competitors to build their own broadband connections within cities.

Continued

Netflix and Comcast are holding continuing discussions over these payments. Level 3 plans to continue publicizing this issue.

Disputes of this type raise antitrust concerns because providers are able to place a lock on access to their residential subscribers. Moreover, content from providers such as Netflix competes with the services offered by cable TV providers. Several of the large cable TV operators own content or are expected to purchase providers that own content. For example, Comcast purchased a controlling interest in NBCU, which owns Universal Media Studios, NBC, Bravo, and others. It is highly possible that Comcast's actions will result in higher costs for competitors and will impair innovation by raising operating costs. In the aftermath of Comcast's actions, other cable TV companies and telephone companies have also started charging fees for these connections to their customers.

Cable MSOs feel strongly that their cable TV services are in jeopardy due to competition with rivals that are getting a "free ride" over their broadband facilities. These rivals can gain customers who are attracted by the lower prices and flexibility of streaming services. In reaction to these offerings, fewer people are signing up for premium cable services, as they switch to lower-cost services streamed over the Internet. Some of these customers keep basic cable services but drop the high-margin premium channels.

Although, the FCC prohibits broadband providers from charging competitors for access to their customers, some providers are negotiating payment arrangements for mobile as well as wireline networks. High volumes of video traffic impact mobile as well as wireline networks.

Network operators in Europe and the United States are negotiating new types of payments or jointly cooperating to increase network efficiency with Google, Inc.'s YouTube division. They are also exploring technologies such as storing more content on mobile devices to lessen the impact of video on wired and wireless broadband networks. It's not clear whether voluntary negotiations or regulations will be required to find a solution. These issues are complex because carriers offer services and billing platforms that compete with companies such as Apple, Google's YouTube, and Netflix.

THE STATE OF THE INDUSTRY ....

The telecommunications industry is dominated by organizations that are among the 100 largest companies in the United States. However, technological innovations have enabled companies such as Apple, Google, Netflix, and Amazon to encroach on services that were formerly the exclusive domain of traditional telephone and cable TV operators. Mobile operators, cable Multiple System Operators (MSOs), and Internet companies now vie with one another for revenue from mobile, Voice over Internet Protocol (VoIP), cloud, and entertainment services.

Traditional Telephone Companies

The two largest traditional telephone companies in the United States are AT&T, Inc, and Verizon Communications. They each offer home telephone service, mobile services, business long distance, global data networking, business telephone systems, and cloud computing. Their data services are supported by hundreds of data centers worldwide.

However, revenue for long-distance service, home telephone service, and business broadband is declining. AT&T, Verizon, and CenturyLink have built up their cloud-based applications and consulting services to compensate for declining revenue from their traditional businesses.

To that end, these carriers made investments, which include purchasing companies with expertise and infrastructure in cloud computing and hosting services. For example, in 2011 CenturyLink purchased Saavis, and Verizon purchased Terremark. Both of these acquired organizations offered cloud computing and hosting to business and commercial entities. Hosting refers to locating servers and entire data centers at a provider's data centers.

To build up their consulting resources, AT&T and Verizon hired staff members and brought in outside consultants to work with them on projects requiring special knowledge about particular software packages. These services are offered to small and midsize organizations as well as to global enterprises.

In addition to beefing up cloud computing and consulting services, AT&T and Verizon have made significant investments in mobile networks. They have both stated that mobile services are expected to be their largest source of revenue growth in the future. By the end of the first quarter of 2011, Verizon's mobile services accounted for 63 percent of its total revenue and AT&T's mobile services accounted for 45 percent of its total revenue.

The fiber structure over which AT&T and Verizon offer cable TV, home phone service, and Internet access services to their residential customers represented the first major wireline competition for all three services to most large cable TV operators. Previously, cable operators competed mainly with satellite for pay-TV services. However, due to the large investments and long time periods until these investments are profitable, AT&T and Verizon have suspended building out these "triple-play" facilities to additional areas.

They are now concentrating on marketing their pay-TV and broadband in areas where upgraded networks are currently available. The cost to add new customers in these areas is much lower than the cost to build new facilities. Once fiber is on telephone poles or in neighborhood nodes, a wire needs only to be run from the street directly to the subscriber. AT&T's U-Verse service does not include fiber directly to premises. Rather, U-Verse is a combination of fiber in the neighborhood, and copper cabling between the customer's home and the neighborhood fiber.

Verizon's FIOS (fiber-optic service) is available in approximately 58 percent of its territory. By the first quarter of 2011, AT&T stated that its U-Verse, cable TV/broadband offering is available in about 10 percent of its territory. According to media and communications analyst SNL Kagan, by the end of the first quarter of 2011, cable TV operators had 59.6 million subscribers, satellite providers had 33.6 million, and telephone companies had 7.3 million.

Both AT&T and Verizon are continuing to offer DSL service in areas where they don't provide pay-TV service. See Chapter 5, "Broadband and Wide Area Network Services," for information on DSL. However, their largest investments are in mobile networks and networking and cloud services to enterprise customers.

Mobile Operators

AT&T Mobility and Verizon Wireless are the largest mobile operators in the United States; they are also the only ones with nationwide coverage. Each of their networks covers areas that encompass approximately 300 million of the 312 million people in the United States, as of June 2011. Verizon Wireless is 55 percent owned by Verizon Communications; the United Kingdom's Vodafone owns the remaining 45 percent.

Cellular service, which was first available in 1984, was primarily used for voice until the late 1990s when text messaging became available on GSM mobile services. By 2001, Vodafone reported that it derives more revenue from text messaging than voice services. Advancement in mobile technologies has resulted in subscribers increasingly using their handsets for Internet access and e-mail as well as text messaging. Subscribers have substituted text messaging and e-mail for voice calling and are purchasing multipurpose smartphones that handle Internet access and apps in addition to voice. As mentioned earlier in the chapter, the term "app" is short for an "application" designed specifically for particular smartphones and tablet computers (as opposed to comprehensive and full-featured applications designed for use on more powerful computers, such as Microsoft Word or Adobe Photoshop).

In the face of declining voice revenue, carriers are seeking to increase revenue and profits by promoting data plans to customers and upgrading networks for additional capacity. These network upgrades require sizable capital investments in equipment and spectrum. Spectrum is made up of the airwaves that carry wireless signals. See Chapter 7 for more information on spectrum and mobile technologies. Carriers now also "cap" the amount of data that subscribers can transmit monthly and offer tiered options, with higher rates applied to customers who transmit higher amounts of data.

In addition to increased revenue, apps are making it more complex for customers to change carriers. Customers often find it simpler to remain with their carrier so that they don't have to repurchase their apps. In recent years AT&T and Verizon have had lower *churn rates*. This refers to the percentage of customers that change carriers annually. Lower churn rates result in savings on customer service for activating new customers and deactivating former customers' accounts.

Industry Consolidation

Until mid-2004, there were six major mobile carriers in the United States: AT&T Mobility, Verizon Wireless, Cingular, Sprint, Nextel, and T-Mobile USA. In 2004, Cingular purchased AT&T Wireless and changed the Cingular name to AT&T Mobility. In 2005, Sprint merged with Nextel, bringing the number down to four large mobile providers. Table 3-4 lists the largest facilities-based mobile carriers.

Industry consolidation that results in near-monopoly conditions has ramifications for customers as well as competitors. For customers, it can mean higher prices and less innovation. This is because monopolies have few incentives to be competitive with regard to prices or develop new features to attract customers.

Smaller mobile competitors suffer the disadvantage of higher operating costs. For example, large carriers have the clout to bargain for discounts on quantity purchases of cell phones and network equipment. These discounts are often unavailable to small carriers. Another disadvantage is that smaller providers don't have the resources to mount large TV and Internet advertising campaigns; thus, it's more difficult to attract new customers.

In addition to the resources to launch broader advertising campaigns, large mobile carriers have the financial strength to lease spectrum needed for additional capacity and next-generation data networks. In the 2008 FCC spectrum auction, Verizon and AT&T's combined bids were $12.8 billion; that was 67 percent of the $19 billion that was bid in total at the auction. This spectrum is suitable for next-generation Long-Term Evolution (LTE) data networks.

Table 3-4 *The Ten Largest Facilities-Based Cellular Companies in the United States*

Cellular Provider	Number of Connections*	Recent Acquisitions
Verizon Wireless	104 million	Purchased Alltel Corporation and Rural Cellular in 2008
AT&T Mobility	95.5 million	Purchased Centennial in 2008
Sprint Nextel	51 million	Owns 48 percent of Clearwire
T-Mobile USA	33.6 million	
MetroPCS	8.9 million	
Clearwire Corporation	6.2 million	Includes wholesale and retail
US Cellular	6 million	
Leap Wireless (Cricket brand)	5.9 million	
C Spire Wireless (formerly named Cellular South Inc.)	880,000**	
Cincinnati Bell	504,000	

**Source: Company web sites; includes postpaid, prepaid, and wholesale. Connections refer to the number of accounts rather than the number of subscribers. Some customers have more than one account.*

***Figure is approximate due to the fact that C Spire Wireless is a private company.*

In addition to the spectrum it leased in the latest FCC auction, AT&T announced its agreement to purchase unused spectrum for $1.93 billion from Qualcomm in 2010. Regulatory approval for the purchase was granted in December 2011. AT&T announced that it will be used for downlink capacity to accommodate traffic from its network to subscribers. The technology to use this particular spectrum will be available on the next generation of LTE technology by sometime in 2015.

Another disadvantage for many smaller carriers is their higher percentage of prepaid customers. Prepaid customers have higher churn rates and lower average revenue per user (ARPU). Because of higher costs and churn rates and lower ARPU, small carriers as a rule earn lower profits. According to an April 7, 2011 article on Reuters.com, "FCC mandates wireless data roaming," by Jasmin Melvin, if the AT&T Mobility purchase of T-Mobile USA had been approved, between them, AT&T and Verizon would have had 80 percent of all postpaid wireless customers.

The Canceled AT&T/T-Mobile USA Merger

In March 2011, AT&T announced an agreement to acquire T-Mobile. The merged company would boast 131.4 million mobile subscribers, which is 43.3 percent of the total mobile subscriptions in the United States. The CTIA, a nonprofit wireless industry association, reported that by December 2010, there were 302.9 million connections in the United States. The three largest mobile providers would have had 284.1 million subscribers, or 94 percent of the total connections if the merger had been approved.

To support its application for merger approval, AT&T filed comments at the FCC stating the following.

- It experienced an 8,000 percent increase in data traffic on its network between 2007, when it launched service for Apple's iPhone, and 2010.
- It didn't have enough spectrum for upgrades in some markets.
- It needed T-Mobile's spectrum for capacity to upgrade to more efficient network protocols.
- It had increased competition from providers such as MetroPCS and Leap.
- MetroPCS had double-digit market share in some key markets.
- USCellular had double-digit market share in many markets.

Most of AT&T's network is currently based on a technology that does not use spectrum efficiently. This decreases its overall network capacity. As AT&T upgrades its network to the current version of LTE, it will be able to carry 30 percent to 40 percent more traffic than it now carries, with the same amount of spectrum. AT&T started making LTE available in the fourth quarter of 2011.

In August 2011, the Justice Department sued to block AT&T's acquisition of T-Mobile, saying that the merger would harm competition and would likely lead to higher prices for consumers because T-Mobile offers more affordable service than AT&T and Verizon. It further reasoned that AT&T could substantially increase capacity by upgrading its network.

In November 2011, the FCC also voted to block the merger. A report it made public stated that the merger would result in layoffs in the merged company and no competition in cities where T-Mobile and AT&T both operate.

AT&T withdrew its application in December 2011 because the FCC and the Justice Department's rejection of the proposed merger made it less likely that the merger would occur. The FCC granted approval for AT&T's purchase of Qualcomm's spectrum in the weeks following AT&T's withdrawal of its merger application. Per its merger agreement, AT&T will pay T-Mobile about $4 billion; $3 billion in cash and the rest in a spectrum transfer because the merger was canceled. T-Mobile's parent company, Deutsche Telekom AG, has stated its intention to find a different buyer for T-Mobile.

Analyzing the Impact of a Merger on Consumers and Competition

Mergers between large telecommunications companies require approval of the Federal Communications Commission (FCC) and the Department of Justice. The FCC bases its approval or disapproval on the impact the merger would have on customers. It might disapprove a merger if it determines that the merger is not in the interest of consumers.

The Department of Justice evaluates mergers based on the competitive nature of markets. The FCC and the Department of Justice keep one another apprised during the process. They also bring in outside consultants to help them evaluate the impact of the proposed merger and additionally accept comments from the public. As a rule, competitors and other companies such as suppliers that might be impacted by the merger submit comments.

Generally, when large mergers are approved, there are conditions that must be satisfied for approval. This occurred when Verizon Wireless acquired Alltel in 2008.

Mobile Virtual Network Operators

Not all cellular companies own the networks over which they sell mobile service. Providers that sell mobile service over other companies' mobile networks are called Mobile Virtual Network Operators (MVNOs). MVNOs buy mobile airtime in bulk at discount rates. They mark up and resell airtime and mobile services to their own customers. MVNOs bill customers and provide customer service for repair and billing issues. TracFone Wireless, Inc., a unit of Mexico's TelMex, is an MVNO. It supplies prepaid service under a number of brand names but owns no mobile network infrastructure. Other MVNOs have been successful tapping into particular ethnic groups. For example, China Telecom announced plans to start an MVNO targeting Chinese residents such as students, tourists, and business people who travel between China and the United States. It plans to offer handsets that can operate in both countries.

AT&T, Verizon, and Sprint offer wholesale services to MVNOs. Wholesale services are a way for network owners to recoup some of their investments associated with upgrading networks. Sprint sells unused capacity to MVNOs. It is able to "fill up more of its pipes" and earn revenue, even though revenue per user for wholesale services is lower than that for retail customers.

Carriers also arrange for connectivity to their network to be embedded in devices. For example, e-readers, USB modems (also referred to as dongles), and laptop computers can have cellular connections embedded directly in them. This is a way for developers of new applications to gain access to mobile networks.

Selling Wholesale Services Exclusively

All major mobile operators offer wholesale services to other carriers, but some operators provide wholesale services as their primary or only strategy. The availability of wholesale networks has important implications for competition and innovation. Organizations that develop innovative mobile services on handsets are able to offer them on wholesale carriers' networks, thus precluding the need to build their own. This is important because mobile network operators that sell directly to customers might be reluctant to provide their finite network capacity for competing offerings.

Another advantage of wholesale networks is that these operators can offer competitive roaming rates to carriers without nationwide coverage. Retail carriers have no incentive to provide competitive roaming rates to competitors in the nationwide carrier's territories. Roaming refers to subscribers using their cell phones beyond their own carrier's coverage areas. Competition for roaming can be problematic for data services because they require large amounts of capacity, which might not be available on an incumbent's network if it is near capacity.

Clearwire is an example of a wholesale provider. Clearwire, which is 48 percent owned by Sprint, has some retail customers but is now concentrating on wholesale customers. Time Warner Cable and Comcast, which sold mobile services on Clearwire's network, have announced plans to discontinue these sales. Clearwire has not completed building out its nationwide network. It has nationwide spectrum. Clearwire owns the largest amount of spectrum of any carrier in the United States.

Carriers that operate primarily as wholesalers save money on marketing, retail stores, billing, and staff. It hopes to make up for lower per-user revenues with savings in operating costs and its customers' quantity leases. Depending on the arrangement with each carrier customer, it might also offer handsets and billing platforms to the carrier.

The FCC has repurposed satellite spectrum for terrestrial service to alleviate spectrum shortages. Terrestrial cellular refers to service delivered via towers, as opposed to wireless service transmitted through satellites. It is likely that a satellite provider will request permission to use a portion of this spectrum for terrestrial service.

Cream Skimming: Concentrating on Profitable Markets

When carriers enter a new market, they often do so in areas where there is potential for large profits. This concept is known as *cream skimming*. Cream is skimmed from lucrative markets such as wealthy suburbs or markets with few providers. This occurred when AT&T and Verizon first offered cable TV service bundled with voice and Internet access. They often selected wealthy suburban areas with more customers that could afford high-margin premium cable channels and video on demand. They avoided very large cities where difficult-to-cable areas could drive up their installation costs. Mobile companies such as MetroPCS expanded to large cities such as Boston and New York City that have large concentrations of customers. New entrants often compete in part by setting their prices lower than existing mobile, cable TV, or wireline carriers. MetroPCS targets young and lower-income subscribers.

Cable Multiple System Operators

Cable TV companies with more than one system are known as Multiple System Operators (MSOs). At the end of the fourth quarter of 2011, there were a total of 60 million cable TV subscribers in the United States. Despite competition from satellite TV and telephone company pay TV, MSOs are still the dominant providers of pay TV and residential broadband. However, MSOs lost subscribers between the first quarter of 2010 and the first quarter of 2011 (see Table 3-2).

Moreover, their revenue from premium content is slipping as consumers increasingly sign up for lower-cost "over-the-top" (OTT) movies and TV from providers such as Netflix and Hulu. Subscribers are also switching to satellite TV and telephone company pay-TV services. Economic downturns and annual price increases for cable TV have also spurred subscriber losses. Table 3-5 shows the quarterly increases in satellite TV and telephone company pay-TV subscribers, and decreases in cable subscribers.

At the same time that MSOs are facing increasing competition, their costs to license content have increased. Certain of these pricing increases have resulted in stand-offs between MSOs and content providers. One dispute resulted in cable TV channels going dark for a few days during Major League Baseball's 2010 National League Championship Series.

Comcast is by far the largest cable operator, with service in 39 states and a 38 percent share of total cable TV subscribers. One factor in Comcast's market share is its 2002 acquisition of the former cable arm of AT&T, AT&T Broadband. AT&T Broadband had previously purchased the largest MSO, TCI, as well as MediaOne. In 2006 Comcast and Time Warner Cable each purchased the properties of bankrupt Adelphia Communication that were adjacent to their coverage areas.

Table 3-5 Quarterly Trends in Satellite TV, Telco, and Cable TV Subscribers

Multichannel Subscriber Summary Q1 2011 (in millions)

Company	Subscribers Q1 ′10	Q4 ′10	Q1 ′11	Year over Year % Change
Satellite TV				
DIRECTV	18,660	19,223	19,407	4
DISH	14,337	14,133	14,191	(1)
Total DBS*	**32,997**	**33,356**	**33,598**	**2**
Telco				
Verizon	2,914	3,472	3,664	26
AT&T	2,295	2,985	3,205	40
Other Telco	350	451	467	33
Total Telco**	**5,559**	**6,908**	**7,336**	**32**
Cable				
Comcast	23,477	22,802	22,763	(3)
TW Cable	12,817	12,422	12,357	(4)
Charter	4,725	4,520	4,497	(5)
Cablevision†	3,367	3,314	3,306	(2)
Suddenlink	1,249	1,216	1,217	(3)
Mediacom	1,234	1,193	1,175	(5)
Insight	723	692	693	(4)
Total	**47,592**	**46,159**	**46,008**	**(3)**
Other Cable‡	14,210	13,677	13,624	(4)
Total Cable	**61,801**	**59,836**	**59,632**	**(4)**

**DBS = Direct Broadcast Satellite*
***As of first quarter 2011. Includes facilities-based video subscribers only.*
†Cablevision pro forma acquisition of Bresnan in December 2010; estimated first quarter 2010 and reported figures in fourth quarter 2010 and first quarter 2011 include Bresnan.
‡Includes estimates for Cox, Bright House, and other MSOs.

To broaden the scope of its offerings, Comcast purchased controlling ownership of NBCUniversal in 2010. Comcast previously owned E!, Versus, and the Golf Channel. As a result of the NBCU purchase, Comcast now owns the NBC broadcast network, MSNBC, USA, BRAVO, and Universal Studios. This provides Comcast with control of both content and distribution for its customers. It additionally earns revenue for licensing rights from pay-TV operators that air its TV shows and movies. It both competes with and sells to satellite TV, telephone companies, Apple, Amazon, and others.

Cable Service for Business Customers

When MSOs first offered "triple-play" (voice, cable TV, and Internet), they pulled residential voice and Internet access subscribers away from telephone companies. MSOs compete with them for business customers, as well. They offer Internet access and voice calling to small-business customers. To develop new revenue streams over their existing cabling infrastructure, many now offer an expanded suite of services to mid-size organizations, as well.

Time Warner Cable, Inc., also known as tw cable, has expanded its voice and Internet access services to include data communications between customer sites, security services, and cloud computing. Time Warner Cable was formerly part of entertainment conglomerate Time Warner, Inc. To enhance its cloud computing and hosting capabilities, tw cable purchased NaviSite in 2011. NaviSite operates nine data centers in the United States and the United Kingdom.

Another service that cable operators offer to business and retail customers is TV. For example, they might install television service in every room in a hospital or hotel. They also sell TV service to restaurants, bars, and doctors' offices.

Delivering TV and Movies to Mobile Devices

In response to competition from OTT providers such as Netflix, YouTube, and Hulu, cable operators are in various stages of making their content available on more devices than just TVs connected to set-top boxes. They also see this as a way to retain subscribers that use tablet computers as their entertainment platform, Most pay-TV operators are planning to allow only their own subscribers to view their content on mobile gear.

The following are among the hurdles that cable TV operators need to overcome to offer their entertainment on mobile devices.

- **Rights** It's not clear if MSOs' rights to content only include airing TV shows and movies over their own cabling infrastructure. New, complex arrangements and contracts need to be negotiated to license content for distribution to mobile handsets. Currently, MSOs are engaged in disputes with content providers such as Viacom over rights to stream TV and movies to tablet computers over the MSO's cabling infrastructure.

- **Number of devices** Each operator must determine the number of devices on which each user account is allowed to view content. If too many are authorized, will subscribers give their passwords to friends and relatives?
- **Technological issues** Operators need to make their content compatible with the operating systems and software of the many different mobile handsets that can be used to view video.

Backhaul Services

Another way that cable operators add services to their existing infrastructure is by leasing spare capacity on their backbone networks to mobile operators. MSOs use their backbone networks to link their local cable TV facilities to centralized headends that distribute TV and movies and perform functions such as billing and links to the Internet and other networks. Backhaul services that mobile providers lease link cell sites (towers and antennas) to the data centers that support functions such as security and billing. Large cable TV operators as well as small mobile operators lease backhaul capacity in locations where they don't have their own backhaul infrastructure. See Chapter 7 for more information on backhaul and cell sites.

Endeavors in Mobile Services

Cable MSOs offer limited wireless services on Clearwire's and Sprint Nextel's mobile networks. Of Time Warner Cable's 12 million subscribers, only 13,000 subscribed to mobile broadband by the end of 2010. These services are offered on Clearwire's network and are for data only, not voice. Comcast also offers mobile services in certain of its cities on Clearwire's network. However, both Time Warner Cable and Comcast have announced plans to end their partnerships with Clearwire. Comcast along with Time Warner Cable and Bright House Networks have all invested in Clearwire. Due to Clearwire's continuing losses, Comcast and Time Warner Cable have written down the value of their investments in Clearwire.

The major MSOs purchased large swaths of valuable spectrum that cover 80 percent of the continental United States through their joint consortium, SpectrumCo, LLC. The consortium was formed to jointly invest in spectrum. Its current investors are Comcast, which owns 63 percent, Time Warner Cable with 31.2 percent, and Bright House Networks at 5.3 percent. The consortium purchased its spectrum at the 2006 FCC auction.

Sprint Nextel and Cox sold their interests in the SpectrumCo consortium. Cox kept the spectrum that was in its own territory. Cox purchased additional spectrum in a 2008 FCC auction and used its spectrum to begin building out a mobile network. It offered service in three markets in 2009 and two more markets in early 2011. In May 2011, Cox announced that it was shutting down its mobile network and that it preferred to offer service on Sprint's network.

The cable companies with spectrum that SpectrumCo won in the 2006 auction were required to build a network on the spectrum by November 29, 2021 or forfeit their rights to it. (FCC auctions specify dates by which bidders must build networks on the spectrum that they've been awarded.)

In December 2011, Verizon Wireless announced that it had entered into an agreement with SpectrumCo to purchase its spectrum for $3.6 billion. SpectrumCo had paid $2.2 billion for the spectrum and thus will realize a profit of $1.4 billion if the FCC approves the purchase (as of this writing, the proposal is still being evaluated and mobile competitors are protesting that the sale will give Verizon an unfair advantage).

As part of the agreement, they will sell each other's services. Verizon will sell the cable companies' broadband and TV services and the MSOs will sell Verizon Mobility services. If the spectrum sale is approved and the agreement implemented, MSOs will concentrate investments and expertise on TV and broadband services to residential and business customers.

The agreement specifies that in four years, customers of Verizon and the cable TV operators will be able to receive a single bill for mobile, TV, broadband, and voice services. Prior to that, the partners will sell the services to one another's customers, but MSOs and Verizon will continue to bill for services on their networks. Profit margins will be lower than sales of services on their own networks, but capital and operating expenses will be minimized on the wholesale offerings.

In December 2011, Cox also entered into an agreement to sell spectrum to Verizon. The agreed upon price was $315 million. They further decided to sell each other's services and to collaborate on ways to integrate wireless and wireline services. Cox is selling only a portion of its spectrum to Verizon.

Other Competitors to Broadband Providers

Overbuilders were the first facilities-based competitors to cable TV operators. They began offering service immediately following passage of the Telecommunications Act of 1996, which permits competitors to offer services "over" incumbent cable TV operator's equipment. Overbuilders run their cables over incumbent MSOs' cables on telephone poles in residential neighborhoods. However, they reuse the drop wires installed by the incumbent cable TV operator. A drop wire is the cable from the telephone pole to an individual residence. RCN and Atlantic Broadband are examples of overbuilders.

In contrast to direct broadcast satellite television, overbuilders offer voice telephone service and Internet access in addition to pay-TV. Some also sell services to business customers in areas where they operate.

However, overbuilders underestimated the cost of building and maintaining these networks. They also overestimated their ability to win customers from incumbent cable television operators. One factor in the difficulty of attracting enough customers to be profitable was their lack of financial heft to mount the widespread TV and print advertising campaigns incumbents mount.

RCN Corporation is the largest overbuilder. It offers service in New York City, eastern Massachusetts, Philadelphia, and Washington, DC. RCN declared bankruptcy in 2004 and still was not consistently profitable after emerging from it. Private equity firm ABRY Partners purchased RCN in 2010. ABRY has investments in a number of telecommunications firms including cable TV providers Atlantic Broadband and Grande Communications.

Competitive Carriers

Competitive carriers offer similar products and services as AT&T, Inc., and Verizon Communications. Windstream and EarthLink are examples of competitive carriers. These carriers sell advanced data communications services, Internet access, and voice calling, and after 2006, they branched out to hosted and cloud computing services. For the most part, they do not offer mobile services. Competitive broadband providers are also referred to as Competitive Local Exchange Carriers (CLECs) or integrated network providers.

CLECs compete against incumbent telephone companies, cable TV operators, and one another for commercial customers. For the most part, they sell to small and mid-size companies rather than international conglomerates because they don't have the nationwide coverage or intracity last-mile connections directly to customers that large incumbents own.

Those competitive carriers that remain are facilities-based operators that own inter-city fiber-optic networks and the equipment (switches and multiplexers) used to transmit traffic between locations. Although these facilities are not as extensive as AT&T, Verizon, and CenturyLink, they do give them control over the quality of services over interstate networks and often metropolitan areas where they offer service to customers.

These competitors compete with cable TV operators and large incumbents. Many of them have purchased other providers. This increases their coverage area, and enables them to cut overhead costs, expand their offerings, and gain bargaining clout with suppliers. It has also provided them with the resources to mount more sophisticated marketing campaigns.

In addition, the industry has benefited from a slimmed-down structure with customers divided among a more limited number of carriers. These mergers often are for companies with cloud and managed service infrastructure in the form of data centers and the technical staff to support these computer services. Table 3-6 lists a sampling of mergers between competitive providers.

Table 3-6 *A Sampling of Competitive Provider Mergers*

Parent Company	Acquired Company: Year	Information about Acquired Company
EarthLink Formerly sold Internet access to residential and business customers. Now concentrates on business customers.	Deltacom: 2010	Owned a fiber-optic network in the Southeast. Offered services to small and midsize businesses.
	One Communications (DBA One Comm): 2010	One Communications was created through a 2006 merger between CTC Communications, Conversent Communications, and Choice One Communications. Offered voice and data services in the Northeast, Midwest, and mid-Atlantic regions.
Level 3 Originally sold mainly wholesale IP over its global fiber network. Due to a series of purchases of smaller competitive local exchange carriers (CLECs), it now offers hosting and data services to business and government customers. Also provides content delivery network (CDN) service, in which it stores frequently requested entertainment-related web content near customers. CDN services are based largely on patents purchased from Savvis, Inc., in 2007.	TelCove: 2006	Owned a fiber-optic network on the East Coast plus facilities within cities.
	Progress Telcom, ICG Communications, WilTel Communications Corp.: 2006	All owned fiber networks in many of the same markets as Level 3.
	Broadwing Corp.: 2007	Sold services to business customers, Internet access, and wholesale transmission to carriers on its 19,000-fiber network. Sold service throughout the United States. Was headquartered in Austin, Texas.
	Looking Glass Networks: 2007	Owned fiber networks and connection facilities for other carriers in major metropolitan areas.
	Global Crossing: 2011	Owned long-haul fiber-optic links, mainly in the United States, Europe, and Latin America. Provided Level 3 a foothold in Latin America.

Parent Company	Acquired Company: Year	Information about Acquired Company
TelePacific Communications California-based competitive provider. Also provides service in Nevada.	NextWeb (DBA Covad Wireless): 2011	Covad provided hosted VoIP phone systems and other hosted services as well as fixed wireless broadband Internet access to business customers. Wireless in California, Nevada, and suburban Chicago. Formerly owned by MegaPath.
	IXC Inc. (DBA Telekenex): 2011	IP service provider in California and Washington. Offered hosted VoIP telephone and security as well as managed network services.
	Orange County Internet Exchange (DBA OCiX): 2011	CLEC in California and Nevada that offered voice and data communications.
tw telecom inc. Previously owned by Time Warner Cable. Offers a range of web-hosted and data services. It owned fiber networks between cities and connections to some commercial buildings in part of its territory.	Xspedius Communications, LLC: 2006	Offered voice and data services over its fiber-optic networks in 31 metropolitan markets throughout the South, Texas, and the Southwest. Headquartered in Missouri.

Table 3-6 *(Continued)*

Parent Company	Acquired Company: Year	Information about Acquired Company
Windstream Communications	CT Communications: 2007	A local phone company in North Carolina.
In 2006, Sprint spun off its incumbent phone company Alltel, which was headquartered in Kansas. Windstream was formed through its merger with Valor Communications, the local phone company headquartered in Arkansas. Windstream operates in mainly rural areas in the South. Its acquisitions in 2010 and 2011 provide resources for its current focus on broadband and enterprise services. Majority of revenue from broadband and enterprise services.	D&E Communications	A local phone company in part of Pennsylvania and a CLEC elsewhere in Pennsylvania.
	Lexcom Inc.: 2007	Was a small phone company in North Carolina.
	Iowa Telecom: 2010	Local phone company in Iowa and Minnesota.
	NuVox Inc.: 2010	CLEC with approximately 90,000 business customers.
	Q-Comm Corp.: 2010	Regional fiber network. Provided local phone services in Indiana.
	Hosted Solutions: 2010	Provided hosting and cloud services to businesses and co-location services to carriers.
	Paetec Holding Corporation 2011	Adds seven data centers and plans for an additional five that support managed and cloud services. Paetec also has a 36,700-mile fiber network and a large portfolio of business and commercial customers. Brings Windstream coverage to parts of 46 states and additional urban areas.

Independent Telephone Companies

Independent telephone companies are incumbent local telephone companies that have never been part of the former AT&T's Bell System. They are often located in rural areas that AT&T had no interest in serving and in small and midsize cities. Like Verizon and the current AT&T, many of the largest independent phone companies have purchased competitors and expanded into new data services. Examples of large independent phone companies include Cincinnati Bell, Frontier Communications, Fairpoint, and Windstream. Table 3-6 lists the acquisitions that have enabled Windstream to grow and enter new markets.

Because many customers have replaced home telephones with cell phones, revenues from voice calling have declined sharply. This has motivated large independent telephone companies to branch out into other services including cloud computing and managed services. Managed services are functions such as security, a data center, or a software application such as security for customers that are implemented and managed by a provider. Acquisitions and data services have often resulted in geographic expansion.

While independent telephone companies are often the only choice consumers in rural areas have for home telephone and cable TV service, these phone companies frequently face competition from mobile providers. In response, some independents have built their own mobile networks; others resell mobile services that they purchase wholesale. This is the case with Frontier Communications, which offers its customers mobile services on the Verizon Wireless network.

Independent telephone companies also compete with cable TV operators in parts of their territories. In response to competition from large cable TV operators, companies such as Frontier sell deeply discounted satellite TV, where they don't have their own infrastructure for cable TV.

The following are examples of two independent telephone companies.

- Cincinnati Bell, headquartered in Cincinnati, Ohio, offers service in southwestern Ohio, and northern and southeastern Kentucky. It is hoping to grow and expand its offerings through its 2010 acquisition of CyrusOne. CyrusOne manages data centers for its installed base of small and midsize business customers. It operates seven data centers in Texas and is planning to build a new one in London.
- Frontier Communications, formally called Citizens Communications Corporation, is headquartered in Stamford, Connecticut. It purchased 4.8 million rural phone lines from Verizon Communications in 2010, giving it a total of 5.6 million phone lines. It is attempting to offset losses in revenue from voice services by building up its broadband offerings to consumers and business customers in its coverage areas.

Agents

Agents act as independent representatives for carriers. Like insurance agents, a carrier's agent receives commissions on services that it sells. AT&T, Verizon, and CenturyLink started agent programs as a way to lower the cost of selling services to small businesses. Today many agents sell telephone services as an adjunct to the telephone and networking systems that they offer. Agents are certified and receive some training from the telephone companies they represent. They do not bill customers directly for the voice and data services they sell; rather, customers receive bills directly from the carriers.

Primarily small and midsize organizations use agents because they are often easier to reach and some have the ability to help troubleshoot problems when it is not apparent whether the problem is in the carrier's connections or the onsite equipment. Smaller competitive carriers also use agents. Moreover, carriers often prefer to serve smaller business customers with agents to reduce their own staffing and selling expenses.

Retail outlets such as Best Buy, Radio Shack, and Staples act as agents for cellular providers and prepaid cellular services. Wal-Mart and Amazon sell TracFone's prepaid mobile phones and services. In addition to large retailers, there are often networks of small retailers that act as agents for larger companies such as T-Mobile and Verizon Wireless. The small retailers display the logos of the carriers that they represent in their stores and sell hardware and accessories for mobile phones in addition to service plans.

Resellers

Like agents, resellers do not own network infrastructure. Unlike agents, however, resellers provide billing and customer service for their customers and market services under their own brand. Resellers sell wireline service such as data (T1, T3, and other high-speed services), calling cards, Internet access, local calling, long-distance, mobile services, VoIP services, and international calling.

Resellers purchase services at discounts, mark them up, and often offer them at below retail cost. Resellers offer services carried on networks owned by AT&T, Sprint, Level 3, Verizon, and other carriers, worldwide. Competitive providers such as TelePacific and tw telecom resell service in areas outside of their own coverage areas. This provides them a way to offer nationwide service. In their own coverage area, these and other competitive providers have their own networks and switches but might lease just the last-mile broadband from incumbents.

NONTRADITIONAL COMPETITORS: AMAZON, APPLE, GOOGLE, MICROSOFT, AND NETFLIX.............

Amazon, Apple, Google, Microsoft, and Netflix have all developed innovative products and software that have had enormous influence on the Internet, consumer services, and business operations. They are formidable competitors to older companies. Improved software, availability of financing, cash from years of high-margin operations, and high-capacity networks have fueled innovation and provided the wherewithal for each of them to expand the scope of their services.

Ready cash from operations was one factor in Google's ability to purchase more than 100 companies between 2001 and 2011. Because of acquisitions of startups and software firms in possession of key patents or software, Google has enhanced its advertising offers with important billing and automation capabilities. Facebook, Apple, and Netflix had the cash to lure skilled software engineers who incorporated appealing, user-friendly interfaces into their services. These companies regularly acquire specialized skills by poaching employees from companies with particular expertise. In one case, Amazon hired IT staff members away from Wal-Mart to develop its e-commerce billing and shipping applications. Wal-Mart sued, and the case was settled out of court.

Companies that were associated with Internet-only services are now competing with more traditional carriers for entertainment and VoIP calling. Microsoft and Amazon offer VoIP, streaming TV and movies, and importantly, cloud services. These offerings compete directly with cable TV operators, telephone companies, and mobile carriers. Boundaries between industries have blurred.

Microsoft, which sells the lion's share of office productivity software, has seen that business eroded by cloud-based office software from Google and Amazon, which by virtue of their pay-per-use models offers savings to businesses and consumers over traditional software licensing fees. Netflix, the largest distributor of video in the United States, has competition for its TV and movie streaming from Amazon and Apple. Amazon in particular has an advantage through its low-priced tablet. The tablet is a vehicle for downloading books and streaming and downloading TV shows and movies from Amazon's cloud. Cable companies are under pressure from Netflix, and other streaming and mobile providers are losing voice revenues in part because of Microsoft's Skype service.

Cable TV operators and many of the telephone companies in the United States provide service only or primarily in the United States. (AT&T and Verizon do have a global reach, but only for business and commercial customers.) In contrast, Internet companies, while needing to conform to regulations in other countries, are not as restricted by geography and can more readily offer services worldwide. The growth of mobile computing in developing nations provides them with additional growth opportunities.

Google's Strategy of Enhancing Service through Acquisition

Google is a global technology company that operates what many consider to be the largest collection of indexed information on the Web. It was incorporated in 1998 as the culmination of a Stanford University Ph.D. project by its founders, Larry Page and Sergey Brin. The project centered on the development of an algorithm to prioritize the placements of responses to searches. Google's early search service was based on this algorithm.

Over the years, Google purchased other companies and patents to improve search results and to monetize search by improving services to advertisers. It has also made acquisitions as a way to gain intellectual property needed to enhance its range of service offerings. Table 3-7 lists Google's key acquisitions.

Google earns the majority of its revenue from advertising on its search sites. During the first quarter of 2011, advertising revenue accounted for 97 percent of Google's total sales. Recently, Google's main competition for ad revenue has come from Facebook and from Chinese search company, Baidu. To diversify and develop new sources of revenue, Google mounted a head-on challenge to Facebook by developing Google+, a new social networking application. To differentiate itself from Facebook and attract customers, Google added features including the ability to organize friends into groups such as family, relatives, and professional contacts.

Table 3-7 *Google's Key Acquisitions*

Acquired Company: Year Acquired	*Description of Purchased Organization's Technologies*
Applied Semantics: 2003	Its product, AdSense, is the basis for Google's paid search advertising technology.
Picasa: 2004	A photo sharing site.
Keyhole Technologies, Zipdash, Inc., and Where2, LLC: 2004	Software from these three organizations was used to develop Google Maps.
Android: 2005	Developed the now-ubiquitous mobile operating system that Google provides at no charge to mobile carriers in exchange for being the default mobile search engine on Android mobile handsets.
YouTube: 2006	Initially for sharing short videos, now streams TV shows and feature-length movies. Provides a site for video ads.
DoubleClick: 2007	Developed technology that automates placements of display ads for ad agencies and advertisers. Display ads are large and splashy.
GrandCentral: 2007	Used for Google Voice. Also acquired GlobaIP in 2007 which provided VoIP and video conferencing capabilities for mobile hardware manufacturers.
AdMob: 2007	Mobile advertising network. Advertisers can use advertising networks to place ads on multiple sites simultaneously.

Acquired Company: Year Acquired	Description of Purchased Organization's Technologies
Postini: 2007	Developed technology for businesses to block spam and archive business customers' messages. Google uses this software in Gmail, its e-mail service.
Plannr: 2010	Mobile schedule manager and event coordinator.
ITA travel service: 2011	Flight information for airlines, travel agencies, and other search engines.
Admeld: 2011	Developed software that helps large web sites sell and manage advertising on their sites.
Motorola Mobility Holdings, Inc.: Announced in 2011	Approved by federal and European Union regulators. Approval by China pending. This $12.5 billion acquisition (the company's largest to date) will provide Google with design and manufacturing capabilities for mobile devices and cable TV network infrastructure. Motorola has a large portfolio of valuable wireless and telecommunications patents.

In response to competition from Facebook and search companies such as Baidu, and in order to diversify, Google has developed a variety of offerings, including the following

- Online music storage
- Web-based movie rentals
- E-book purchases
- E-mail service (Gmail)
- Mapping (Google Maps and Google Earth)
- Instant messaging (Google Talk)
- Payment services (Google Checkout)
- Mobile operating system (Android)
- Computer operating system (Chrome OS)
- Internet browser (Chrome)
- Over-the-top video (Google TV)
- Social network (Google+)

In addition to these offerings, Google has undertaken initiatives in broadband. It led a consortium of six other companies that built a trans-Pacific cable between Tokyo and California that was completed in 2010. It also announced plans in 2010 to build a high-speed fiber network in a number of small cities. Its stated purpose for the network was to experiment with applications for rural residents that required higher-capacity networks than those currently available. To that end, it opened a bidding process for communities to apply for the ultra-fast fiber network. Eleven hundred cities submitted requests; Google chose Kansas City, Kansas, as the first city to receive the network. Google announced that the network would be available in 2012, pending permits from the city. As part of the project, Google is working with local organizations to develop gigabit applications for the network.

Another Google initiative focuses on mobile, contactless payment systems using Near Field Communications (NFC) technology. NFC is a system by which mobile smartphone users can pay for purchases by simply waving their phones close to retail credit card readers. Contactless technology refers to the fact that the payment device does not have to physically connect to the payment reader. This contrasts with current credit card scanner technology which requires the card to be swiped through the reader.

Google will not receive transaction fees for the services. Rather, it has announced that it will make applications available for Android handsets, on which subscriber-targeted ads or discount offers will be displayed. This is an avenue to increase mobile advertising revenue. The initiative is a joint effort with MasterCard and Citigroup, which will provide the banking service, and VeriFone Systems Inc., which will supply credit card readers in retail outlets.

The NFC initiative is part of Google's mobile software strategy. Other pillars in this strategy include putting the Google name on the mobile smartphone manufactured by Samsung and expanding its app store, Android Market, to include e-books and music. An app store sells programs designed specifically for mobile devices. These efforts are in direct competition with Apple, Amazon, and other mobile carriers. To lessen subscribers' dependence on Facebook, Google's new mobile operating system no longer enables subscribers to sync their Facebook contact list to their Android device. Syncing enables changes in one contact list to be automatically updated on the other contact list.

Amazon

Amazon.com is currently the largest online retailer in the world. When it was founded in 1994, it only offered books from its online site. It later diversified into electronics, home goods, clothing, and many other areas. Many of these products are offered by third-party retailers who offer products on Amazon's site in exchange for a share of Amazon's revenue. In addition to its United States–based web site, it has online stores in Canada, China, France, Germany, Japan, and the United Kingdom. Its sites in China and the United Kingdom grew out of acquisitions of online sites in those two countries.

Amazon leveraged its data center expertise and infrastructure to create its cloud computing services, Amazon Web Services. It also offers small and midsize companies access to its data center technology for developing and testing software applications. Amazon created the first large-scale cloud computing platform that it offers to residential as well as business customers.

In conjunction with its cloud offerings, Amazon also sells music and video storage, in direct competition with Apple and Microsoft. It has branched out to a subscription service with a low annual fee that provides access to free streaming from its library of 5,000 DVDs. For an additional fee, Amazon also offers short-term video rentals that can be ordered online.

Another major innovation was Amazon's introduction of its Kindle e-reader. Kindle has had a major impact on publishing and the way people purchase books. Customers now purchase more electronic books than printed books from Amazon. Like Apple devices, the Kindle is based on a proprietary format (.mobi). Only books in a compatible format can be downloaded to the Kindle. Sales of online e-books benefit Amazon in two ways: It saves money on mailing and warehouse expenses, and Kindle owners are locked into purchasing e-books from Amazon. With the introduction in 2011 of its low-priced tablet computer, the Kindle Fire, Amazon has the potential to attract many more Kindle Fire consumers to its video streaming, as well.

Amazon has invested strategically for the long term in data center infrastructure and key offerings. For example, it priced the Kindle Fire below cost to further sales of online e-books, entertainment, and cloud storage. This is analogous to razor companies selling inexpensive razors but earning high profits in sales of razor blades.

All of Amazon's services and capabilities have been strengthened by acquisitions. A sampling of Amazon's acquisitions is listed in Table 3-8.

Table 3-8 *Amazon's Key Acquisitions*

Acquired Company: Year Acquired	*Description of Purchased Organization's Technologies*
Bookpages.co.uk: 1998	Online book retailer, based in the United Kingdom.
Telebook: 1998	Operated under the brand name ABC Bucherdienst; was the largest online book retailer in Germany. It became Amazon's web site in Germany.
Internet Movie Database (IMDb): 1999	User ratings and information on movies, actors, crew members, and other associated contributors.
Joyo.com: 2004	Chinese e-commerce web site.
BookSurge: 2005	A print-on-demand book company.
Mobipocket.com: 2005	An e-book software company.
CreateSpace.com: 2005	Distributor of on-demand DVDs.

Table 3-8 *(Continued)*

Acquired Company: Year Acquired	Description of Purchased Organization's Technologies
Brilliance Audio: 2007	Publisher of audio books.
Audible.com: 2008	Provider of digital audio books. Audible.com audio books can be downloaded to Amazon's Kindle e-reader.
Zappos: 2009	Online shoe and clothing retailer.
Touchco: 2010	A developer of touch screens using lower-cost technology than that on the iPad and iPod. As of July 2011, Amazon's Kindles were equipped with touch screens.
Woot: 2010	A deal-a-day web site.
Lovefilm: 2011	Offered streaming movies, DVD, and game rentals throughout Europe.
Book Depository: 2011	One of the three largest online retailers along with Amazon in the United Kingdom.

Apple

As of this writing, Apple, Inc., is the world's most valuable company with a market value of approximately $510 billion. It creates both the hardware and operating system software on its desktops, laptops, tablets, and media players. To a large extent, it also controls the applications that users download from its App Store. Apple screens every application before it allows developers to sell apps in its online store.

This control is one factor that has enabled Apple to maintain the high quality of its products. Apple is currently the leader in premium, high-end products. Its devices are priced at the high end of their respective market segments.

Apple devices are based on proprietary operating systems and software. They are "closed" systems that require applications and printers that are compatible with Apple's operating systems. Customers who purchase its iPods often use Apple's iTunes store for music downloads. Compatibility between the applications in its App Store and the iTunes web site provides a compelling reason for customers to continue purchasing Apple gear so that generally all-new apps are not needed for new mobile and wired computers.

Apple's major innovation is its user-friendly interfaces, which have been a factor in the company's success since its inception, across all of its product lines. Prior to its introduction of the iPad in 2010, only a small number of tablet computers were sold annually. In contrast, Apple sold 14 million iPads worldwide during the first year they were available because of the iPad's innovative, touch-screen interface. This spurred other manufacturers to introduce their own tablet computers and changed the way many people in business and homes use computers and watch video today.

Tablet computers benefit their users with large screens, but they are usually hampered by limited storage. Thus, tablets spurred the adoption of cloud computing and the use of wireless networks for viewing video. To take advantage of opportunities in cloud storage, Apple introduced its iCloud music, photo sharing, and video storage service in 2011. Subscribers can access their music and video stored on iCloud from any mobile or wired computer.

The wireless technology, design, and staffing in its retail stores are another example of Apple's innovations. Apple uses wireless service with which its sales associates can accept credit card payments, print receipts, and have e-mail receipts sent to customers, all through handheld devices. The handheld devices include barcode scanners to enter the purchased item and card readers to accept credit card payment. This results in customers not having to wait in line to pay for purchases, thus saving time and retail space. There are also demonstration computers, tablets, and iPods on display for customers to try out. In addition, Apple improved customer service by introducing the Genius Bar in each store. The Genius Bar is staffed by technical employees who provide diagnoses of hardware and software issues for customers. The retail stores have a web-based system for customers to make appointments with the Genius Bar before coming to the Apple store, further alleviating long waits and lines.

Like Amazon and Google, Apple acquired expertise for a host of its offerings by buying companies with the technologies needed for new products and services. Table 3-9 presents a partial list of acquisitions.

Table 3-9 *A Partial Listing of Apple's Key Acquisitions*

Acquired Company: Year Acquired	*Description of Purchased Organization's Technologies*
NeXT: 1997	Founded by Steve Jobs to develop user friendly, graphics-capable computers. Became the basis for Apple's Mac computers.
Emagic: 2002	Software used by musicians to produce music. Used in Logic and GarageBand applications.
Placebase: 2009	A replacement for Google Maps.
Lala.com: 2009	A music cloud storage and streaming service. Used for iCloud and iTunes Match for music storage.
Quattro Wireless: 2010	Software for mobile advertising.
Siri: 2010	Developer of speech recognition software used in iPhones.
IMSense: 2010	Developer of software for cameras. Used on iPhones and iPads.

Microsoft

Microsoft Corporation is the largest software company in the world. It develops office productivity software, software for servers, operating systems for mobile handhelds, the Windows operating systems for computers, and the Xbox 360 video game system. Because tablet computers use competitors' operating systems and sometimes cloud-based office software, sales of Windows operating systems and Microsoft's Office productivity software have declined. Microsoft earns the bulk of its revenue from its Windows operating system and its Office productivity suite.

To broaden its product lines, Microsoft has developed a cloud computing platform whereby its software customers are able to use office and collaboration applications hosted in Microsoft's data centers. Collaboration software enables groups of people to work together simultaneously on documents and projects that are stored in centralized databases.

In another step to becoming more web centric, Microsoft introduced its Bing search engine in 2009. Bing is now the third-largest search network in the United States, behind Google and Yahoo! Prior to developing its own search software, Microsoft attempted to acquire Yahoo!; however, Yahoo! rejected the merger offer. But, it did form a ten-year partnership wherein Microsoft provides Yahoo!'s core search technology in exchange for 20 percent of Yahoo!'s search revenue.

One of Microsoft's most successful recent innovations is its Xbox 360 video game system. Xbox 360 includes game consoles, accessories, and the actual game software. In 2010, Microsoft introduced motion-sensing capability for the Xbox 360, the Kinect for Xbox. Microsoft was the first video game publisher to develop a way to control video games through hand and body gestures. Kinect for Xbox 360 reacts to gestures including kicking, punching, ducking, diving, and jumping. In another effort to become web centric, Microsoft purchased 17.6 percent of book store Barnes & Noble's Nook e-book subsidiary in 2012. The purchase provides Microsoft with an e-book reader for Windows-based mobile and tablet devices.

Kinect was an instant success, with 8 million units sold in the first 60 days after it was introduced in November 2010. To widen applications for Kinect beyond games, Microsoft released a software development kit (SDK) that developers can use to create other ways to use the motion detection. One example is the ability to control browsers through hand and body gestures. Table 3-10 includes a partial list of Microsoft's acquisitions. (The full list would require a separate book.)

The $8.5 billion purchase of Skype brings with it a number of potential advantages for Microsoft. The majority of Skype customers are currently residential subscribers. However, Skype has been upgrading and promoting its services for small and midsize businesses. The service can be integrated into the Avaya and ShoreTel telephone systems so that business customers can easily use the Skype service. In addition, many business people who travel for work use Skype on the road for video and audio conferencing and international telephone calls. Microsoft has stated that it intends to integrate Skype into its own Lync IP telephone system server.

Table 3-10 *A Partial Listing of Microsoft Acquisitions*

Acquired Company: Year Acquired	*Description of Purchased Organization's Technologies*
Hotmail: 1998	Web e-mail. Microsoft uses the technology to attract traffic to its Bing search and its Office 365 cloud applications.
Visio: 1999	Charting software used for applications such as project management.
Bungee: 2000	Microsoft's successful Halo series of games that operate on the Xbox 360 hardware are based on Bungee software.
TellMe: 2007	Automated telephone directory activated by voice commands. Used by telephone companies for directory assistance and by large corporations such as airlines, which use it for reservation systems.
aQuantive: 2007	Online advertising software.
Skype: 2011	Skype is the most widely used service worldwide for making international voice calls and audio and video conferences.

In addition, Microsoft stated that it plans to blend the Skype service into its mobile operating system software. This will add functionality such as video conferencing and low-cost VoIP calling to its mobile operating system. These are competitive advantages for Microsoft's mobile operating system which is used on fewer handsets than those from Apple and Google. Microsoft has also stated plans to blend Skype service into its video game systems.

One challenge is integrating Skype's staff into Microsoft's. The cultures of these two organizations are markedly different. Microsoft is a large established conglomerate with many layers of management. Skype is a smaller, less-structured organization.

Netflix

Reed Hastings founded Netflix in 1998. His vision at that time was to eliminate late fees on rented DVDs. This grew out of his own dismay at owing a $40 late fee on a film rental. Other features of the original service were the convenience afforded by the red envelopes with prepaid postage that subscribers used to mail back DVDs to Netflix. Like Amazon, Netflix developed a recommendation system. Netflix's system is based on a user's past DVD ratings and rentals, presented on an easy-to-navigate web interface for ordering DVDs.

By 2004, the company stated its long-term vision of streaming TV and movies directly to users. During Netflix's third quarter 2004 Earnings Conference Call, CFO Barry McCarthy laid out his vision for the future of the service:

> *I believe that the downloading market will evolve with slow but steady progress enabled by the availability of low-cost devices, which are going to move that content from the Internet to the TV set. We need to be on as many of those devices as we can be, so that will be a core strategy for us.*

Netflix has the largest number of subscribers of any provider in the United States. Its monthly subscription fees include options of streaming TV and movies, and DVD rentals. Figure 3-1 presents a comparison of Netflix against other pay-TV providers. By 2010, Netflix customers watched more content via streaming than on DVDs. In 2011, Netflix announced the availability of a lower-priced, streaming-only service and an extra fee to receive DVDs by mail. Previously, customers were automatically enrolled in both services. Netflix is promoting its streaming service—which avoids mailing and warehousing costs—prominently on its web site.

Netflix had earlier expanded its streaming service to Canada in 2010 and to 43 countries in Latin America and the Caribbean in 2011. Although licensing rights for TV shows and movies in Latin America are low, broadband penetration there is low, and is saddled by high costs and slow speeds. However, the region does have a large and growing population. In the absence of wired broadband, some customers with tablet computers and smartphones might choose to stream directly to these devices over mobile networks. In 2012, Netflix launched its streaming services in Ireland and the United Kingdom.

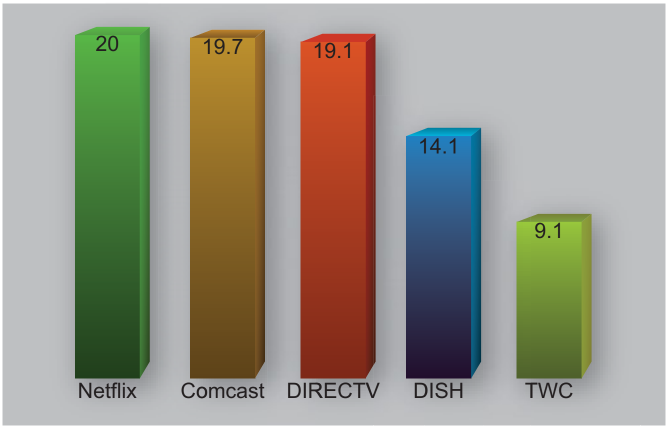

Figure 3-1 A comparison of pay-TV providers in the United States. (Courtesy MediaCensus © MediaBiz 2011)

Netflix and other streaming services face competition from one another as well as from cable TV operators, telephone companies, and satellite TV operators, all offering video on demand. In addition, Netflix faces rising costs, primarily for licensing fees for content as well as the unavailability of particular entertainment. Studios not owned by cable TV operators or other competitors now view streaming by Internet-based companies as sources for revenue growth.

The broadband wired and mobile providers controlling access to the vast majority of customers are also starting to demand monthly fees for carrying streamed traffic. Showtime (a division of CBS Corporation), which offers streaming in competition with Netflix, announced in 2011 that it would no longer grant rights to Netflix for streaming its content. In response to the challenges of obtaining rights to content and its rising costs, Netflix announced in 2011 that it acquired the rights to and would produce and distribute its own miniseries, *House of Cards*, based on a book and a BBC miniseries.

APPENDIX

Table 3-11 *Regulatory Highlights*

Landmark Acts and Court Rulings	*Summary of Acts and Rulings*
The Federal Communications Act of 1934	Congress created the FCC and gave it the authority to regulate interstate telephone, radio, and telegraph companies.
The 1956 Consent Decree	The Justice Department allowed AT&T to keep its monopoly but restricted it to common carrier functions. The Consent Decree mandated that any patents developed by Bell Labs, then AT&T, be licensed to all applicants requesting them. This led to the availability of—among many other things—microwave technology to MCI and the ability of competitive carriers to build fiber-optic-based long-distance networks.

Table 3-11 *(Continued)*

Landmark Acts and Court Rulings	Summary of Acts and Rulings
The 1969 MCI Case	The Federal Communications Commission ruled that MCI, then known as Microwave Communications, Inc., could connect its equipment to the public network provided that the network was not harmed. This decision opened the competitive premises equipment (CPE) market to AT&T rivals such as Northern Telecom and Executone. Prior to this, only AT&T was allowed to provide telephones for connection to the Public Switched Telephone Network (PSTN).
The 1982 to 1983 Modified Final Judgment	The Justice Department, in agreement with AT&T and with approval by Judge Harold H. Greene, agreed to a settlement that • Divested the then 22 Bell Operating Companies (BOCs) from AT&T • Prohibited BOCs from inter-LATA long distance, sale of CPE, and manufacturing • Mandated that the local exchange companies provide equal access (dial 1) from end users to all interexchange carriers
The 1984 Divestiture	The terms spelled out in the Modified Final Judgment were implemented on January 1, 1984. The 22 Bell telephone companies were merged into seven Regional Bell Operating Companies (RBOCs). The RBOCs were allowed to sell local and toll calling within the 197 defined local or in-state Local Access And Transport (LATA) areas. They also retained the Yellow Pages. AT&T retained manufacturing and inter-LATA (primarily interstate) and international toll calling.

Part III

Wide Area Networks and the Internet

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4 Carrier Networks

In this chapter:

Carriers are striving to streamline functions to save money on labor and equipment costs, and to increase productivity while upgrading networks to carry additional traffic. Upgrading networks, while costly, simplifies the tasks of carrying mixed types of traffic including analog telephone, Internet, high-definition television (HDTV), and movies. Through these improvements, carriers can manage all of this varied traffic by using the same multipurpose equipment and management software.

Simplifying network structures saves money on staffing. This is because fewer technicians and engineers are required to manage, maintain, and install software and equipment. Certain installation functions that formerly required multiple trips to a site by a technician can now be performed remotely, cutting down on technical staff visits. Moreover, customers can now make changes to enterprise services via web interfaces that in the past needed to be made by technicians. In addition, there are fewer types of maintenance software with simplified, standardized equipment and centralized maintenance. Expertise on a reduced number of software packages and types of equipment requires fewer sets of skills. This results in more efficient labor pools and permits flexible deployment of technical personnel who can fill in for one another, as required.

The fast pace of technological change is a challenge to carriers. They face questions about which new technologies to adopt, while at the same time facing pressure to lower prices in response to competition. This is occurring simultaneously with the loss of telephone customers to mobile services. Additionally, cable TV operators that previously only had competition from satellite TV now also compete with telephone companies that are promoting their own cable TV services, and with competitors such as Netflix and Apple that offer TV and movies streamed over the Internet. Lower profit margins and competition are factors in the reluctance to make investments in new technologies. New technologies must demonstrate clear opportunities for operational cost savings or increased revenues from new services before carriers will make any investments.

One way that networks increase efficiency is in the technology used for back up service in the event of fiber cuts along transoceanic and other heavily trafficked fiber routes. In older equipment, backup gear and fiber sat idle unless there was a disaster or a fiber cut. The backup equipment and fiber are also referred to as the *protect services*. The term “protect services” denotes the backup links on which traffic is transmitted during network outages. Using a newer technique called *mesh technology*, back up is accomplished by using equipment and fiber on existing routes. In addition, carriers are deploying Voice over Internet Protocol (VoIP) equipment centrally rather than older traditional switches in hundreds of locations closer to customers. Eventually, it is hoped that this will enable carriers to support a few centralized VoIP switches rather than the many local switches that are currently interlaced throughout networks.

In densely populated urban and suburban regions within the United States and throughout most of the developed countries in Asia, the Middle East, and Europe, consumers and commercial organizations have reasonably priced high-speed Internet access. However, many rural areas lack these connections due to the economics of sparse populations and long distances between providers and customers. This is because there are fewer customers in these areas over whom providers can spread the costs of upgrading cabling and equipment. Furthermore, long distances result in higher initial costs to install new fiber-optic cabling. These are major roadblocks that in addition to high consumer prices and slow Internet access have also rendered these areas unattractive to private investors. Rural areas are attempting to overcome these hurdles through a combination of government subsidies and municipally backed build-outs.

THE PUBLIC NETWORK

The structure of public networks can be broken up into three categories: the core section, Metropolitan Area Networks (MANs) within cities, and last-mile or access networks. The list that follows provides a brief description of each.

> NOTE Workers in the telecommunications and data-network industry often use different nomenclature for the same equipment or type of network. For example, core networks are also referred to as long-haul and backbone networks and last-mile networks are sometimes referred to as first-mile networks. Long-haul has the same meaning as core networks, and first-mile and last-mile networks are used synonymously with access networks. In addition, the terms "providers," "carriers," and "Internet Service Providers" (ISPs) are also used synonymously. They all provide voice, mobile service, video, or Internet access.

- **Core networks** These links span hundreds of miles and carry traffic between distant cities. In the United States, examples of core networks are those connecting Los Angeles to New York City, and Boston to Chicago. Undersea cables that span oceans are another example of long-haul networks. They carry intercontinental traffic thousands of miles and connect the United States with Europe and Asia with Europe.
- **Regional core networks** connect cities that range from 200 to 400 miles apart. This includes Boston to New York City, and New York City to Washington DC.
- **Middle-mile networks** These are networks that link MANs within cities to core (backbone) networks. They consist of the fiber or wireless links from a carrier's main switch within cities and rural areas to the intercity network and the Internet.

- **Metropolitan Area Networks (MANs)** These links carry traffic within large cities to headend switches or routers where traffic is aggregated and connected to core networks. MANs provide an on-ramp to core networks. These networks run from a carrier's equipment in towns to Points of Presence (POPs) and *wiring centers*. A wiring center is a location with a local telephone company switch and connections and electronics for outside cabling. A POP is the location where a switch hands off traffic to long-haul providers, and vice versa. Traffic is also often handed off to the Internet from gear within the same building.
- **Access networks** These are also referred to as first-mile or last-mile networks. These are the networks that link a customer's premises to its provider's switch. Because there are so many cable runs to individual residences, these are often the last networks to be upgraded. Access networks also include connections from major skyscrapers and office parks to a carrier's equipment. For the most part, local telephone companies and cable companies own access network cabling and electronics. However, they also provide network access to other providers that sell services to customers located in another cable TV or local telephone company's network.

LONG-HAUL NETWORKS: THE CORE

The core, largely based on IP while still carrying older non–Voice over Internet Protocol (VoIP) voice traffic, transmits the largest concentration of traffic in public networks. It transmits packetized voice (VoIP), non-VoIP voice traffic, data, and video traffic between switches on high-speed fiber-optic cabling. Traffic in the core is transmitted across countries and continents and dropped off at wiring centers and Points of Presence (POPs) from where it is routed via Metropolitan Area Networks (MANs) and last-mile networks to subscribers. From there, either the traffic is handed off to other carriers or the long-haul carrier might transmit it over MANs directly to residential and business customers.

Carriers also transmit data and VoIP traffic between enterprise sites on long-haul networks. Special arrangements are made with these customers for optional services such as security and priority treatment for voice and video conferencing. These networks are considered part of a carrier's *private data networks*. They are separate from the Internet and offer guaranteed speeds and low latency (no or unnoticeable levels of delay) on an end-to-end basis. For more on this, see Chapter 5, "Broadband and Wide Area Network Services."

Core networks also carry *circuit-switched voice* and T1/E1 and T3/E3 traffic. Circuit-switched voice is an older technology that guarantees a path for each voice call by setting up a dedicated path for the duration of each call. See the section "Circuit-Switched Voice and T1/T3 over Fiber," later in this chapter, for more on circuit-switched voice. T1/E1 and T3/E3 traffic is based on Time-Division Multiplexing (TDM), which, like circuit switching, guarantees time slots for all calls and data traffic. See Chapter 5 for more information on T1/E1 and T3/E3.

Transoceanic Network Systems

Intercontinental voice and data traffic is carried over hundreds of undersea cables. TeleGeography (a division of PriMetrica, Inc.) is a telecom market research firm located in Washington, DC. In April 2010, it profiled 228 active international undersea systems. The number of new and upgraded undersea cables is growing due to the increasing amounts of video and data traffic on the Internet and between enterprises. In 2009, 16 new systems were completed and eight additional systems were finished in 2010. For the most part, carriers such as Tata Communications (headquartered in India), Verizon Communications, and AT&T, Inc., participate in consortiums that build undersea cables. The carriers reserve exclusive use of some fibers in the cable system for their own international traffic rather than paying other carriers to transmit it. This assures them adequate capacity. They also offer space on these cables to other carriers on a wholesale basis. But this is not their primary motivation for constructing these cabling systems. An exception to this model is the new undersea cable on the east coast of Africa, which was built exclusively for the wholesale market. Most undersea cables on the east and west coasts of Africa are built by consortia made up primarily of local African carriers and a smaller number of international carriers.

Each undersea cable system has drop-off points at multiple cities. Early systems, constructed in the 1990s, provided only shore-to-shore service, from one shore of an ocean to its other shore. Undersea cable operators now generally provide city-to-city service. As part of a package, they transmit the traffic from one major city, through the undersea cable, and then overland to cities on the remote end of the undersea cable over their own fiber networks. Figure 4-1 depicts an example of just such a system. A cable that spans the Atlantic Ocean between Europe and the United States can carry traffic to a co-location site where many carriers have routers. One of these co-location sites is on Eighth Avenue in New York City. At the co-location facility, multiple carriers interconnect their networks and carry one another's traffic to other cities.

The consortia that fund new transoceanic cables are typically made up of around six investors. A consortium usually includes both noncarrier investors and providers, and one of the carriers is generally given a management contract to operate the cable system on behalf of all the members. This enables streamlined operations because decisions can be made on upgrades and operations without requiring unanimous consent from the entire group on every decision.

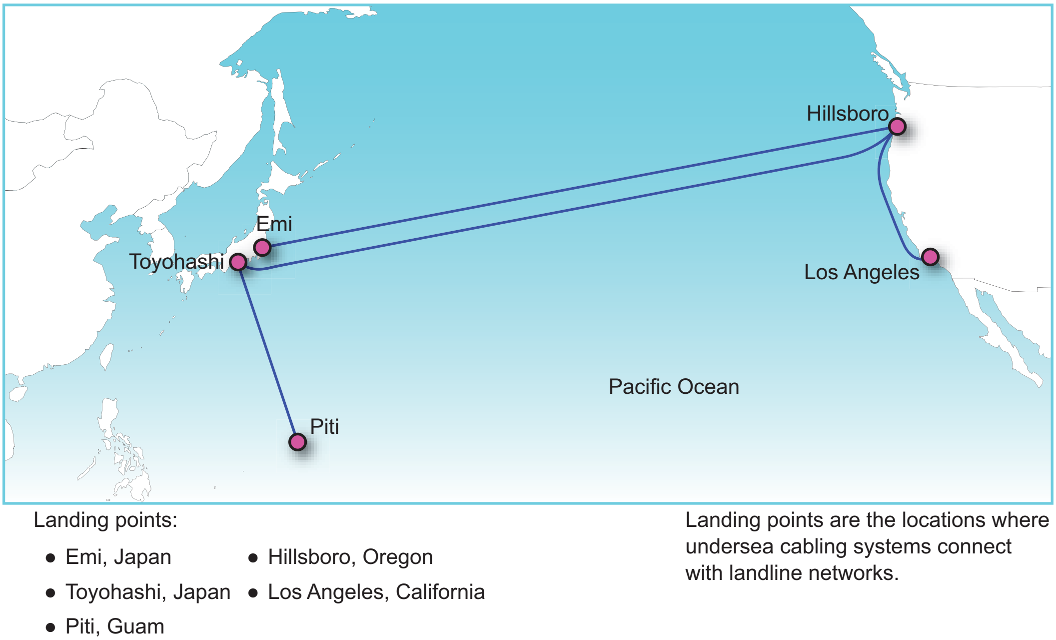


Figure 4-1 *The Tata TGN-Pacific undersea cable, which was completed in December 2002, connects the United States with Japan. It is configured in a self-healing ring. (Courtesy TeleGeography)*

Technological Advancements

Improvements in optical electronics have enabled undersea cable speeds to increase from 2.5Gbps to 10Gbps. Although 100Gbps electronics are available, the prices are currently too high to be economically practical. Interestingly, because of technological improvements, the newest of three cabling systems connecting Europe and the Middle East, SeaMeWe-4, installed in 2005 but upgraded many times since, now has 80 percent of the total capacity of all three undersea cables. (New cabling systems are in the process of being constructed on this route.)

Strategies to Increase Capacity on Existing Undersea Routes

Upgrading the electronics connected to optical cabling can increase capacity. In addition, unused fibers within existing "dark" fiber bundles can be "lit." *Dark fiber* refers to fiber cabling pairs on which no electronics have been connected. *Lit fiber* is fiber to which electronics are connected. When carriers lay fiber, they always add more fiber to cable bundles than is needed at the time the cables are deployed. This is because fiber is relatively inexpensive, but the costs for labor and for remotely operated underwater equipment to dig trenches and lay the actual cable are high. The SeaMeWe-4 cabling system is an example of upgraded undersea routes. It was installed in December 2005 with an initial capacity of 160Gbps. The lit capacity at the end of 2009 between Europe and Egypt was 1,580Gbps. Upgrading is costly because electronics must be changed or added at every drop-off city where speed is intended to be increased, not just at the ocean's edges. In addition, older fiber that has had a number of fiber cuts and repairs does not support the same high speeds as newer fiber cabling.

TECHNOLOGIES USED IN CARRIER NETWORKS. ....

Carriers use a mix of Synchronous Optical Network (SONET), Gigabit Ethernet, and older technologies to support legacy networks based on Time-Division Multiplexing (TDM) (T1 and T3) as well as analog circuit-switched voice. Newer networks deploy Optical Transport Network (OTN)–compliant gear athat can efficiently carry both SONET for legacy circuit-switched voice and Gigabit Ethernet for IP data and VoIP traffic.

NOTE *Legacy* is a term used to describe networks and equipment that are based on older technologies such as TDM and analog voice service.

Circuit-Switched Voice and T1/T3 over Fiber

SONET is a North American standard for multiplexing streams of traffic onto fiber-optic cabling and transporting it at Optical Carrier (OC) speeds. SONET was developed to aggregate (multiplex) and carry TDM and circuit-switched voice traffic from multiple sources. The international version of SONET is Synchronous Digital Hierarchy (SDH). SONET SDH carries traffic at Synchronous Transfer Mode (STM) rates. Traffic carried between cities in Europe or in undersea cables is often referred to as being carried at STM-1 (155Mbps) or STM-16 (2.5Gbps) speeds. See Table 4-1 in the "Appendix" section at the end of this chapter for optical carrier and synchronous transfer mode speeds. SONET equipment using STM speeds can communicate with North American–type SONET gear.

When SONET was first introduced in 1994, all public network traffic was essentially based on TDM. Although most public network traffic is now based on IP, there are still many organizations and residential consumers whose voice service is based on circuit switching. Thus, core and metropolitan networks need equipment that handles both types of traffic. SONET equipment is used on fiber-optic networks between central offices in metropolitan areas, and between high-speed switches in the core. A *central office* is the building in which telephone companies install a switch that connects calls to residences, and businesses. In addition, there are SONET *rings* between enterprises and Points of Presence (POPs) that carry their long-distance traffic. Ring technology provides an active circuit to carry traffic, and a backup path and electronics, in case the active circuit or equipment fails.

Carrier Gigabit Ethernet

Gigabit Ethernet is used in both Local Area Networks (LANs) and Wide Area Networks (WANs). It operates mainly over fiber-optic cabling. When it is used in a provider's network, it is sometimes referred to as Carrier Gigabit Ethernet. There are four capacities of Gigabit Ethernet (also referred to as GigE): 1, 2.5, 10, and 100. These are used in core Metropolitan Area Networks (MANs) and access networks. Carrier Gigabit Ethernet is used for VoIP and all IP-packetized traffic. This includes video, data, and graphics traffic that is bundled in packets.

GigE is not, however, suitable for circuit-switched voice, because it does currently not have the timing sources required for voice. A timing source provides fixed, guaranteed capacity that circuit-switched voice requires. Without it, circuit-switched voice sounds choppy because of brief, intermittent delays, which are otherwise imperceptible in IP data. An International Telecommunications Union (ITU) standard called Synchronous Ethernet is being developed for chips with timing sources. Synchronous Ethernet will require costly hardware upgrades in Carrier Gigabit Ethernet switches. In the interim, GPS-based local clocking is being introduced as a stand-in timing source.

The Drive for Higher-Capacity Carrier Gigabit Ethernet

Large providers such as CenturyLink, Telstra (in Australia), and Verizon are building 100Gbps backbone routes in their networks.

The impetus behind 100Gbps Ethernet is the increasing amount of high-definition TV, Video-on-Demand (VOD), network-based storage, and mobile broadband traffic. Gigabit Ethernet is more flexible than SONET and more suited for data. It was expressly developed for IP traffic. In addition, Gigabit Ethernet is less costly to purchase, maintain, and install than SONET, and traffic from multiple sources can be easily added and dropped off from switches.

The wide availability of Gigabit Ethernet switches from many manufacturers has caused Ethernet switch prices to drop. Moreover, because of its standardization by the

Institute of Electrical and Electronics Engineers (IEEE), vendors produce compatible Ethernet gear so that providers are not locked into a single vendor's equipment.

NOTE Carriers deploy Multi-Protocol Label Switching (MPLS) in conjunction with Carrier Gigabit Ethernet in their core networks. MPLS is a Layer 3 protocol that switches traffic between IP addresses rather than Media Access Control (MAC) addresses. MAC addresses are assigned to individual computers. By contrast, IP addresses are assigned to the network or to the Virtual LAN (VLAN). Managing fewer addresses makes routing by using MPLS with its IP addressing less complex to manage. It also enables networks to scale to larger sizes. MPLS is an optional feature in routers. More information on MPLS can be found in Chapter 5.

Carrier Ethernet can operate over copper and wireless media but only for shorter distances. Ethernet over copper is now offered by competitive carriers and some incumbent carriers as a way to provide higher, flexible speeds without the need to dig trenches for new fiber cabling. It operates at speeds ranging from 5Mbps to 100Mbps.

Gigabit Ethernet and Ethernet are often used in conjunction with Passive Optical Networks (PONs), discussed later in this chapter. PONs are a lower-cost method of extending fiber to premises and neighborhoods.

Using Ring Topology for Greater Reliability

SONET and Ethernet can operate as a straight point-to-point line between sites, or in the more fail-safe ring topology. When fiber in a point-to-point arrangement is cut, service is lost. However, reliability on fiber is critical because each failure affects potentially hundreds or thousands of customers, particularly if a failure occurs in long-haul networks.

NOTE *Topology* refers to the design of how devices are physically connected. It is the "view from the top."

When a medium such as copper carries a conversation from one telephone subscriber to another, a failure only impacts one customer. Because of the large volumes transmitted by fiber, failures in these networks can put hundreds of businesses, police stations, or hospitals out of service. For this reason, the majority of carriers deploy bidirectional ring topology in long-haul and MANs, where each fiber ring, multiplexer, and power supply is duplicated.

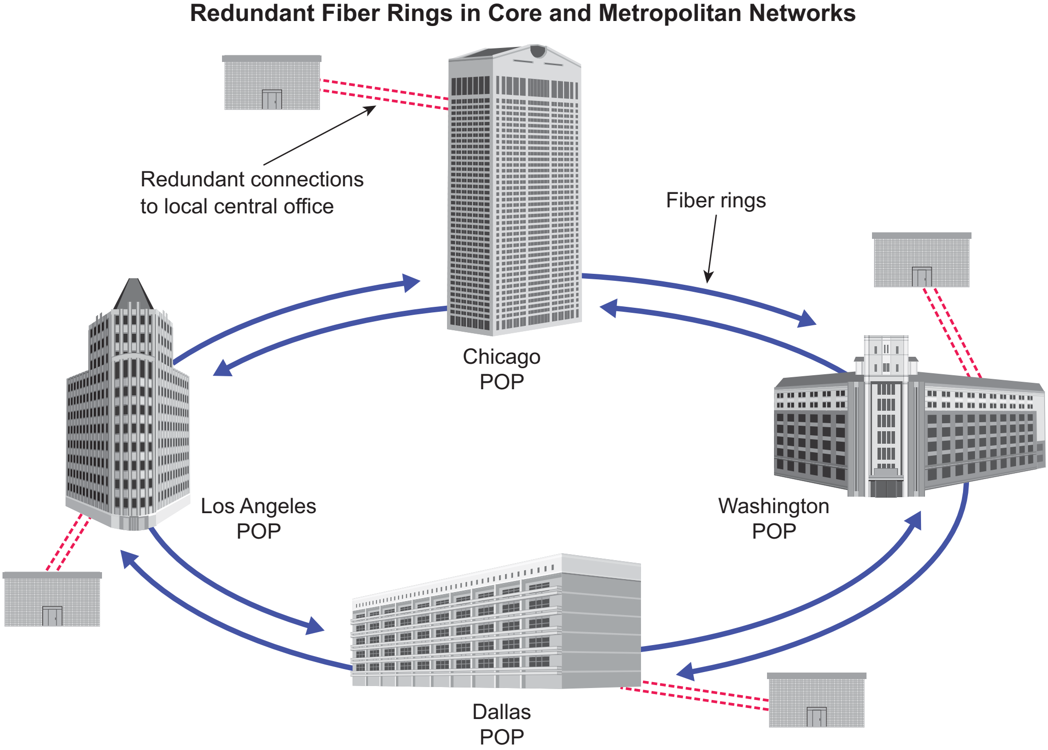


Figure 4-2 *Fiber rings between Points of Presence (POPs), and a connection to a local provider in each city. Each POP has a switch and redundant SONET or Ethernet gear connected to the fiber rings.*

Ring topology is costly because the fiber and the multiplexers are all duplicated, even though this combined capacity is not used on a day-to-day basis. In the bidirectional SONET/SDH or Ethernet ring, one set of fiber strands is used for sending and receiving; the other is the protect ring (spare ring). If one set of fiber strands is broken or the electronics on it fail, the protect ring reroutes traffic in the other direction, as is illustrated in Figure 4-2. Read the section "Mesh Configuration Backups," later in this chapter, to learn about new, lower-cost mesh technologies that are being deployed.

CONVERGENCE IN CORE AND METROPOLITAN NETWORKS

In a telephone interview, Dave Parks, director of Product Marketing for Ciena Corporation, made the following comment:

> *Carriers are investing in a new breed of networks that are all about IP packets on optical cabling. But carriers are not going to throw away their investments in SONET equipment. OTN transport and switching equipment gives them a way to accommodate SONET while migrating customers away from legacy services to higher-capacity Carrier Gigabit Ethernet services of up to 100Gbps.*

Optical Transport Network (OTN) is an International Telecommunications Union (ITU) standard for transmitting, monitoring, and managing traffic on fiber-optic cabling. It is used for *asynchronous* protocols such as Gigabit Ethernet as well as *synchronous* protocols such as Synchronous Optical Network (SONET), T1/E1, and T3/E3. In asynchronous protocols, traffic is sent at irregular intervals, not at specific intervals. This contrasts with synchronous protocols where bits are sent at evenly spaced, regular intervals according to an internal timing source. The OTN standard provides a framework for transmitting both types of traffic.

The OTN standard was created for the efficient operation of providers' multiprotocol metropolitan and global networks using interoperable equipment. The standard provides a framework for programming, monitoring, and installing the growing amounts of IP packet traffic while preserving its capability to carry legacy traffic on optical networks. It does so by specifying the encapsulation of legacy SONET/Synchronous Digital Hierarchy (SDH) traffic into OTN frames and its overhead information for addressing and billing.

OTN-compliant equipment has the capability to transmit, program, and monitor various protocols, and assign Gigabit Ethernet or SONET/SDH to ports on the same line card via software. Thus, as the amount of SONET traffic decreases, port assignments can be reassigned to Gigabit Ethernet without purchasing new hardware. This results in lower operating expense for operators.

OTN equipment has optional modules for Dense Wavelength-Division Multiplexing (DWDM) as well as Reconfigurable Optical Add/Drop Multiplexing (ROADM) so that streams of traffic can be seamlessly added and dropped off at, for example, POPs. Both SONET/SDH and IP traffic can be carried on the same wavelength. (DWDM gear splits each pair of fiber cabling into multiple paths called wavelengths.)

As carriers move to OTN and other technologies that work seamlessly over wired and wireless networks, they are also making plans and designing core, backbone networks capable of carrying data and voice from customers on both wired and wireless networks. This type of *convergence* offers the possibility of saving money on staffing, equipment costs, and operational costs. One group of staff members will be able to monitor and manage a single core network. Carriers that merge their wireless and wireline core traffic into a single network do need to train technicians on monitoring and maintaining new software and equipment.

Automation via Control Plane Technology

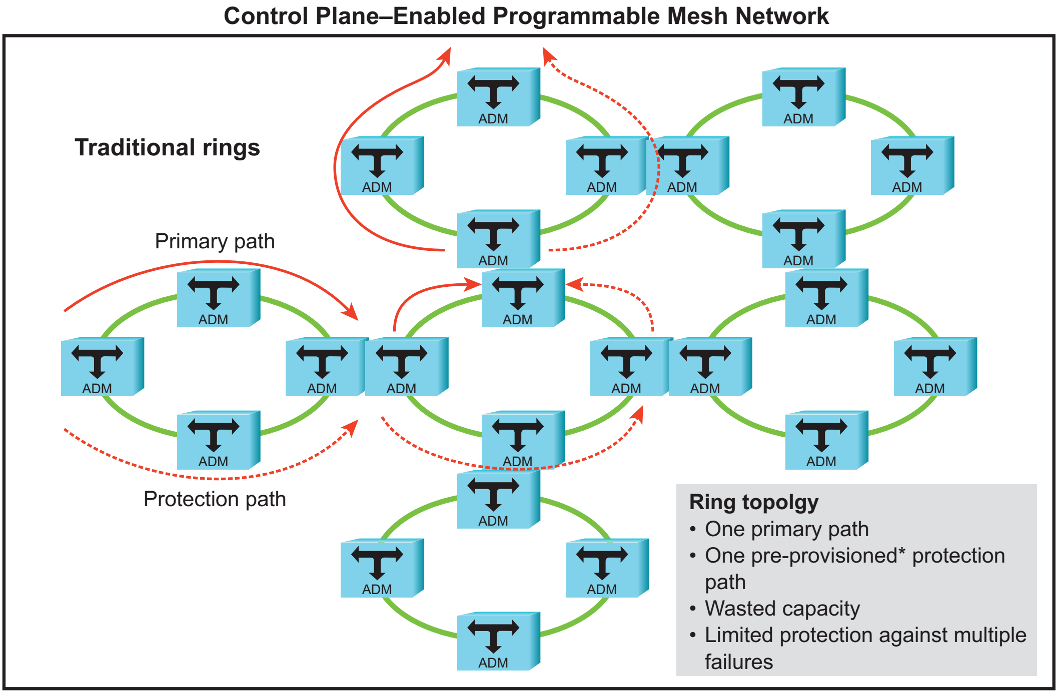
Control plane technology is an ITU-Telecommunications (ITU-T) standard that specifies software control for monitoring networks and provisioning new network installations for enterprise and residential customers as well as new equipment on an operator's network. It is compliant with, and works in conjunction with OTN gear. Control plane technology has the potential to decrease a carrier's operational expenses by simplifying network operations, maintenance, and installation. Like OTN, it can be used for IP as well as older Time-Division Multiplexing (TDM) traffic.

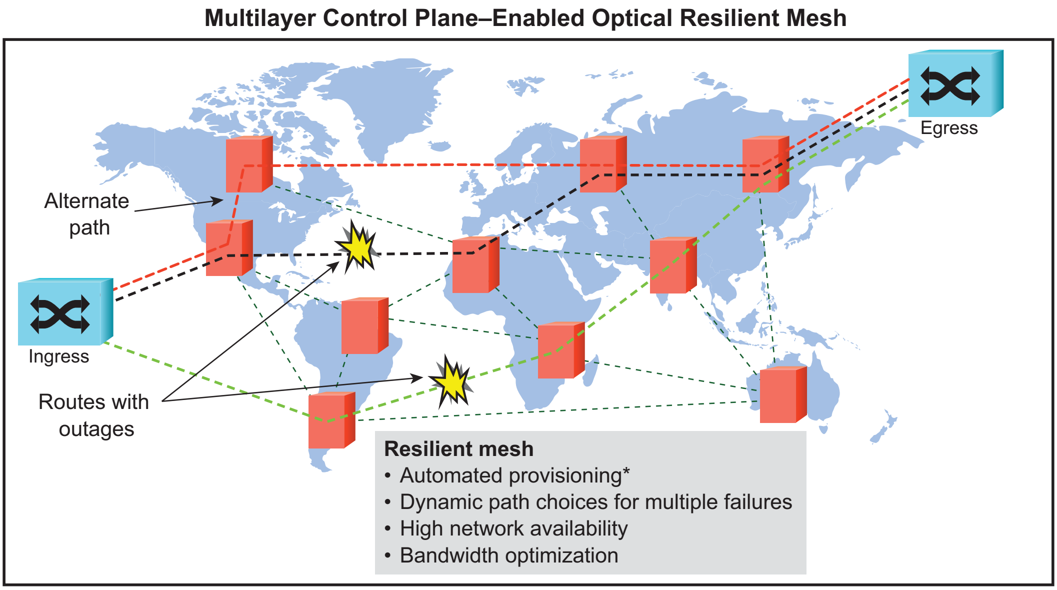
Examples of control plane technology functions include the following:

- Redirecting traffic during peaks.
- Opening bandwidth when it is needed during an event such as a presidential inauguration. For example, carriers commonly rate-limit traffic by running a 1Gbps pipe at 100Mbps. When required, the bandwidth can be easily increased to 1Gbps.
- Reconfiguring an optical multiplexer on the fly, automatically, or manually, via remotely entered computer commands.
- Selling web portal access to IT managers so that they can add more bandwidth for a special event without waiting for the carrier to provision more service.
- Decreasing delays and increasing revenue from new services more quickly by speeding up installations such as cable modems and high-speed network access for commercial customers. This means that an installer can make one visit to an enterprise to install gear, and then power up the service remotely through software. Previously, multiple onsite trips were required for setup.

Mesh Configuration Backups

Mesh backup technology is enabled by signals generated from Control Plane Technology equipment. The service utilizes a logical rather than a physical design. The physical topology is not designed as an actual mesh, wherein each point on a network is connected to every other node. Rather, as demonstrated in Figure 4-3, traffic is backed up in a logical manner with more than one choice of alternate routes. In this way, each carrier and each route do not require duplicated fiber, multiplexing gear, and transmission equipment.





*Provisioning refers to the planning, design, and installation of network equipment and routes.

Figure 4-3 Comparing ring topology with mesh topology for network failures. (Courtesy Ciena Corporation)

Control Plane Technology mesh configurations for network backups are less costly and often provide more diverse routing options than ring topology, because carriers are able to share resources instead of duplicating fiber routes and equipment. They are also more flexible because mesh backups can be configured with multiple backup routes rather than a single backup path.

With mesh backup technology, if a cable is cut or equipment connected to fiber is out of service, traffic is automatically sent to other routes within a single carrier's network or to an entirely separate network operated by other providers. Signals, or the absence of signals between the OTN equipment on the fiber and the Network Operations Center (NOC), triggers software commands that automatically re-route traffic. Some carriers might prefer the option to have engineers manually activate alternative routing during outages.

Mesh technology ensures that the many organizations and consumers who depend on core fiber networks have uninterrupted service during outages. When the glitch is repaired, traffic is automatically directed back to the original network route. Mesh technology is a critical tool during national disasters. It has the capability to provide alternate routing for both wireless and wireline networks. During hurricanes, for instance, traffic in the affected area of the carrier's network can be rerouted to other sections of the provider's network, or to other carriers altogether, depending on logistics and agreements between carriers.

Mesh technology assumes adequate capacity on backup routes. If this capacity is not sufficient, delays will occur. It's a trade-off between flexibility in having multiple backups, idle capacity when the network is operational, cost savings, and possible congestion during emergencies.

Using Mesh Configuration to Back Up Undersea Cable Service

The reliability of undersea cables is critical, because entire countries or metropolitan areas often depend on a single undersea cable for international service. Due to the complexity of repairing cabling systems on the ocean floor, major outages can put regions or countries out of contact with the rest of the world for a week at a time. Beginning in 2003, carriers started using mesh technologies as a backup service for undersea cables. Prior to that, only costly ring topologies were viable, though at least half sat idle unless there was an outage. New undersea cabling systems use mesh technology and operators make arrangements with other carriers for backup on other undersea systems.

Providers often have agreements for backup on more than one route. This affords more options during disasters such as earthquakes that can affect multiple cables to the same country. If no viable undersea cable on the same route is available, traffic is routed overland to the nearest distant city with an alternate undersea cable.

Repairing undersea cable cuts requires the costly deployment of submersible robots tethered to and controlled by mother ships. Large trawling fishing nets are responsible for the most fiber cuts. These nets are weighted and often snag cabling as they are being dragged across ocean floors. The second most frequent cause of outages results from ship anchors dragged across the ocean floor. To reduce the incidence of costly cable cuts from fishnets and ship anchors, cable companies provide maps of their cable routes to fishing companies.

Using ROADMs to Add and Drop Off Traffic

Using Reconfigurable Optical Add/Drop Multiplexers (ROADMs), carriers can more easily add, separate out, and drop off traffic carried on optical rings to and from other providers and to other network sites without converting signals to electrical signals and back to light signals. Prior to the availability of ROADMs, light signals had to be converted to electrical signals before they could be added or dropped off and routed elsewhere. ROADM equipment eliminates the extra cost and maintenance for this conversion equipment.

ROADMs were first deployed in core networks so that, for example, some of the traffic between cities such as New York and Chicago could be more easily routed to Los Angeles. As traffic within metropolitan areas increased, ROADMs began to be used in these areas as well. Dense Wavelength-Division Multiplexers (DWDMs) can be equipped with ROADM cards so that fewer pieces of gear need to be maintained.

Transitioning Broadband Customers to Voice over Internet Protocol

Local telephone companies use legacy local Class 5 switches to provide service to customers who are still using analog telephones on copper cabling. Providers initially replaced core toll switches (also called tandem switches in North America and transit switches in Europe) with Voice over Internet Protocol (VoIP) technology. One reason they replaced toll switches first, rather than Class 5 switches, is that there are far fewer voice switches in the core than in last-mile networks. Thus, costs are lower because there are fewer switches to replace and maintain.

NOTE *Class 5 switches*, also known as local switches, are those that are located closer to customers than core switches. A small town might have one Class 5 switch, whereas larger towns with 40,000 or more residents might have two Class 5 switches.

Many Class 5 switches connect to a single, centralized switch in the core. In addition, VoIP switches did not have the large number of features that telephone companies desired at that time. This is not an issue for toll switches, which primarily set up and tear down large numbers of calls between central offices.

The Decline of Telephone Revenues and the Transition to VoIP Service

A major factor in the low investment in Class 5 switches is the decline in local telephone service. Traditional telephone companies have lost large numbers of phone wireline customers to wireless providers and cable TV Multiple System Operators (MSOs). This has led to lower profit margins on Plain Old Telephone Service (POTS). As a result, telephone companies have needed to develop strategies to invest in their mobile businesses and in high-speed data networks for enterprise customers. Rather than investing in new local softswitches, (VoIP equipment) while local circuit switches are still operational, they are transitioning to a more cost-effective, IP-centralized infrastructure for customers who have telephone service installed on broadband infrastructure.

Although these centralized switches still do not have all of the 200 or 300 features installed on Class 5 switches such as Integrated Services Digital Network (ISDN) and payphone service, many of the features that are available offer greater flexibility than those available on analog telephones. Customers have the option of having calls ring on both their mobile and landline telephone numbers without giving out their mobile numbers. They can also opt to receive their voicemail messages in their e-mail inboxes.

Moreover, many smaller providers as well as some larger traditional ones are using their centralized VoIP platforms to offer the hosted telephone service described in Chapter 2, “Data Centers and Internet Protocol Private Branch Exchanges.” With hosted telephone service, also referred to as IP Centrex, the VoIP infrastructure is located at the provider’s site rather than at the customer’s site. Scott Hoffpauir, chief technology officer and cofounder of BroadSoft, a VoIP software company for mobile and wireline networks, believes that IP Centrex sales to small and midsize enterprises were booming even during the 2009 recession because customers recognized the savings in outsourcing their phone systems.

Centralized VoIP Services Architecture

Carriers support centralized packetized voice (VoIP) and enhanced applications such as unified messaging as well as voice and video conferencing in their core networks. Centralization has been made possible by the high-speed fiber-optic networks that connect broadband customers to long-haul networks. This phenomenon is similar to the Internet and cloud models in which applications are also supported centrally.

VoIP servers are based on standard computer processors and open-standards protocols.

Softswitches and Gateways

Softswitches process calls, provide routing for calls, transfer control of calls to other networks, and interface with billing systems. Processing calls involves setting up, transferring, and ending calls. In the early 2000s, application servers (described later) were generally referred to as softswitches. This has changed as these servers now hold more applications. Media gateways described in this section are now considered to have integrated softswitch capability. They set up end-to-end paths for voice, data, and video calls.

Gateways are servers that convert protocols so that networks and equipment that use different signaling protocols or other incompatible protocols can interoperate with one another.

The following are the key software functions that support VoIP services.

- **Application servers** These are the workhorses in VoIP networks. They process calls and contain applications. The term “processing calls” means that they issue commands to set up and end calls. Application servers, referred to as *feature servers* by some manufacturers, also communicate with the billing systems used to generate customer invoices. Moreover, they contain subscriber profiles indicating features assigned to each user and which applications each customer has permission to access. These functions provide the capability of acting as network control points. In addition, application servers hold applications such as call forwarding, call waiting, video and audio conferencing, and unified messaging (the ability to access voicemail, e-mail, and fax messages on personal computers).
- **Media servers** Media servers generate and detect touch-tone signals, play announcements and voicemail prompts, record audio, and set up paths (routes) for audio and video conferences. Application servers issue commands to media servers that indicate which announcements to play and paths to set up.

NOTE The term *media*, as used in the context of IP traffic, refers to any call, whether it comprises audio or video content.

- **Network servers** These servers keep track of maps for routing instructions and master directories to applications. They can contain databases that specify how each call should be billed and whether a call is charged at long-distance, intrastate, local, or international rates. Network servers use the maps for routing policies so that traffic is sent to the softswitch closest to the called party.
- **Session Border Controllers (SBCs)** These controllers connect calls to the Public Switched Telephone Network (PSTN) by translating protocols between public network trunks such as T1 and T3 trunks and IP networks. They also translate calls between networks that use incompatible IP signaling protocols. SBCs combine *media gateway functionality* with softswitch functionality. These are a new type of central office switch that handles calls between different networks. Older types of central office equipment switch an entire circuit (an electrical path between devices). SBCs transfer packets containing voice traffic, video sessions, and data between networks.

Depending on the manufacturer, all of these functions can be combined onto a single multifunction server. In addition, applications such as unified communications in a large carrier's network can be installed on separate servers. See Figure 4-4 for an example of VoIP architecture.

The Migration to VoIP by Cable TV Companies versus Traditional Telephone Companies

For the most part, cable TV providers began offering voice service over broadband at a time when VoIP was a trusted solution. Because it was already an accepted technology, most cable providers have centralized softswitch architectures. They are not saddled with the burden of supporting the hundreds of local *legacy switches*. Legacy switches refer to the older, less-efficient circuit switches connected to subscribers who have analog telephones. Furthermore, although they have traditionally used standards developed by the cable industry's standard setting organization, CableLabs, they now use standard IP protocols for their VoIP infrastructure.

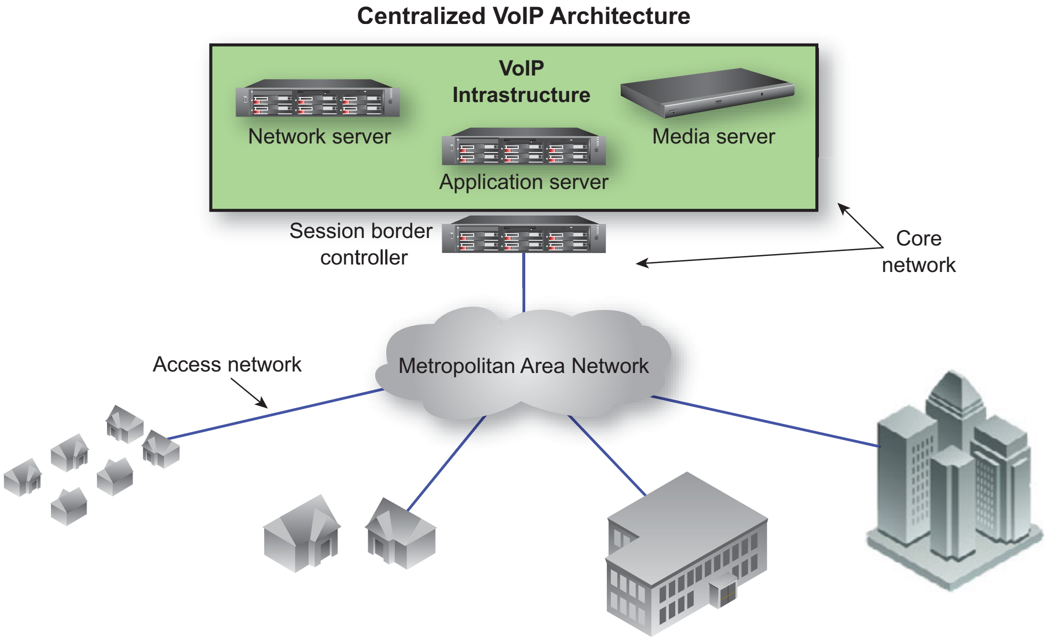


Figure 4-4 In a centralized Voice over Internet Protocol (VoIP) architecture, the application server is the central "director" and contains applications. The network server has information for routing traffic, and the media server plays announcements and detects tones. The session border controller converts signals between networks to compatible types of signals.

Employing Redundancy to Back Up Centralized IP Servers

Redundancy is particularly critical for centralized VoIP servers because they support large numbers of subscribers. Newer ones are capable of supporting up to 600,000 VoIP lines. If any one of these servers fails, entire VoIP networks can be incapacitated. The most common causes of failure are power losses and fiber-optic cabling cuts. To protect networks from these outages, providers often build backup Network Operations Centers (NOCs) in different geographic regions. The main centers have the ability to automatically fail over to the backup center in the event of a malfunction. Once the main center is operational again, service automatically reverts to it, as depicted in Figure 4-5.

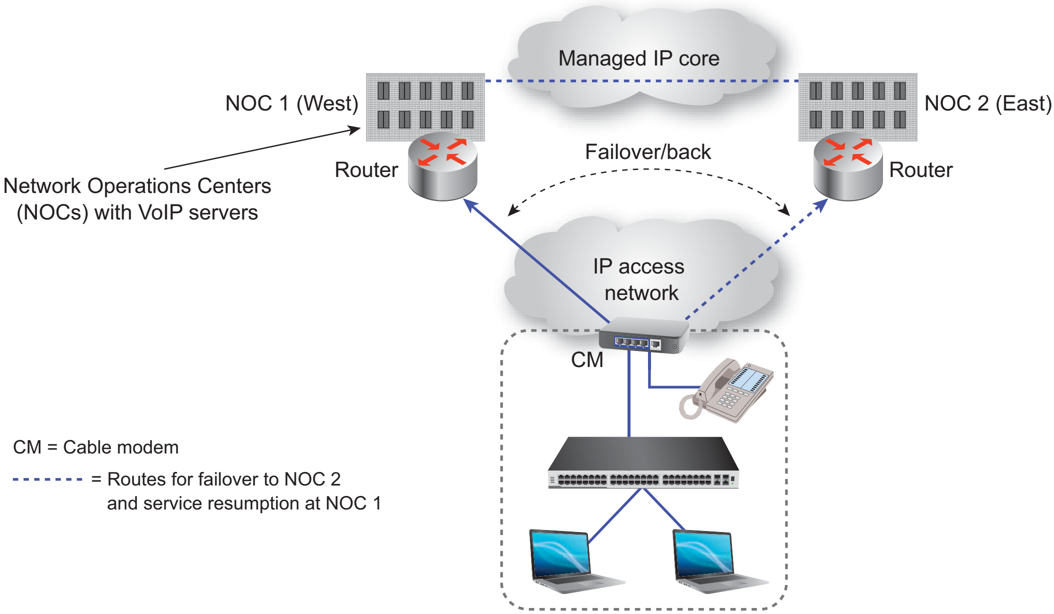


Figure 4-5 A Network Operations Center (NOC) with paths (routes) to a backup NOC. (Courtesy BroadSoft)

IP Multimedia Subsystem for Mobile and Wired Access to an Application

IP Multimedia Subsystem (IMS) is an open-standards architectural framework made up of multiple protocols and standards by which customers can access the same application from both wireline and mobile devices. These applications, including unified messaging and multiplayer games, are installed in a provider's network.

In essence, IMS separates the access signals from the application. It is a form of Fixed Mobile Convergence (FMC) with which both wireline and wireless network operators can install and maintain a single application for their customers. Subscribers can then use these core applications on an interoperable basis.

IMS provides methods to convert signals from mobile switches to those compatible with wireline IP networks, as seen in Figure 4-6. It has the additional advantage of providing carriers that offer wireless, circuit-switched and broadband services with a way to merge operations in core networks so that the same staff supports, for example, one voicemail server.

IMS is based on IP protocols. It was first developed for 3G networks and later expanded to include Wireless Local Area Networks (WLANs), Wi-Fi, and wireline

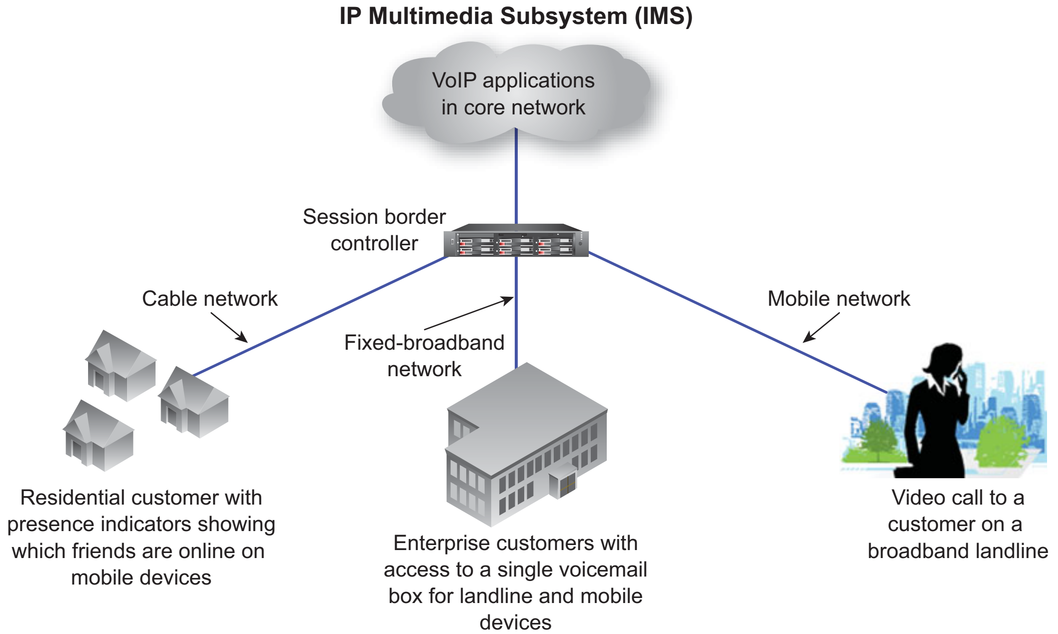


Figure 4-6 IP Multimedia Subsystem (IMS) with common VoIP applications for both mobile and landline subscribers. A Session Border Controller converts signals from the mobile network to those compatible with VoIP equipment.

networks. Interoperability and control of sessions in ongoing online games, conference calls, instant messages, and so on are managed in Session Border Controller (SBCs) and signaling gateways. SBCs are located at sites where carriers connect their IP networks to one another. These controllers have functions such as security, session management, policy control, and address translation. Policy control refers to the ability to prioritize certain traffic, based on agreements between carriers.

IMS users with wireline devices are able to interact with people using wired broadband for access. The following is a sampling of applications that users can access from both mobile and landline devices:

- Presence so that subscribers are able to determine if friends and colleagues are available online
- Advertising that works across wired and wireless platforms
- Gaming so that users can participate in online games together
- Instant messaging
- Video calling

TRANSPORTING MOVIES AND TV IN THE CORE......

Both telephone service providers and cable TV companies have infrastructure in their core networks to receive and transmit entertainment content to customers. They each do this from centralized *headends*.

Using Headends to Receive and Transmit Programming

The term "headend" refers to the site where providers transmit content that they receive from satellites. A group of satellite dishes that receives content is referred to as a satellite farm. Central office switches and Voice over Internet Protocol (VoIP) equipment to support telephone services are also located at headends. Network Operations Centers (NOCs) capable of monitoring and making programming changes to the network as well as operations support systems can be located here, as well. These centers typically serve seven to ten towns. Multiple hubs that distribute content are connected to the headend, as shown in Figure 4-7.

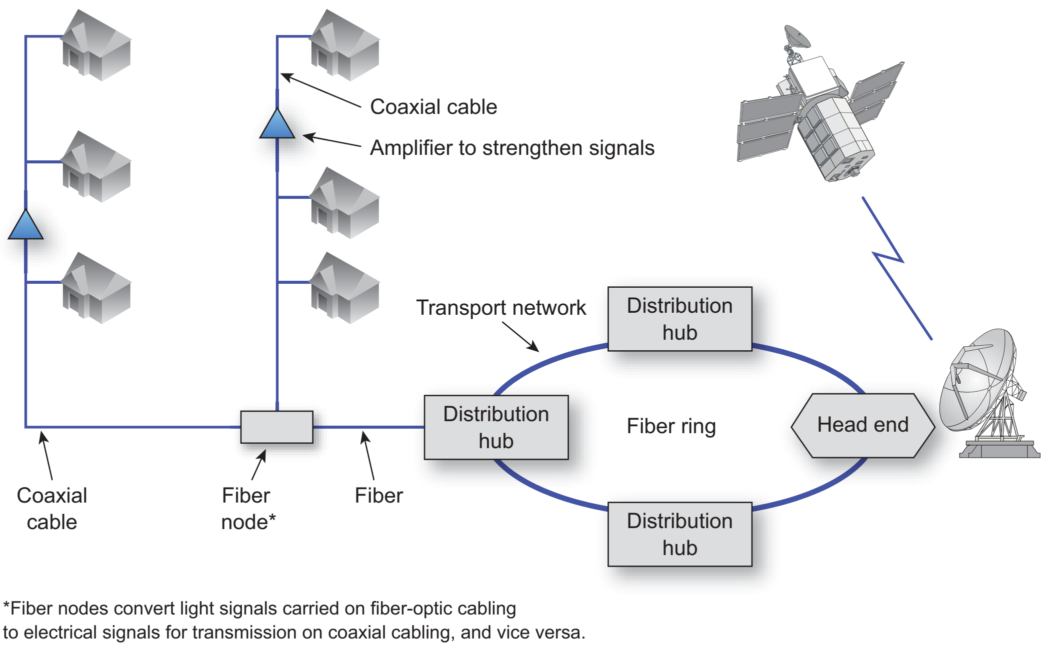


Figure 4-7 *A fiber/coaxial network with transport network linking distribution hubs to the headend.*

Hub Sites

Hubs, also referred to as *distribution hubs*, are small buildings that are located closer to customers than headends. Local programming or frequently downloaded content might be located at a hub, which serves between 10,000 and 50,000 residences. In addition, cable modem termination systems, which manage traffic to traditional cable TV customers' modems and to the headend, are located at hubs. For more information, see the section "Using CMTS for IP Traffic," later in this chapter. A hub might serve a metropolitan area. Large towns would have two hubs.

Linking Hubs and Headends via Metropolitan Area Networks

Metropolitan Area Network (MANs) are also referred to as *transport networks*, or *regional transport networks*. They link hubs to headends. MANs typically operate over shorter distances than core, backbone networks. They carry a mix of voice, data, and video on demand, as well as television signals.

Older MANs transmit traffic to headends over Synchronous Optical Network (SONET) rings. Cable operators and traditional telephone companies have transitioned some of their metropolitan networks to all-IP, Gigabit Ethernet networks or to a combination of SONET and Gigabit Ethernet. It is complex and costly to upgrade all of a carrier's MANs simultaneously. However, carriers have the option of gradually upgrading a few networks at a time. Unlike large core networks, they don't involve the immense upgrades as do core networks. MANs are equipped with either redundant fiber rings or the simpler Optical Transport Network (OTN) option as backup technologies, in the event of a fiber cut or equipment failure.

MIDDLE-MILE NETWORKS ....

Middle-mile networks are the sections of networks between the access provider and the connections that carry traffic to the Internet and to national and international core networks. Figure 4-8 shows an example of connections on middle-mile networks. Middle-mile networks can be the source of congestion on both wireless and wireline networks because they transport increasing amounts of Internet, smartphone, and video traffic. This is straining existing infrastructure.

Middle-mile networks include the fiber or wireless connections between switches in small cities and the carrier's equipment that transmits traffic to a major carrier's Point of Presence (POP). Within middle-mile networks, the POP serves as the location where a provider's switches and connections for multiple carriers connect to the

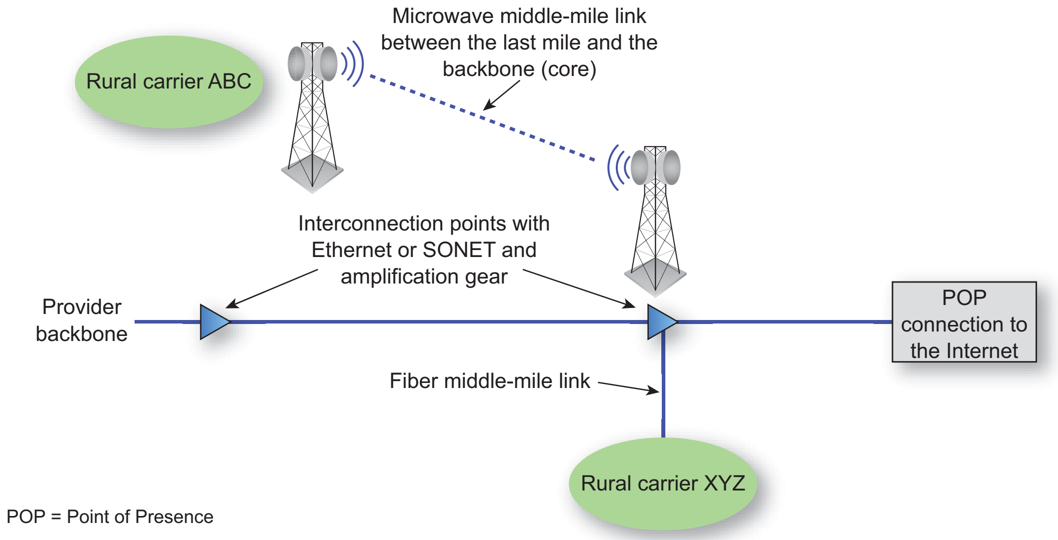


Figure 4-8 *The middle-mile connection between rural last-mile providers and a core network interconnection point for transport to the Internet.*

Internet or to a national or undersea cable. The core switches of large providers are also located at POPs.

Independently operated data centers where data is managed for multiple enterprises are another example of sites that require middle-mile connections. These data centers generate large amounts of traffic for which they require high-speed connections on middle-mile networks to backbone POPs.

Large carriers such as Verizon and AT&T in the United States carry the majority of middle-mile traffic. Level 3 Communications is an alternative option in some areas. Level 3 offers to connect these rural areas to POPs using spare capacity in its regional and long-haul networks. In the newer networks of these providers, hubs with Gigabit Ethernet switches are able to add and drop off traffic. Connections to Gigabit Ethernet are less costly than those to older SONET/Dense Wavelength-Division Multiplexing (DWDM) facilities. However, they require costly fiber cabling or wireless infrastructure from the rural provider's first-mile network to the middle-mile network switch.

The High Cost of Rural Internet Connectivity

High-speed middle-mile connectivity is a major problem in rural and sparsely populated areas, worldwide. Although there are a growing number of fixed-wireless Internet access options, a majority of providers in these areas offer Internet access—predominately Digital Subscriber Line (DSL) service—with some providing cable modems (see Chapter 5 for a more in-depth description of DSL service). The high costs of laying fiber or high-speed wireless connections to reach a broadband carrier for transport are passed on to customers and result in high end-user prices for cable TV and Internet access. In addition, the DSL broadband speeds to customers are slower than those in densely populated urban areas; thus, the percentage of customers who opt for broadband is lower.

The National Exchange Carrier Association (NECA) is a nonprofit association of small, rural carriers that was formed by the Federal Communications Commission (FCC) to administer access charges. Access charges are the fees long-distance companies pay to access the networks of local phone companies to complete their long-distance customers' calls. In its publication, *Trends 2009, A Report on Rural Technology*, NECA stated that in the United States, while broadband-based Internet access is available to 92 percent of these regional areas, only 31 percent of the customers of the 1,100 rural operators opt for it. In its report, NECA further commented that the long distances and low population densities in these areas are the primary causes of the high cost of deploying connections to backbone carriers.

The middle-mile costs associated with interconnection to the Internet are passed on to end users in the form of higher Internet access fees. These higher fees are one factor that inhibits many customers from purchasing Internet access in rural areas. Slower speeds that make surfing the Internet sluggish and cumbersome are also a factor in low adoption rates in these areas.

According to Paul Savill, vice president of Product Management at Level 3, the lowest-priced way to reach Level 3's *interconnection point* is microwave at $150,000 to $200,000 for the tower and about $40,000 for equipment at the tower. An interconnection point is the equipment cabinet with Ethernet or SONET gear that connects the rural provider's network to networks such as Level 3's nationwide, backbone network.

The costs to install microwave are less than the $800,000 to $1 million needed for a five-mile buried fiber cable run. Aerial fiber is less expensive than buried cabling, but more subject to environmental damage such as tornados, snow storms, fallen branches, and so on. Savill believes these investments are too costly for the small rural carriers that NECA reports have an average customer base of only 4,324 access lines. Only 10 percent of NECA's carriers have more than 10,000 access lines in service, which is the threshold at which these connections become economically viable.

In some countries with large rural areas, such as Australia, the government subsidizes construction of middle-mile networks. In the United States, the FCC is providing grants to some rural carriers through its National Broadband Plan. However, it is anticipated that these grants will not be sufficient to provide adequate, affordable, middle-mile connectivity to all small rural providers. These providers now have high-priced interconnections, the costs of which they pass on to consumers. The relatively low rate of broadband adoption combined with long distances and expensive interconnection leaves most rural providers without the resources to invest in high-speed broadband service.

A Unique Model for Bringing High-Speed Broadband to Sparsely Populated Areas

Many of Utah's municipalities are located in mountainous areas where they have struggled without success to obtain affordable service from large providers. In addition, businesses were moving away from these areas because of the scarcity of broadband service. These municipalities realized that they didn't have expertise in the telecommunications business and decided to create a separate, nonprofit entity to build and manage the network. In 2003 and 2004, 16 cities formed the Utah Telecommunications Open Infrastructure Agency (UTOPIA), a high-speed, fully fiber-optic network. Each municipality's governing body approved the formation of UTOPIA, and each city has a representative on UTOPIA's board.

The UTOPIA member cities look upon the fiber-to-the-premises broadband network as vital infrastructure (similar to roads, electricity, and sewers) needed to attract businesses and jobs, and to allow people to participate more fully in today's world. UTOPIA received initial funding through bond offerings by the member cities. Today, it assesses each residential and business customer an initial fee of less than $3,000 that the customer can pay off either over time or as a lump sum up front. For those customers who wish to pay off the fee in installments, towns are able to add a small monthly assessment to their tax bills. The typical installment payment period is 20 years, but like a loan, customers are able to pay the sum down more quickly, if they prefer to.

UTOPIA's redundant fiber backbone network runs from north to south and supplies fiber to each customer's location. When it started, the network was capable of dedicated 100Mbps fiber to each customer, but it now offers 1Gbps speeds in new areas. It was able to increase speeds because new Gigabit Ethernet switches are less costly than those purchased initially. UTOPIA also built a video headend where satellite dishes receive feeds from national content sources such as Turner Broadcasting System and CBS affiliates so that providers can offer cable television and entertainment without building infrastructure.

UTOPIA is a wholesale provider that does not sell service directly to end users. UTOPIA partners with service providers who offer retail services such as TV, hosted PBX service, Internet access, and voice telephony, as well as cloud computing directly to residential and business customers. This multiple-provider, *open-access* network operated by UTOPIA creates an environment in which providers offer services on a competitive basis. Thus, everyone in the UTOPIA coverage area has a choice of a pool of providers. They are not limited to a few—sometimes only one or two—carriers. In its newest area, nearly 35 percent of residents purchased access to UTOPIA's network. They are receiving services such as HDTV, high-speed Internet access, and voice telephony.

Continued

UTOPIA's executive director, Todd Marriott, stated the following in a telephone interview:

> *We now have more than a dozen service providers and are adding more. Our network is open to any interested service provider if they are financially and technically qualified, and able to provide quality service. Because there will be huge financial challenges in the next few years, we're grateful to have a strong service provider base, and we realize more than ever that we need to be efficient in funding fiber build-outs.*

UTOPIA's network engineering manager, Roger Timmerman, has also stated that UTOPIA's largest costs are for trenches for its fiber and conduit. UTOPIA's current fiber network reaches 60,000 residences and businesses. It hopes to reach additional buildings in the future.

LAST-MILE ACCESS NETWORKS..............................

Last-mile networks are the portions of a carrier's network that connect subscribers directly to the provider's equipment. The large number of connections usually means that the last-mile networks are the last portions of a carrier's network that benefit from upgrades. The terms "access networks," "last-mile networks," and "first-mile networks" are used interchangeably.

Adding Capacity to Access Networks

Upgrading access networks involves numerous devices because service to each telephone company and cable TV customer as well as equipment in neighborhood locations must often be changed. This is a challenge for both traditional telephone companies and cable TV Multiple System Operators (MSOs). However, cable TV providers have newer voice infrastructure than traditional telephone companies because the cable TV providers only started delivering these services around 2004. Thus, their voice switches don't require upgrades at this time. However, upgrading cabling and electronics connected to them for higher capacity is costly and complex.

The driving force behind upgraded access networks is the need to support more channels of high-definition television (HDTV) and Video-on-Demand (VOD) so that individuals are able to select from a menu of movies and premium television. In addition, customers are requesting HDTV, which requires more bandwidth and complex electronics than standard definition. Three-dimensional television (3D-TV) will also require upgrades as subscribers purchase 3D-compatible televisions and as content in 3D becomes available.

Improved compression and other techniques such as *rate shaping* provide the capability to carry additional video traffic. Rate shaping adds capacity by using a form of over-subscription. It's analogous to pouring one-and-a-quarter quarts of water into a pail that holds only a single quart. Rate shaping equipment discards bits in real time so that adding eight megabits of traffic to a six-megabit channel does not impact quality.

Supporting More Video by Converting to Digital Cable TV

Competition from former telephone companies moving into their territories is driving cable TV providers to focus on upgrading their infrastructure. This competition has resulted in lower prices and the drive to offer more channels of entertainment to match the offerings of their competitors. One way cable TV providers are gaining more capacity is by converting their infrastructure from analog to digital. Analog video requires an entire 6MHz channel for each movie or show. However, digital cable's increased capacity can transmit 10 to 12 channels of standard-definition video and two to four channels of HDTV or 3D video on each 6MHz channel. Standard-definition TV has lower resolution than high-definition television. Moreover, digital cable results in improved resolution because there is less interference from noise, which creates snow and shadows that appear on the television screen.

Because of its higher capacity, cable providers such as RCN and Verizon have converted their entire infrastructure to digital. In areas where providers still transmit in both digital and analog formats, customers that sign up for the higher-priced digital cable pay an extra fee for premium channels only available in digital formats. A consumer can opt for set-top boxes with hard drives capable of storing content and playing it back at her convenience. Digital cable is also the basis for VOD. Nearly 100 percent of all cable TV subscribers in the United States are located in areas where they can receive digital cable.

Lower-Resolution HDTV

Digital cable operators implemented digital television in the United States using a different transmission technique than that used for HDTV for over-the-air digital television. (Over-the-air television is delivered by national broadcasters such as ABC, NBC, CBS, and Fox from towers to antennas on televisions.) The transmission technique (*modulation*) refers to how bits are carried over the airwaves. However, standards used by over-the-air broadcasters and specified by the Advanced Television Systems Committee (ATSC) are all based on MPEG-2 compression, a way of encoding and decoding bits before and after they are transmitted. In contrast, the majority of cable operators use the lower-resolution Quadrature Amplitude Modulation (QAM) method. QAM enables providers to pack more digital channels and their associated audio and closed-caption services into the same 6MHz channel than what is specified by ATSC for over-the-air TV in the United States. This frees up capacity for more services and television channels.

New HDTV sets are often equipped with ports for QAM as well as ATSC service. Customers of providers that transmit digital signals using QAM are able to connect their television directly to the cable service without renting a set-top box. However, these customers will only be able to receive over-the-air channels and local access programming, which broadcasts local government and school programming. This is because cable providers scramble premium channels such as HBO and ESPN to prevent piracy. Thus, a customer that wants digital channels, other than those rebroadcast from national broadcasters, must rent a set-top box.

Using Set-Top Boxes to Interface to Cable TV

Cable TV set-top boxes are interfaces between televisions, satellite TV, subscription television, and cable TV networks for access to television and other services. At the most basic level, they are tuners that filter out all of the channels except the one selected by the viewer. Because each tuner filters only one channel at a time, set-top boxes used for more than one television simultaneously will require multiple tuners. Personal digital video recorders such as TiVo also have two tuners so that one tuner filters a channel that is being recorded and the other tuner filters the channel currently being viewed. Other tuners in end users' televisions filter signals for interactive services such as programming guides, VOD, and pay-per-view.

Cable operators remotely administer filters and traps in set-top boxes to allow subscribers access to basic cable TV or premium channels. Set-top boxes also have advanced security functions and contain links to billing systems. The security function scrambles and unscrambles TV signals based on the information provided by the billing system as to which channels the subscriber is permitted to receive. Security is higher and TV theft is lower on digital service because of improved scrambling (encryption).

The High Capital Cost of Set-top Box Upgrades

On a cost-per-subscriber basis, when cable TV networks are upgraded to all digital service, the new set-top boxes required cost more than it costs to upgrade any other part of the network. This is because upgrades to the headend or core network are amortized over the entire network. By contrast, each set-top boxes is amortized from payments received from the individual customer. New set-top boxes add up to an enormous amount of money for cable providers with millions of customers. In addition, set-top box upgrades require more administrative time for programming the set-top boxes and answering customer inquiries.

These costs are a major factor in many providers' decision to gradually implement digital service in their coverage areas. This spreads out the costs over a few years rather than during a single year.

Legacy Circuit-Switching Service

Switched services operate on landline and cellular networks. When a person makes a call, the network sets up a path between the caller and the dialed party. Importantly, the path is available exclusively for the duration of the call. The path is not shared. Natural pauses in conversation and data transmission are not used for other voice or data calls. Capacity is reserved in the network for the entire duration of the transmission. This exclusivity causes wasteful utilization of network capacity.

Circuit switching is being gradually phased out in public and wireless networks. Because of circuit switching's smaller capacity and inefficiencies, advanced, fourth-generation mobile protocols specify non-circuit-switched, IP packet technology. Carriers increasingly add IP equipment when replacing fully depreciated, older voice switches or when building new infrastructure.

Last-mile access networks use a mix of IP and circuit switching to carry voice. Traditional telephone companies, which have investments in older infrastructure, are in the process of transitioning to IP in their last-mile infrastructure as they move customers to IP voice. When customers select their telephone provider for Internet access and TV services, the provider offers to move the subscriber's voice service to the same broadband infrastructure as that used for data and TV. Most of them provide VoIP over the broadband.

The Economics of Fiber to Large Apartment Buildings and Enterprises

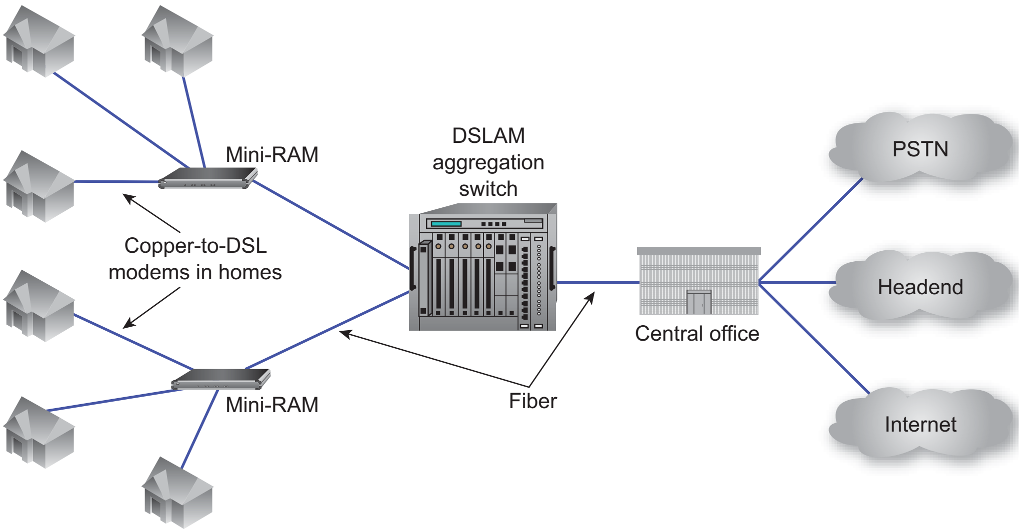
In contrast to the last-mile networks in residential areas, the vast majority of which are made up of twisted-pair copper or hybrid fiber/coaxial, cable TV providers and traditional telephone companies lay fiber to their large business customers. This is because the expense of supplying fiber cable to office and apartment buildings with multiple tenants can be spread across many customers. In addition, fiber is required to handle the large amounts of data traffic that enterprise customers generate.

Digital Subscriber Line Access Multiplexers

Telephone companies that have not invested in fiber to the premises (FTTP) offer Digital Subscriber Line (DSL) service over twisted-pair cabling for Internet access. (Cable TV providers use other technologies over the coaxial cabling portion of their hybrid fiber/coaxial cabling plant.) Former telephone companies deploy DSL Access Multiplexers (DSLAMs) to aggregate traffic from multiple DSL modems in neighborhoods and combine it into higher speeds before sending it to the Internet or data networks over fiber-optic cabling. DSLAMs are located in a carrier's central offices or in remote terminals, which are cabinets placed between the central office and the subscriber. The connection between the DSLAM and an ISP is a potential site for network congestion. If capacity is insufficient, a customer might experience delays.

Using Small DSLAMs and Mini-RAMs for TV and Higher-Speed Internet Access

When providers such as AT&T and CenturyLink move fiber closer to customers in neighborhoods, they often support fewer customers per fiber run and use mini Remote Access Multiplexers (mini-RAMs). Shorter copper lengths support the higher speeds required for TV, movies, and Internet access. They connect this copper cabling to lower-cost, smaller DSLAMs and mini-RAMs. Mini-RAMs are about the size of two pizza boxes, stacked one atop the other. They can be located on utility poles or in stand-alone boxes on the ground and serve 10 to 24 customers (see Figure 4-9). Local power is not required because it is fed to mini-RAMs through the copper telephone lines either on the pole or underground.



DSLAM = Digital Subscriber Line Access Multiplexer
PSTN = Public Switched Telephone Network

Figure 4-9 *Mini Remote Access Multiplexers (mini-RAMs), located in neighborhoods, deliver cable TV and high speed Internet access.*

Because the fiber is closer to customers, these cable configurations avoid most of the impairments found on longer copper lines farther from central offices. These impairments cause DSL speeds to decrease dramatically and often prevent DSL from being viable at even slower speeds. The dilemma is that, as the fiber and mini-RAMs are located closer to customers, the overall costs increase and fewer customers are served. Overall there are more fiber runs, more mini-RAMs, and more equipment to maintain and install. Traffic from mini-RAMs is aggregated in DSLAMs, from which it is transmitted to central offices and the Internet.

Passive Optical Networks

Telephone companies and cable operators install Passive Optical Networks (PONs) to lower the cost of deploying fiber-optic cabling directly to residential and business customers. It is also a less costly way to bring fiber closer to homes and run coaxial cabling or unshielded twisted-pair over the last few hundred or fewer feet to subscribers. PON technologies are less costly because the devices in the neighborhoods are small and passive. They don't require electricity and can be mounted directly on utility poles or in existing equipment cabinets.

Prior to the introduction of PONs, when fiber was run into neighborhoods, more costly equipment was required and a single pair of cables had to be run from the telephone company's local switch all the way to the customer. With PON technology, only one pair of fiber is brought to the neighborhood but multiple pairs are run from PON interfaces to homes. *Splitters* divide the capacity of the fiber among up to 32 customers. Figure 4-10 shows one possible scenario. Splitters are passive in that they don't require electricity and they are small; they're about the size of a smartphone. These are key factors because space in the network is at a premium and electrical costs are soaring. The other devices in PONs—at the central office, at the customer's premises, and in neighborhoods—do require electricity.

Copper for DSL is often connected to the fiber on the PON to improve DSL speeds and performance on a telephone company's network. The PON equipment converts the electrical signals to optical, and vice versa. Cable operators also install PON technology in their networks, enabling them to more cost-effectively deploy fiber closer to homes. They use cable modems and other electronics to split up the frequencies on the coaxial cabling between voice, Internet access, and video. PONs have been widely deployed in Asia in countries such as Japan and South Korea, and in Hong Kong, where much of the infrastructure was upgraded or built from scratch. China currently does not have as great a percentage of fiber in its last mile as these countries, but it is adding fiber at a rapid pace. Figure 4-11 presents a list of countries with the most fiber to the home (FTTH) or building (FTTB). Fiber to the building is fiber terminated inside multitenant buildings, with data-grade copper to each unit.

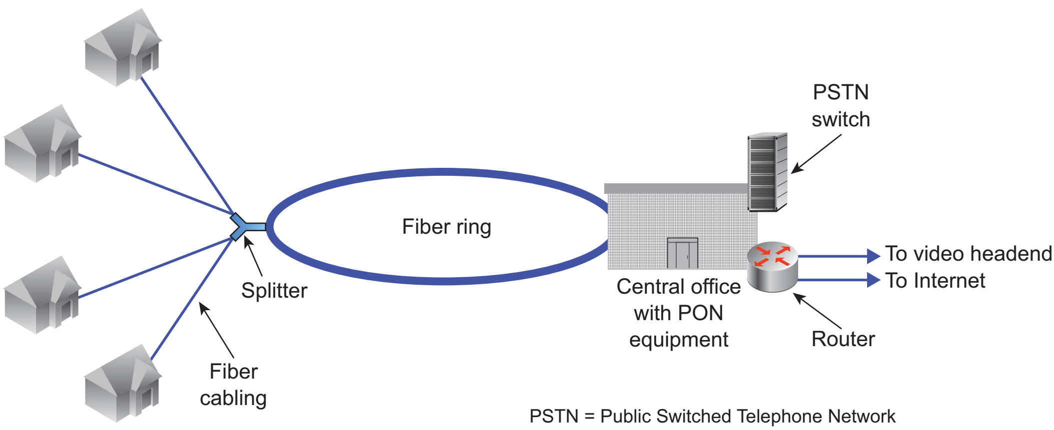


Figure 4-10 *Passive Optical Networks (PONs) increase the capacity in one pair of fiber cables to up to 32 customers. The splitter is about the size of a smartphone and does not require electricity.*

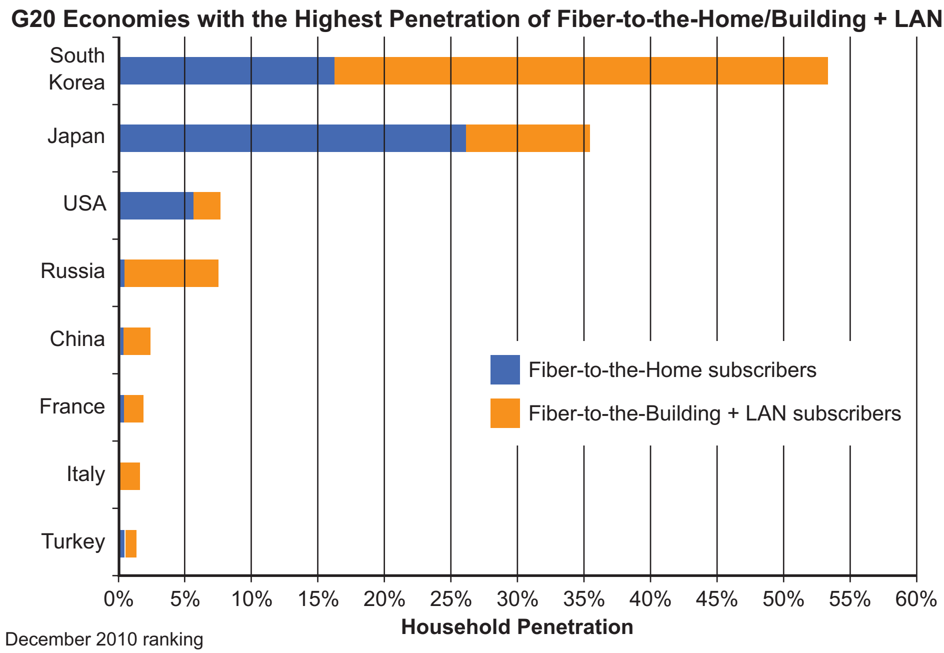


Figure 4-11 The global percentages for Fiber to the Home (FTTH) and Fiber to the Building (FTTB) in countries with at least 200,000 households where the penetration of FTTH/B has reached 1 percent of the total number of homes, apartments, or office buildings. The FTTH Global Ranking is based on the FTTH Council's definition of FTTH/B, which includes FTTB, where fiber terminates inside the boundary of a multitenant building. (Figure courtesy Fiber to the Home Council)

The following is additional information related to Figure 4-11.

- FTTB represents majority (~60 percent):
  - South Korea is number 1 (percentage of households)
  - First country to surpass 50 percent FTTH/B household (HH)
- Top seven global economies (subscribers):
  - South Korea, Japan, United States, China, Russia, Italy, and France
  - Represent more than 90 percent of all FTTH/B subscribers
  - South Korea and Japan surpass 35 percent HH* connected

Using PONs to Deliver Fiber to the Premises, Curb, Basement, or Neighborhood

PON devices located in the access network enable carriers to dynamically allocate capacity on a single pair of fibers to multiple homes, buildings on a campus, apartments, and small and midsize businesses. PONs are used for the following.

- **FTTH** Fiber to the home.
- **FTTP** Fiber to the premises.
- **FTTN** Fiber to the node. This serves about 100 to 200 homes with copper twisted-pair or coaxial cabling from PON equipment in the neighborhood to homes.
- **FTTC** Fiber to the curb. This serves 12 or so homes with copper cabling from the PON equipment at the curb to homes.
- **FTTB** Fiber to the basement of multistory dwellings or businesses.

The term “FTTx” is used to refer to PONs that terminate in any of the preceding locations.

Telephone companies and cable operators deploy PONs differently. Verizon, independent telephone companies, municipality-controlled utilities in mostly rural areas, and Nippon Telephone and Telegraph (NTT) in Japan deploy much of their PON infrastructure to homes and basements of larger buildings. AT&T, CenturyLink, and most cable Multiple System Operators (MSOs) bring fiber deep into neighborhoods and then use twisted-pair or coaxial cabling to serve 110 to 500 customers. Some providers bring fiber all the way to curbside pedestals in much of their territory. These implementations serve only 8 to 12 customers per PON device. PON service closer to customers is more expensive per subscriber to deploy but provides higher-speed service because fewer customers share it.

PONs are also used to bring fiber all the way to premises in new “greenfield” developments (new industrial or residential developments). In addition, they are the basis for wireline infrastructure in developing countries. This is the result of decreasing fiber costs and increasing copper costs, which makes the cost of new fiber and copper about the same.

Using PONs for Remote Administration and Bandwidth Allocation

PONs enable up to 32 locations to share the bandwidth on a pair of fibers. An advantage of PONs is that changes to the allocation of capacity among the 32 premises can be carried out remotely by computer commands rather than by dispatching a technician.

Thus, the programmability of PON devices enables carriers to manage complex networks more efficiently.

Gigabit Ethernet Passive Optical Network

Gigabit Ethernet Passive Optical Network (GPON) is more flexible, and faster than the three earlier PON standards. Most new PON installations are based on GPON. However, a new, faster standard, 10Gbps Ethernet Passive Optical Network (10G–EPON), has been ratified. It supports 10Gbps speeds to customers. 10G-EPON equipment has started to be introduced. For more information about the PON standards, see Table 4-2 in the "Appendix" section, at the end of this chapter.

Gigabit Ethernet is suited for both circuit-switched traffic such as T1 as well as IP voice and data. An important advantage of GPONs and 10G-EPONs is that they can be configured in redundant rings. If one ring fails, traffic is rerouted onto a backup ring (protect ring) and backup PON equipment. Because of their high speed, flexibility, and redundancy, GPONs and 10G-EPONs are well suited for high-definition digital television and for transporting corporate data to storage networks in metropolitan areas.

Verizon uses GPONs for its FIOS fiber-optic service to home installations. This service supports speeds of 15Mbps to 50Mbps downstream from Verizon to the customer, and 5Mbps to 35Mbps upstream from the subscriber to Verizon. For an additional fee, Verizon offers symmetrical service by which upstream and downstream channel speeds are the same. Often, business customers who send as well as receive large files select symmetrical service. In the United States, Verizon is the provider with the largest installed base of FTTH connections.

Using Digital Loop Carrier Systems to Extend Fiber

Prior to the introduction of PONs in the early 2000s, providers installed the more costly Digital Loop Carriers (DLCs) when they extended fiber closer to customers. Carriers ran fiber to the neighborhood and terminated it in DLCs. In addition to being more expensive, DLCs take up more space, require electricity, and are less flexible than PONs.

DLC systems have multiplexing and demultiplexing functionality. At the central office, traffic is combined into high-speed optical streams. The DLC separates out (demultiplexes) the traffic and sends it to end users in analog format on twisted-pair copper cabling. It also converts the optical pulses to electrical signals, and vice versa. Most DLCs support Plain Old Telephone Service (POTS), T1, E1, and Integrated Services Digital Network (ISDN) technologies. DLCs are also used to improve speeds on Digital Subscriber Line (DSL) systems by facilitating shorter copper cabling runs.

DSL speeds decrease as copper cabling distances increase. See Chapter 5 for information on ISDN, T1/T3, and DSL technologies.

ACCESS NETWORKS IN CABLE OPERATORS' NETWORKS

Access networks in cable operators' and traditional telephone companies' networks use a different type of customer modem. However, both telephone companies and cable Multiple System Operators (MSOs) face the challenge of upgrading access networks to increase capacity. Access networks are those portions of a network between a provider's equipment and that of the customer.

NOTE MSOs are large cable TV providers with service areas that extend over many states. They are referred to as MSOs because they grew by purchasing other cable companies and merging operations with these often-smaller companies' systems. Comcast Corporation, Cox Cable, and Time Warner Cable are examples of MSOs in the United States.

Asymmetric Channels

MSO offerings for residential-consumer Internet access are often *asymmetric*, with higher speeds in the downstream channel from the cable provider to the subscriber, and lower speeds upstream from the subscriber to the provider. Splitting the frequencies into different ranges enables the same coaxial cables to be used for both sending and receiving signals. Unlike fiber cabling, for which separate strands of fiber are used for sending and receiving, a separate coaxial cable does not need to be installed for the reverse, upstream channel.

Using Cable Modems to Access the Internet

The basic functions of cable modems are to convert digital signals from computers or data networks to those compatible with coaxial cabling and to convert radio frequency (RF) from cable TV networks to digital signals suitable for Internet access. In cable TV, electromagnetic waves carried on coaxial cabling are referred to as RF signals.

The Cable Modem "Handshake"

Cable modems perform a "handshake," an exchange of signals before data is transmitted to and from the Cable Modem Termination Systems (CMTSs) located at the cable operator site. (See the following section for information regarding CMTS equipment.) Complex signaling, use of frequencies, the speed at which to transmit, and authentication are agreed upon between the two devices. At startup, the network checks the user's login before allowing access to the Web or certain web sites.

Using CMTS for IP Traffic

CMTSs are located at the cable or distribution center (the hub). They ***mo**dulate* and ***dem**odulate* (hence, the term "modem") digital voice and data signals and place them on cable infrastructure. Modulation is the technique of making digital signals suitable for radio frequencies (electromagnetic waves) that carry signals on cabling infrastructure. CMTSs demodulate signals received from customers to make them suitable for transmission on a cable company's fiber-optic rings, which connect smaller hubs to headend facilities.

In addition, CMTSs monitor the level of traffic at each fiber node so that cable providers are aware when congestion occurs and nodes need to be added to serve fewer homes per node. Moreover, they are responsible for encryption to ensure privacy, security, and *conditional access*. Conditional access is the determination of whether a customer is entitled to certain features. CMTS devices have built-in routers that send traffic to different destinations such as the Internet, long-distance providers, or the cable MSO's VoIP equipment.

CMTSs are similar in function to Digital Subscriber Line Access Multiplexers (DSLAMs) that are used in traditional telephone company networks in that both devices translate between modems at customers' premises and equipment in backbone networks. They both also aggregate traffic from multiple subscribers into a single stream for transmission in the backbone. (See the section "Digital Subscriber Line Access Multiplexers," earlier in this chapter, for a discussion on DSLAMs.)

Cable Modem Standards to Transition to Higher Speeds

Cable standards are intended to provide a technology "road map" for cable MSOs to move toward implementing higher-speed IP networks. The cable industry sets modem standards through CableLabs, the research and development arm of the North and South American cable TV industry. These standards are known as the Data Over Cable System Interface Specifications (DOCSIS). The European Telecommunications Standards Institute (ETSI) and the International Telecommunications Union (ITU) have approved the standards listed in Table 4-3 in the "Appendix" section of this chapter. However, the international versions of DOCSIS vary a little from that used in the United States.

Offering Higher Speeds by Upgrading to DOCSIS 3.0 with Bonding

The DOCSIS 3.0 standard specifies support for 38Mbps per 6MHz (6 megahertz) channel. Users on the same node share this capacity. This is why customers might experience delays during peak usage periods. DOCSIS 3.0 is currently the fastest, most advanced cable modem standard. *Bonding* enables support for higher speeds of 173Mbps to 343Mbps downstream to homes, and 123Mbps upstream to the cable operator.

> NOTE
>
> *Bonding* is the process of combining adjacent channels into one large channel to support higher-speed services. For example, bonding four channels together that each comprise 38 1Mb channels creates a single 152Mb channel. In effect, bonding creates a bigger pipe that is shared by homes connected to the same node.

Because of its support for Quality of Service (QoS), DOCSIS 3.0 can support applications such as voice and video, which are sensitive to delays. An upgrade to DOCSIS 3.0 requires a new DOCSIS 3.0–compatible cable modem at the subscriber location and at the CMTS. This makes it a costly endeavor.

According to a January 30, 2010 article by Todd Spangler in *Multichannel News*, titled "Ahead of the Broadband Curve," cable operators in the United States offer DOCSIS 3.0 service to more than 52 million consumers. These customers can select options for higher speed and more costly Internet access. According to the article, competition from carriers that offer FTTP is one factor that's spurring implementation of these higher-speed offerings. It is intended to support video over broadband as well as high-speed services to business customers.

Capacity on Coaxial Cable

Signals on coaxial cable in cable TV networks are transmitted as electromagnetic waves (radio frequencies [RF]). Capacity on these coaxial cable systems and on TV channels is measured by the amount as a function of frequency. This amount is determined by the difference between the highest and lowest frequencies on the coaxial cabling. For example, a 6MHz channel might be within the 60MHz and 54MHz range (60 – 54 = 6). Upgrading to gigahertz from megahertz networks adds capacity for additional video channels and higher-speed Internet access for subscribers. See Chapter 7, "Mobile and Wi-Fi Networks," for information on frequencies.

Limitations of Bonding: Stealing from Peter to Pay Paul

Bonding increases capacity and speeds for Internet access. However, it does so by using channels previously available for video, which of course, decreases the number of available video channels. It does not increase the total amount of capacity on cable networks, many of which have a top capacity of 860MHz. Bonding, rate shaping, and improved compression increase the amount of data (throughput) that the network can handle, but they do not increase overall capacity. For more information on rate shaping, read the section "Adding Capacity to Access Networks," earlier in this chapter. Cable companies use other techniques such as switched video to manage spectrum utilization. Fiber-optic cabling supports more capacity than current hybrid fiber/coaxial cabling. For example, Verizon's FTTP cabling enables it to use its entire 860MHz for TV, with an additional 2.5 gigabits available for voice and Internet access.

NOTE *Switched video* is a technology that enables MSOs to send particular movies or TV shows to only a subsection of customers who order them. Switched video is a way to manage spectrum utilization because all streams are not broadcast to every customer. Thus, these video streams do not use up capacity in the entire network. This frees up channels for video to other subscribers.

Adding Capacity by Upgrading to 1GHz

Unlike bonding, rate shaping, and switched video, all of which help providers manage capacity, upgrading to 1GHz capacity adds capacity for services. Unlike bonding, it does not decrease the amount of capacity for video. However, it is more costly than all of these methods. Optical transceivers and receivers as well as amplifiers and set-top boxes might need to be replaced or upgraded, depending on the age of the existing cabling and electronics. Optical transceivers and receivers convert signals on optical cabling to those compatible with copper cabling, and vice versa. Amplifiers strengthen signals that naturally weaken after traveling over certain distances.

TELECOMMUNICATIONS SERVICES IN NATIONAL EMERGENCIES ....

During natural disasters, extreme weather conditions, and even armed attacks, the government, military, first responders (hospitals, police, 911 call centers, and firefighters), and ordinary citizens depend on communications to coordinate rescue operations and to stay in contact with family members. Even in the absence of a disaster, the ability to call police, fire departments, and hospitals is critical so that people can report emergencies and assistance can be dispatched as quickly as possible. For these reasons, governments worldwide regulate network reliability and sustainability. Equipment and network *sustainability* refers to the capability to operate continually during adverse conditions.

In the United States, the Federal Communications Commission (FCC) requires outage reports from the following providers:

- Wireline
- Wireless
- Paging
- Cable TV
- Satellite
- Signaling systems

They must further report disruptions that affect the following:

- E-911 facilities
- Major military installations
- Key government facilities
- Nuclear power plants
- Certain airports

In addition, fiber-optic outages on cabling that carries traffic between backbone network switches must be reported as well as outages of 30 minutes or longer in duration that impact 900,000 or more user-minutes at these key facilities. Reports on outages are reviewed quarterly by the Network Reliability Steering Committee (NRSC), which is made up of representatives from nationwide wireline and wireless providers. The committee looks for patterns by type of failure so that they can determine ways to prevent them.

Key Factors Affecting Reliability and Sustainability

Carrier networks are now largely IP-based, converged networks, wherein a single network infrastructure carries data as well as telephone traffic. (The Internet and most mobile networks are made up of separate infrastructure.) Thus, outages cause disruptions to businesses, governments, and consumers. In addition, traffic volume increases significantly in emergencies.

During widespread emergencies, mobile carriers free up capacity for the additional volume required by assigning less frequency to each call. Thus, more calls can be carried, although at lower sound quality. They can also quickly set up portable cell sites and additional generators at towers or mobile switches that lose power. This enables mobile providers to restore service to these areas. In addition, if one part of the country is hit by a natural disaster, other carriers will send staff members and equipment to assist in restoring service.

Carriers plan for emergencies in various ways. For example, they build backup wireless routes between critical switches and public safety answering points (PSAPs) for E-911 calls. They also look at ways to increase security against hackers and terrorists at peering sites where carriers exchange IP traffic. In addition, providers consider methods to avoid user errors. User errors occur most often during network upgrades and programming changes.

Electrical Requirements for Towers, Residential Service, Digital Loop Carriers, and Digital Subscriber Line Access Multiplexers

Prior to the use of Digital Loop Carriers (DLCs) and Passive Optical Network (PON) equipment, telephone companies supplied low-voltage, direct-current electrical power for residential telephones on the copper cabling that carried telephone signals. The power was carried from the central office to customers and each central office was equipped with generators and backup batteries. Thus, during disasters when commercial power was lost, telephones still functioned.

However, equipment connected to fiber at customer premises and DLCs requires electricity to operate. In addition, equipment at cell phone towers requires electricity to operate. This is a problem because there are many more of these devices than there are central office switches, mobile switches, and IP voice servers in the network. Thus, it is more complex and costly to provide backup power in the form of long-lasting batteries or generators for all of these devices to keep them operational in power outages. During these times, it is common for all of the switches to be operational; however, the gear located between the customer and the provider's main servers and switches is likely to fail. In these cases, providers restore service at the most critical locations first. These include fire and police stations, government offices, hospitals, and E-911 centers.

Internet Security

Internet security is a global issue that cannot be isolated within a single country. However, the Federal Communications Commission (FCC) currently has no authority to require that Internet providers report network outages and details about cyber attacks. In its 2009 National Broadband Plan, the FCC recommended looking at ways to ensure sustainable communications over the Internet. It also stated the desirability of expanding international participation and outreach to manage cyber security information. Part and parcel to that, the FCC would like a vehicle for collecting more detailed information about cyber security. The report also expressed concern about how dependent first responders are on Internet communications. The FCC further declared that it is considering asking Congress for the authority to require reporting on these issues.

Because the Internet is classified as an *information service* rather than as a telecommunications service, the FCC has limited authority in regulating it. An information service is defined in the Telecommunications Act of 1996 as a service that adds value to a basic transmission path through functions such as processing information. *Telecommunications* is defined as the basic transmission (delivery) of voice and data. It's essentially the path over which voice is carried as well as the equipment used to send and receive voice and data traffic.

Because of its critical role, the FCC is attempting to alter the way the Internet is regulated so that the agency has more oversight on cyber security and sustainability. It is attempting to have the Internet classified as a telecommunications entity rather than a value-added service. The FCC has announced that it will do this by recognizing the transmission component of Internet services, not the information contained on web sites.

SIGNALING ....

Signaling is the process of sending control information over landline and mobile networks to monitor, control, route, and set up sessions between devices. These sessions include video and audio conference calls, data sessions, video calls, and mobile and landline telephone calls. Signaling is also used to set up instant messaging and chat sessions. Signaling is used within public networks and the Internet as well as for intercarrier connections and billing.

An Overview of Signaling

Signaling is used to process every call on the Public Switched Telephone Network (PSTN) and public cellular network. When a caller dials a number, he can hear progress tones such as dial tone, ringing, busy signals, or reorder tones. These are all signaling tones. In addition to tones, callers might hear digital messages informing them that the number they dialed is not in service or has been changed.

The PSTN uses Signaling System 7 (SS7); IP networks mainly use variations of Session Initiation Protocol (SIP) as the common platforms for call setup, teardown and activation, and control of advanced features. SIP was originally designed for the Internet, but is now used in private packet networks, as well.

Signaling is the basis of interconnection between mobile, global wireless, and multiple providers' networks. When AT&T controlled most of the public network in the United States, it had the necessary control of the public network that enabled it to set a standard (SS7) that was followed across the country and was later adopted, with variations, by the international community.

SIP is an Internet Engineering Task Force (IETF)–approved standard. In both SIP and SS7 protocols, signaling messages are carried separately from user content. In addition, they both provide common functions.

The Basis for Billing and Monitoring

Signaling networks monitor traffic on networks around the clock, worldwide. When network problems are detected, alerts are sent over the signaling network to centralized Network Operations Centers (NOCs) where technicians see visual indications of alarms on wall-mounted, computerized displays. Moreover, sections of carrier networks can be quickly reconfigured from commands sent by centralized network control centers.

In addition, when carriers transmit traffic to other providers, signaling messages are used to identify each carrier's traffic. This is the method by which carriers bill one another for services that they provide. No carrier has facilities everywhere, so they must rely on other providers' networks outside of their coverage area. For example, a provider that sells toll-free service to customers nationwide pays a fee for each call that terminates in another carrier's coverage area. *Termination* refers to the traffic destination. In the preceding example, a call terminates at the subscriber's location where it is answered.

Signaling in Mobile Wireless Networks

Second-generation (2G) and third-generation (3G) cellular networks use Signaling System 7 (SS7) technology to support roaming for voice traffic. Every cellular provider has a database called the Home Location Register (HLR) where complete information is kept about each subscriber. They also have a Visitor Location Register (VLR), which keeps temporary records for callers who are visiting from other areas. When a cellular subscriber roams, each visited system exchanges SS7 messages with the "home" system. The home system also marks its HLR so that it knows where to send calls for roaming customers.

As mobile networks transition to fourth-generation services, they will use different signaling protocols. Long-Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) are fourth-generation (4G) upgrades that provide higher capacity for data and voice. In the United States, AT&T and Verizon are rolling out LTE. Sprint is converting its WiMAX network to LTE. 3G mobile protocols specify circuit switching for voice and IP for data traffic, adhering to SS7 for voice. However, 4G mobile protocols specify IP for both voice and data traffic. These networks will use SIP-type protocols for all of their 4G traffic. Most mobile carriers continue to use 3G protocols for voice when they initially implement 4G mobile service.

Incompatibilities between Different SIP Implementations

SIP is an extremely flexible protocol that offers different ways to implement many IP applications. These differing methods are referred to as Requests for Comments (RFCs). RFCs were originally used only to solicit comments when standards are being developed. Once approved by standards bodies, the final versions of standards are then published as RFCs.

SIP has many RFCs, which has been a complicating factor when carriers connect with one another at peering sites and when carriers purchase new IP equipment from manufacturers that use different SIP implementations than the carrier utilizes. In these cases, manufacturers modify their equipment to match the RFC implemented by the carrier for its network. The SIP Forum, a nonprofit organization that advances interoperability and hosts interoperability testing, has been attempting to simplify internetworking between carriers as well as between carriers and enterprises. The forum recommends specific profiles (RFCs) to use when connecting enterprise SIP trunks for VoIP service. Most carriers are now transitioning to these and other specified profiles.

Interconnecting Carriers and Providing Secure Space for Equipment in Co-Location Facilities

Co-location facilities are sites where network service providers house their switches and routers and connect to one another's networks. Co-location facilities are also referred to as *carrier hotels*.

There are up to 200 carriers located at the very largest co-location sites. Co-location facilities are connected to the Internet, public and private data networks, and the PSTN. Because so many network providers depend on co-location facilities, security and sustainability in the face of natural and man-made disasters are critical. For these reasons, co-location facilities are located in secure buildings with few windows and no company logos to identify them. They are also monitored by security cameras and heavily guarded by security firms.

Carriers rent space in co-location facilities because no provider has outside cabling everywhere. In addition, certain providers have no cabling facilities. Instead, they own switches, which they connect to other carriers' networks. In both of these circumstances, rather than construct their own buildings to house their switches, carriers lease space in carrier hotels. They place their equipment in cages or lease space in equipment cabinets in the carrier hotel. Locked wire cages surround the equipment and access to the equipment is available only to employees of the company that owns the equipment. For even more reliability, some providers place redundant equipment at more than one co-location site.

Leasing space in carrier hotels saves network providers the expense of establishing and maintaining the following:

- Physical security against break-ins
- Access to large amounts of power
- Access to backup power
- Backup generators
- Dual air conditioning systems
- Uninterrupted power supplies
- Fire detection and fire suppression equipment
- Alarms to fire and police departments
- Staff members to plan and maintain the facilities
- Construction of earthquake-resistant facilities

Carriers such as Level 3, AT&T, and Verizon have *carrier-owned co-location* facilities. These are generally in the same building as the carrier's Point of Presence (POP). Carriers offer a bundle of services at these facilities, including connections to routes connected to the co-location facility and connections to the carrier's POP, which is often located in the same building as the co-location services. AT&T and Verizon buy services from each other's co-location sites to reach customers whose locations are outside of areas in which they own access networks.

Another type of co-location facility is a carrier-neutral facility. *Neutral co-location facilities* are owned by noncarrier organizations, including Equinix and Telehouse. Neutral refers to the fact that carriers that use these facilities can send traffic over routes offered by any carrier connected to the same facility. A carrier at a neutral site can lease routes from any other provider at the site, such as Level 3, Windstream, or Time Warner Telecom, Inc. Carriers locate gateways, switches, and routers in these facilities to exchange traffic with other providers and to manage their own traffic.

Connecting Smaller Providers and Competitors to Customers

Telephone companies and Multiple System Operators (MSOs) rent various portions of their networks to smaller providers and to competitors that might have some of their own switches and/or long-haul networks, but no last-mile connections to customers. They offer these services on a wholesale basis. For example, they offer connections between their POPs and their local central offices. These connections are considered *transports*. Smaller providers use these lines to transport traffic between their own switch (which might be located at the POP) and the local telephone company's switch. They also lease last-mile cabling infrastructure to reach each of their customers.

Both large and small providers make these arrangements with one another. For example, Verizon sells services to large enterprises that have offices throughout the United States and around the world. Often, these enterprises purchase nationwide networking services for all of their locations. Verizon rents transport services from providers such as AT&T in cities where it does not own the local cabling infrastructure. Providers make these types of arrangements with carriers in other countries, as well. AT&T, in turn, leases these services for its own large customers' remote offices that are located in areas where AT&T does not have its own last-mile network or central office switches.

SUMMARY

Until the early 2000s, increased traffic on broadband networks was due largely to the growing use of the Internet by enterprises for daily functions and remote access by employees. Consumers increased their Internet access for activities such as reaching friends via social media, shopping, and reading newspapers. In the next decade, traffic on broadband networks will again grow dramatically as consumers and businesses increasingly adopt cloud-based services, including streaming movies and television programs, storing music, and accessing office productivity applications.

This rise in dependence on networks for access to files and applications makes it imperative that carriers continue upgrading networks and planning for future growth. Organizations and consumers take the availability of adequate capacity on broadband networks for granted. These consumers assume that when they add additional applications and content to cloud-based services, they will have access to the network when they need it.

However, providing consistent availability and capacity takes enormous expertise and vast investments by carriers that manage and upgrade networks. Departments tasked with selecting new infrastructure need to understand new protocols and evaluate new types of infrastructure. Installation and maintenance staffs require training in understanding the new capabilities and in programming and monitoring the equipment. These upgrades require enormous investments in equipment, software, training, and staffing.

However, profits at carriers are under pressure because of competition for particular services. Rates that carriers charge for transmission on their core, backbone networks have dropped due to competition on these routes. This pressure on profits is particularly acute for wholesale carriers that sell long-haul routes to carriers without facilities on particular routes. For wholesale carriers, the ability to keep costs as low as possible to earn adequate returns on their investments is critical.

Although rates for transmission on middle-mile and last-mile, access networks have not dropped as much as on long-haul core routes, the costs and complexity to upgrade middle-mile and access infrastructure are higher than those on core networks. This is because additional equipment is required due to the greater number of connections and routes. For example, access networks connect to millions of homes and buildings with vast numbers of separate cable runs. By contrast, undersea cabling systems are thousands of miles long, and intercity routes run hundreds of miles. Thus, they require fewer connections and less equipment.

There are numerous challenges in managing and upgrading networks; they need to be secure from hackers, have adequate capacity, and be sustainable during emergencies. Providing capacity during peak traffic periods is particularly important during disasters caused by severe weather or terrorist attacks, when governments and populations depend on networks to communicate with emergency personnel and families. Providing funding for these capabilities does not add revenue, but is critical to the security of nations, commerce, and the ability to communicate during emergencies.

APPENDIX

Table 4-1 SONET Worldwide Standards and SONET/SDH Capacity

Speed	North American Synchronous Transport Signal (STS) Levels	SONET Channels	European Synchronous Transfer Mode (STM) Levels	Synchronous Digital Hierarchy (SDH) Channels
52Mbps	OC-1	28 DS1s or 1 DS3	STM-0	21 E1s
155Mbps	OC-3	84 DS1s or 3 DS3s	STM-1	63 E1s or 1 E4
622Mbps	OC-12	336 DS1s or 12 DS3s	STM-4	252 E1s or 4 E4s
2,488Mbps	OC-48	1,344 DS1s or 48 DS3s	STM-16	1,008 E1s or 16 E4s
9,953Mbps	OC-192	5,376 DS1s or 192 DS3s	STM-64	4,032 E1s or 64 E4s
39.812Gbps	OC-768	21,504 DS1s or 768 DS3s	STM-256	16,128 E1s or 256 E4s

Table 4-2 PON Standards

	APON ATM PON	BPON Broadband PON	GPON Gigabit Ethernet PON	10G-EPON Gigabit Ethernet PON
Speed	622Mbps* (OC 12) downstream 155Mbps* (OC 3) upstream	622Mbps* upstream and downstream	2.5Gbps downstream 1.25 Gbps upstream	10 Gbps downstream 1Gbps upstream Or symmetric 10Gbps upstream and downstream
Comments	Earliest PON standard	A faster version of APON	Efficient for IP traffic	Symmetric suited for commercial customers

**Optical carrier*

Table 4-3 DOCSIS Standards

Standard	Capabilities
DOCSIS 1.0	Two-way service for Internet access. Upstream speed of 5Mbps. Uniform specifications so that cable modems can be purchased from retail outlets that are compatible with cable operators' infrastructure.
DOCSIS 1.1	Increases the upstream speed to 10Mbps. Improves security and privacy. QoS enables operators to provide differentiated quality for VoIP and interactive services such as realtime multiplayer games. Tier-based services such as higher speeds to heavy users who use more bandwidth or purchase additional data service.
DOCSIS 2.0	Increases upstream speed to 30Mbps per second. Symmetric services such as those for business customers. Peer-to-peer such as VPN with site-to-site connectivity (see Chapter 5 for further information on VPN service).
DOCSIS 3.0	Supports higher speeds of 173Mbps to 343Mbps downstream to homes, 123Mbps upstream to the cable operator, and bonding. DOCSIS 3.0 includes support for IPTV.

5 Broadband and Wide Area Network Services

In this chapter:

INTRODUCTION

Broadband services link residential and commercial sites to the Internet and to other high-speed networks. Individual buildings are linked by Wide Area Networks (WANs), whether they are within the same city or located far away. Both broadband and WAN circuits are able to carry a mix of data, voice, and video interleaved with one another. But, many experts believe that the capacity on these circuits will not be adequate for future requirements. This adds pressure to increase capacity to more closely match consumer and business consumption of data and video services.

A number of factors are increasing the demand for bandwidth. For enterprise and commercial customers, the trend toward centralizing applications within enterprise and cloud data centers is a key cause. As more remote offices and telecommuters access centralized files, high-speed links are becoming increasingly critical at remote offices, cloud-based data centers, and the data centers that need bandwidth to handle these requests.

The high cost of travel, lost productivity, and improvements in video conferencing are additional factors contributing to increased demands on bandwidth. Skype video conferencing was initially used by consumers and then adopted by enterprises. Its ease of use and worldwide adoption meant anyone with broadband Internet access could spontaneously initiate video conferencing at the office, from home, and while traveling.

Large enterprises that use Skype often also often use the higher-quality video conferencing that consumes large amounts of bandwidth on LANs and requires priority service. For this reason, many videoconferences now take place on quality-controlled, private IP networks offered by carriers. These networks use Multi-Protocol Label Switching (MPLS) and are operated separately from the Internet. Customers access MPLS networks via high-speed links, such as Gigabit Ethernet (GigE), T1, and T3.

T1 and T3 services are examples of older Time-Division Multiplexing (TDM) technologies. These services are limited to speeds of 1.54Mbps on T1 and 44Mbps on T3 links. TDM technologies save fixed capacity for each message and voice conversation. Although this guarantees voice quality, it is inefficient because capacity is wasted during pauses in transmissions. (See the section "T1 and the Inefficiencies of Time-Division Multiplexing," later in this chapter, for a more detailed discussion of TDM operation.) In addition, speeds are inflexible. The only way to increase speeds is to upgrade from T1 to T3, or add new T1 or T3 circuits. In both cases, new equipment is required and customers must wait from two to four weeks for carriers to implement these changes.

In contrast to TDM's fixed capacities, Gigabit Ethernet over fiber is scalable. It supports speeds ranging from 10Mbps to 10Gbps in some cases. At higher speeds, Gigabit Ethernet is less costly than equivalent T3 services. Moreover, prices for Gigabit Ethernet have recently decreased enough to be affordable for midsize customers. Another advantage is that upgrades to higher capacity can be achieved by programming alone, without the time-consuming and costly changes for T1 and T3 upgrades.

This is also the case for Ethernet over copper, which supports from 2Mbps up to 100Mbps. Additionally, both Gigabit Ethernet and Ethernet over copper operate on the same Ethernet technology used in both core carrier networks and internal enterprise networks. This makes them simpler to install because there are fewer requirements to convert between Ethernet on Local Area Networks (LANs) and TDM, and vice versa. Moreover, Ethernet interfaces between the carrier and the customer cost considerably less than those for TDM.

Like T1/E1 and T3/E3, Digital Subscriber Line (DSL) is an older technology, but it is used extensively worldwide. DSL's key advantage is that it operates over the existing outside copper cabling located in the vicinity of most customers. Thus, it is a relatively low-cost option for carriers to deploy and for subscribers to lease for Internet access. Businesses also use it in areas where T1/E1 services are cost prohibitive.

The number of DSL connections is decreasing as more fiber is installed, and as next-generation, high-speed mobile services become available and consumers substitute mobile broadband for DSL. Both of these changes offer the possibilities for higher speeds and cost savings. In addition, mobile services don't limit customers to a single location for Internet access.

Along with their broadband and network offerings, carriers now offer managed services, which they use to induce existing customers to purchase expanded business packages. Some managed services include operating data centers remotely for customers, developing and managing custom software applications, and consulting. Managed services are a source of increased revenues for carriers. They also cement relationships with business and commercial customers.

Managed services are one way that carriers differentiate themselves from other providers, who for the most part offer the same technologies. In addition, large carriers distinguish themselves from smaller carriers by promoting their international presence. This is important for enterprises with a global infrastructure. In most areas, there are only one or two large carriers able to offer broadband on this scale. Thus, multinational organizations have fewer choices for their primary carrier than do smaller or more localized organizations. The next challenge for multinational carriers is to offer affordable, uniform mobile services, worldwide. This is particularly true in high-growth, less-developed parts of the world such as Africa and parts of Asia and Latin America.

A DEFINITION OF BROADBAND

Broadband services are defined as high-capacity network access services able to transmit large amounts of voice, data, and video simultaneously. The definition of broadband is not limited to signals carried over wireline media such as fiber optics, coaxial cabling, or twisted-pair copper cabling deployed in carrier networks. It applies to high-speed wireless services, as well. See Table 5-2 for a list of broadband services used on wired networks. Wireless broadband services are discussed in Chapter 7, "Mobile and Wi-Fi Networks," and Chapter 8, "Mobile Carriers Worldwide."

A report commissioned by the Broadband Forum and conducted by the market analyst firm Point Topic revealed that there were a total of 484 million fixed-broadband subscribers at the end of the first quarter of 2010. The report covers only broadband access over cabling and fixed, point-to-point wireless services. China had the most subscribers at 112.6 million. The country with the second most was the United States, with 87 million subscribers. These findings were reported in a June 16, 2010 *ZDNET* article by Victoria Ho, titled "China Adds More Broadband Lines."

Many people in less-developed parts of the world access the Internet primarily over mobile services. This is because dedicated Internet access over landline networks is frequently either not available or more costly than mobile services in these areas. In addition, electricity is often expensive. In the Philippines, both ISP-delivered dedicated Internet access and electricity are too costly for most citizens. Thus, mobile services are attractive as electricity is only required for charging laptops, tablet computers, and other devices that are equipped with mobile capabilities. Moreover, a single device can be used to make calls and to access sites such as Facebook.

While current mobile networks support broadband services, they're slower than those over most wireline networks. However, new technologies and upgrades to existing technologies are expected to vastly improve Internet access on mobile networks and spur adoption of mobile broadband. Fourth-generation (4G), high-speed mobile protocols such as Worldwide Interoperability for Microwave Access (WiMAX) and Long-Term Evolution (LTE) are in various stages of development, testing, and implementation. In addition to fourth-generation mobile services, worldwide mobile carriers are upgrading existing third-generation networks.

There is large growth potential for higher-speed broadband access in Latin America, Africa, and even China, where, according to a report by the International Telecommunications Union (ITU), as of June 2010, only 7.7 out of every 100 inhabitants had fixed-broadband access. In parts of Latin and Central America and Africa, less than one out of every 100 inhabitants has fixed-broadband access. For many of these areas, many experts believe that most residential subscribers will continue to use mobile services as their primary broadband access. In the future, as mobile services continue to improve, no one knows how many subscribers in developed countries will drop their landline service and depend on only their mobile device for both voice and Internet access.

Actual Speeds versus Advertised Speeds: The Discrepancies Are Large

In a report released August 16, 2010, the Federal Communications Commission (FCC) stated that in the United States, consumers generally get only half of a provider's advertised speed on their broadband service. In 2009, the average broadband speed offered by providers was 7Mbps to 8Mbps. However, the FCC's report revealed that the actual median speed was 3Mbps. This is because providers advertise maximum speeds rather than actual attainable speeds. Maximum speeds are rarely achieved due to factors such as network congestion, slow-loading web sites, and underperforming routers. The FCC report criticizes the advertisement of maximum speeds rather than actual, attainable speeds. The FCC stated that it plans to work with consumer and industry groups as well as technical experts and the National Institute of Standards and Technology on advertising and measuring actual speeds.

VOIP CALLING SERVICES OVER BROADBAND.........

To transmit Voice over Internet Protocol (VoIP), voice is digitized and bundled into packets. Packets are similar to envelopes in that they include headers that specify addressee and sender information (one of the ways that they differ, of course, is that they also provide error correction). Because headers are carried along with data packets, they interface more easily with computer services such as e-mail. Standard computer platforms are used to manage VoIP services.

Lower-Priced, Flexible Consumer VoIP Services

Many consumers and organizations use VoIP for their phone calls. These calls are often carried over their Internet access circuits. Most customers select VoIP to save money on phone calls. These VoIP services include features such as voicemail, voicemail messages in e-mail, audio conferences, and in some instances, video conferencing and unified communications. Although voice quality on VoIP is not as consistent as that on circuit-switched calls, it is less costly and often offers additional features.

Moreover, consistent quality is no longer critical because customers are no longer dependent on their home telephones for all of their communications. Growing numbers of consumers substitute e-mail and cellular devices for some or all of their landline services.

In parts of Europe as well as in the United States, cable TV and incumbent telephone companies have the largest base of VoIP customers. Most cable TV providers began offering VoIP services as a way to lure customers away from traditional telephone companies. They offer, for example, "triple-play" services consisting of television, Internet access, and telephone service. Later, traditional telephone companies started offering VoIP over the broadband facilities used for their new cable TV and Internet access services. As telephone and cable TV providers move more of their customers to VoIP platforms, they will be required to support fewer voice customers on their traditional circuit-switched networks.

This will ultimately save them operational costs as VoIP hardware and software is less complex than equipment on the Public Switched Telephone Network (PSTN) to operate and maintain. This is because centralized VoIP equipment can support multiple subscribers. A separate switch is not required for each metropolitan area. As a result, providers can operate and support a single VoIP switch and its associated gear rather than multiple switches.

Prepaid, Free, and Low-Cost VoIP Services

VoIP providers such as Skype and Google are often referred to as over-the-top (OTT) providers because their services are deployed over cable TV and the cabling infrastructure of incumbent telephone companies. These providers own VoIP hardware and software but not the cabling over which the signals travel. Calls are routed from users' computers to cable TV or incumbent telephone company broadband circuits. From there, they are routed over the Internet for calls to other users with the same provider, or they are routed to the PSTN. For calls to the PSTN, Session Border Controllers (SBCs) convert VoIP protocols to those compatible with the PSTN, and vice versa. OTT providers include Google, Skype, magicJack, and Vonage. Figure 5-1 presents an example of how these calls are routed.

With the exception of Google's service, which is accessed from within browsers, most VoIP services require additional computer software and/or hardware at the customer location. The Vonage service requires an external device into which a telephone is plugged. The external device, a terminal adapter, converts the analog voice signals to those compatible with the Internet, and vice versa. Most of these providers earn revenue from monthly fees, ads on their site, and adjunct hardware sold on their sites.

In contrast, magicJack's revenue is derived in large part from ads on its site and from fees other phone companies pay to the company. This is because magicJack is registered with the United States government as a telephone company. This enables it to collect access fees from all carriers whose customers call magicJack's customers over the PSTN. Telephone companies charge one another access fees for carrying one another's calls between local carriers and long-distance networks on the PSTN. For example, magicJack charges access fees to all telephone companies for each call its customers place to magicJack's customers.

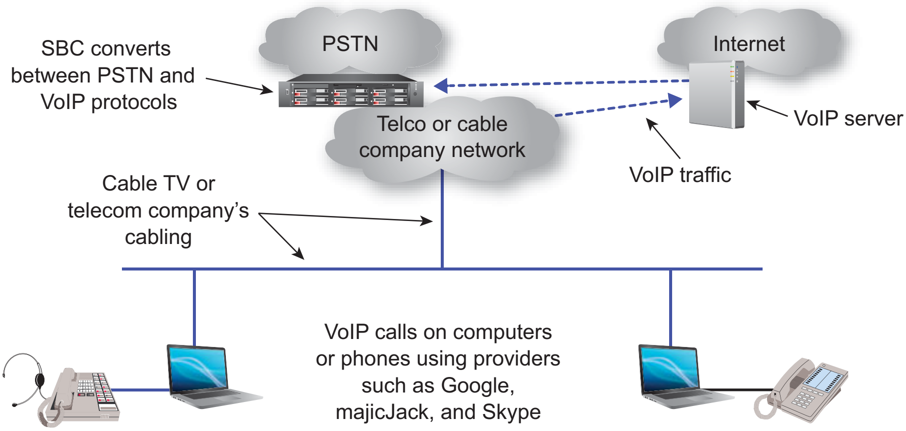


Figure 5-1 *Transmitting Voice over IP traffic (VoIP) "over the top" of carriers' infrastructure.*

OTT VoIP services are generally less costly than those offered by traditional phone and cable TV companies. Their costs are offset by the other sources of revenue and the fact that they don't have the expense of providing their own cabling infrastructure. In addition, OTT VoIP providers generally bill through credit cards and thus don't have the expense of fee collections, and bill generation. These services are usually paid in advance; customers provide credit card information and service providers bill them monthly, in advance.

VoIP Services for Commercial Organizations

Many large and small business and nonprofit organizations now have VoIP telephone systems for internal calls. However, because of its consistent quality, they often use the PSTN for calls to people outside of their organizations. Organizations that use VoIP for internal calls and the PSTN for external calls are required to purchase extra hardware, or gateways, to convert between VoIP and PSTN formats. Moreover, converting between these formats can somewhat lower quality on these calls. In addition, calls on the PSTN, particularly those to international locations, might be more costly than those carried as VoIP traffic on data links or over the Internet.

Newer VoIP systems now often come equipped with interfaces compatible with VoIP networks. These interfaces, which are based on Session Initiation Protocol (SIP), are compatible with the VoIP trunk interfaces of most carriers. Thus, connections between the customer telephone system and VoIP networks do not require gateways. This simplifies hardware requirements on these telephone systems. Carriers send

VoIP-formatted calls to the PSTN. Interfaces at the PSTN convert the VoIP signals to those with which it is compatible (see Figure 5-1).

Hosted IP Centrex Service

Small organizations—meaning companies with fewer than 100 employees—are increasingly using the IP Centrex service as a way to eliminate maintenance and programming tasks for telephone service. The IP Centrex (also called Hosted IP) equipment is located at the provider's data center. These systems enable organizations to take advantage of features such as voicemail, unified communications, and call center services without the added effort of maintaining, upgrading, or expanding them (to accommodate growth). Organizations that use Hosted IP service have the same LAN requirements, data grade cabling, adequate capacity and Ethernet switch port for telephones as do organizations with onsite IP Private Branch Exchanges (PBXs).

During installation, the provider installs or mails telephones to customers. On an ongoing basis, the provider handles repair issues and requirements for additional or fewer telephones. With Hosted IP, incoming and outgoing voice traffic is carried over broadband access circuits. An onsite customer administrator has browser access to menu-driven interfaces known as dashboards with which the customer can easily add and delete telephone users or features for individual employees such as access to long-distance service, international calling, and voicemail.

VoIP for Very Small Organizations

Very small organizations and startups with fewer than 25 employees often use services from companies such as Google, Skype, and Vonage that have been adapted for business. For example, features might include the ability to transfer calls to another employee in the same facility or in a remote office. The features provided also include a fixed, single phone number for mobile devices, work phones, and home phones, with a single mailbox for voicemail for all of these phones. It can also include audio and video conferencing. Some of these features were previously only available for large organizations with complex, onsite phone systems.

These VoIP services enable organizations to develop a new business or service without purchasing hardware for a telephone system. In addition, the services can be used for businesses in which all or many of their staff members work at home or in remote offices.

Even midsize and large organizations with their own onsite telephone systems often use these network-based VoIP services for certain functions. One of the most common functions is desktop video conferencing from Skype or Google. Desktop video conferences are transmitted over data networks, and they typically require nothing more in terms of equipment than the personal computers or laptops of the participants. In particular, people working from home or traveling can participate in these conferences, incurring minimal or no charges.

The Impact on Traditional Carriers of VoIP for International Calling

According to telecom market research firm, TeleGeography, as of the end of 2011, Skype is the largest provider worldwide of international long-distance calling services. Consumers and business people alike use Skype to call home and the office when they travel. In addition, many immigrants use video and audio calling to stay in touch with family members in their native countries. Computer-to-computer calls are free and computer-to-telephone calls on the Public Switched Telephone Network (PSTN) have low fees attached to them. Through its Google Voice product, Google now competes with Skype for international calling and audio conferencing.

MULTI-PROTOCOL LABEL SWITCHING FOR INTEROFFICE CONNECTIONS

Large and midsize organizations link their domestic and international sites together by using Multi-Protocol Label Switching (MPLS), which is a Virtual Private Network (VPN) service. MPLS traffic is carried on a provider's core private data networks rather than on the Internet. MPLS is suitable for transmitting packetized voice (VoIP), video, and data between sites.

MPLS Virtual Private Networks

MPLS is also referred to as *MPLS IP VPN* because it uses the IP and provides VPN functionality. VPNs have the features and functionality of private networks. However, unlike private lines, which are not shared and are for the exclusive use of a single organization, MPLS operates on network links shared by other customers. The links are virtually private, and they still offer many of the features found on private lines such as user control and privacy. In addition, they are less costly than private lines to lease and operate.

Prior to the advent of MPLS, older VPNs offered by carriers were slower and more cumbersome to implement and to add or delete locations. The most commonly used older VPN was frame relay. (See the section "Private Lines, Network Topology, and Frame Relay," later in this chapter, for an explanation of frame relay.)

In addition to higher speeds and less-cumbersome implementations, MPLS has the capability to classify traffic so that voice and video have higher priorities than services such as file transfer and e-mail, which are less sensitive to delay. Because of these and other capabilities managed by providers, MPLS is also referred to as a *managed network service*.

MPLS is inherently more secure than the Internet because it is transmitted over a carrier's private data network. For added protection from hackers, customers often use separate circuits to access MPLS service and the Internet. This is more costly than combining both services on the same line, but it isolates MPLS transmissions even further from viruses and attacks sent over the Internet. Figure 5-2 illustrates an example of segregated circuits for Internet access and MPLS service.

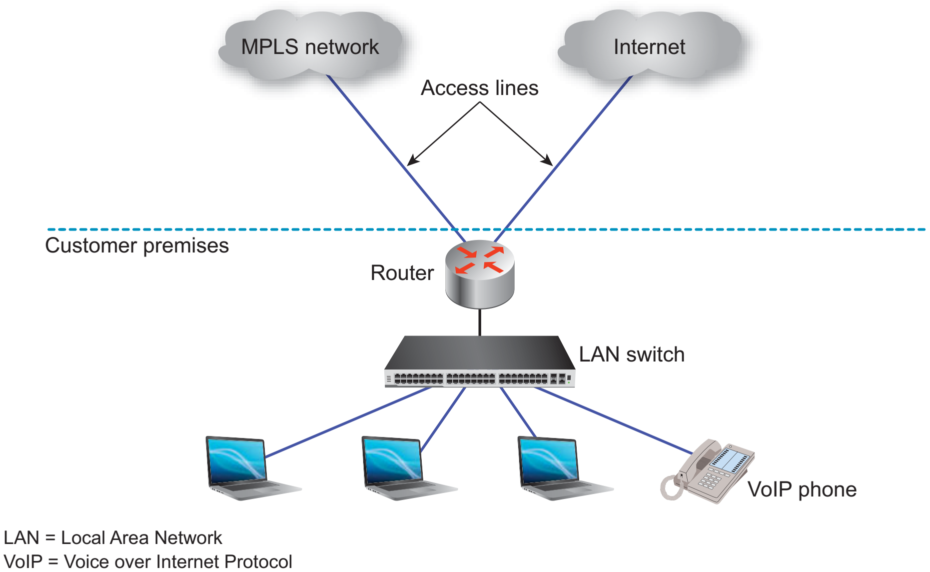


Figure 5-2 *Implementing separate access to the Internet and a Multi-Protocol Label Switching (MPLS) network.*

MPLS Implementation

When customers sign up for MPLS service, they give their provider a list of the IP addresses associated with each site that they want included in their MPLS service. Each IP address identifies a specific location on a network. The carrier uses this list to define a closed group of sites that are allowed to communicate with one another over the MPLS network. The list can be amended by notifying carriers of IP addresses to be added or deleted.

In addition to an IP address, each location connected to the MPLS network requires an access line from the customer to the carrier's network. However, a single link from each location can transmit messages to all sites. Each location does not need a separate physical connection to every other site on the MPLS network. This is referred to as an *any-to-any* network.

MPLS Networks

Traffic intended for the organization's other sites is forwarded to the provider's *edge router*. Edge routers are routers at the edge of a carrier's network that link customer traffic to the carrier's high-speed backbone networks. In contrast to edge routers, which are connected to customers, *core routers* are located in a network's high-speed backbone and are connected only to other routers. Figure 5-3 presents a depiction of where each router is deployed in the network.

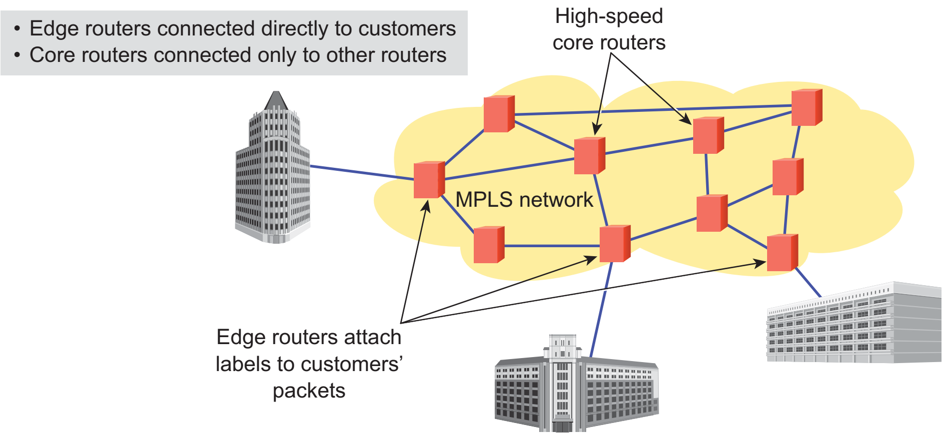


Figure 5-3 Core and edge routers in a Multi-Protocol Label Switching (MPLS) network.

The edge router examines the first packet's header and looks up addressing information in the router's tables for only this packet. It attaches a label with this address data to each subsequent packet of the transmission. The elimination of router table lookups for each packet is a major factor underpinning the high speeds of MPLS. Examining a label is faster than examining headers and looking up router tables.

MPLS minimizes traffic jams by selecting the shortest, least-congested route for all messages in each transmission. All packets in every message are sent over the same route.

MPLS for Multinational Locations

No single carrier provides service everywhere. Internationally, most large providers have a presence in Europe, the United States, the Middle East, and parts of Asia. However, they have less presence in Latin American cities, and the lowest presence in Africa. The term *presence* means that they have a switch in a local provider's Point of Presence (PoP). A PoP is the physical building in which a telephone company's switch (central office) is located. The PoP is connected to the Internet as well as to other central offices that are located close to customers.

For remote countries in which carriers have a presence, the carriers have agreements with local providers. These agreements specify the type of circuit (local access line) and at what price the local provider will lay cabling from the distant office to the MPLS carrier's switch. In some countries, E1, E3, or Gigabit Ethernet (GigE) is available. In other areas, only DSL or satellite are offered. MPLS carriers place orders with local providers for access lines to the remote offices of MPLS customers. This creates international MPLS networks.

Repair and installation problems on MPLS most often occur on the access line or the equipment directly connected to the access line. When problems occur at remote locations to which other providers have installed the local circuit, resolving issues can result in finger pointing. Problems most often occur when new service is deployed. It's not always clear whether it involves the customer's equipment, the local circuit, or the programming in the MPLS network. This is particularly difficult to determine for locations where language and time zone differences can impede communications.

Another issue in designing MPLS networks for international organizations is that rural and sparsely populated areas often don't have MPLS available from the same carrier that installs the service for the rest of the enterprise. (Because of technical and network management incompatibilities, MPLS requires that the same carrier supply end-to-end service for each site on the network.) This is particularly problematic in underdeveloped areas such as parts of Africa and outside of most populated cities in Latin America.

Many companies with offices in less developed countries or rural areas have a mix of MPLS services for which their carrier has a presence, but they use the Internet for communications to the rest of their organization. However, Internet access in many less developed and rural areas is prohibitively expensive, costing thousands of dollars monthly for even T1 speeds of 1.54Mbps.

Prioritizing Traffic via Classes of Service

When customers want to differentiate certain traffic for specific treatment, they select from their carrier's list of classes of service. These classes of service are used to define the priority given to traffic for each class. For example, there might be three classes for data, one for voice, and another (the most expensive) for video. Voice and video are generally assigned higher priorities than data. Routers at customer sites add bits to packet headers with Class of Service (CoS) designations. At the MPLS edge router, these designations are added to the MPLS labels, along with addressing data.

Some organizations use the lowest-priced CoS for most data and higher-priced CoS for database lookups. This can vary by industry. Retail organizations that depend on point-of-sale credit card lookups for revenue might assign these applications the highest priority.

One aspect behind the popularity of MPLS for multisite organizations is the growing adoption of centralized *Unified Communications* (UC). UC denotes the use of one server to deliver e-mail, voicemail, and fax messages, as well as audio and video conferencing through a single computer desktop application. Because it's centralized, all sites depend on consistent, high-speed network connections. This is particularly applicable for audio and video conferences, where latency (delays) noticeably degrades quality.

Operating conferencing services over data networks is less costly than using long-distance services. Some organizations save money by using the Internet for conferencing services. Thus, prioritization is an important element toward ensuring that the audio is clear and the video is continuous and without distortions. However, there is no guarantee of consistent quality levels on Internet-based video conferences.

Specifying Performance Levels in Service-Level Agreements

As part of their MPLS contracts, for an additional fee, most carriers offer Service-Level Agreements (SLAs) in conjunction with MPLS VPNs. These agreements offer guarantees regarding issues such as the following.

- Uptime, which is the percentage of time that the service operates.
- Latency, which is the delay in milliseconds between when packets are sent and received. Low latency is important for voice and video quality.
- Restoral time per failure.
- Packet loss.
- Access line (the line from the customer to the carrier) uptime.

Carriers apply CoS according to tags attached to packets for each protocol. Routers attach a different type of tag to packets containing e-mail messages than for those that contain video. Carriers that don't meet these SLAs generally rebate agreed-upon credits to customers.

MPLS Service Components

In addition to classes of service, customers also specify the following.

- A *port speed* at the provider's Point of Presence (PoP), often at a lower speed than their access line. The port speed refers to the number of bits per second that can enter the carrier's network.
- Additional managed services, including managed security, CoS, and the use of the provider's network and staff for operating, setting up, and managing the video conferences.
- The *speed of the access line*, which is the circuit connecting the customer to the provider's network. Typically, remote offices use T1 services at 1.54Mbps; higher-trafficked headquarters use T3 at 44Mbps or Carrier Gigabit Ethernet at speeds ranging from 100Mbps to 1Gbps. Higher-speed services cost more than slower services.

Virtual Private LAN Service versus MPLS

Virtual Private LAN Service (VPLS) emulates a private Local Area Network (LAN). It operates over a provider's MPLS networks. However, it is an end-to-end Ethernet service similar to LANs, and thus requires Ethernet access because Ethernet is based on IP. Therefore, only Ethernet or Gigabit Ethernet access can be used.

The use of MPLS in the carrier's network provides higher speeds and enables VPLS to act like unified LAN segments connected to one another with physical private lines. VPLSs are considered Ethernet switched services with the core MPLS network providing the switching function present in private LANs. The MPLS network transmits messages to individual MAC addresses of each device as though all ends of the transmission are in the same LAN. This results in higher speeds and fewer delays.

VPLSs are designed for a smaller number of sites (approximately ten). This is because the route to each site requires its own data path and control signals within the network. It is essentially a virtual mesh network. Figure 5-3 shows an example of a mesh network. VPLS is used for communications to bandwidth-intensive sites such as data centers. A large organization might have a mix of VPLS and MPLS sites. Figure 5-4 presents an example of VPLS.

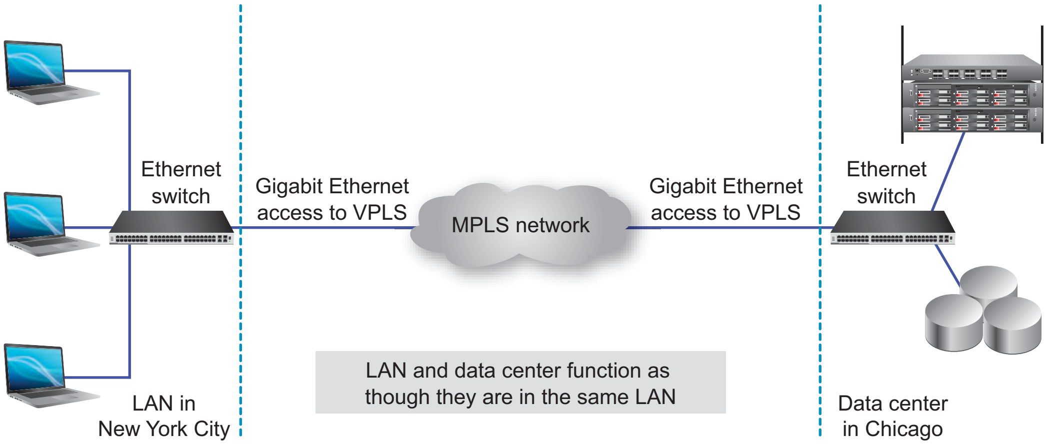


Figure 5-4 *Using Virtual Private LAN Service (VPLS) with MPLS to connect a LAN to a remote data center.*

INTERNET PROTOCOL VIRTUAL PRIVATE NETWORKS OVER THE INTERNET

Internet Protocol Virtual Private Networks (IP VPNs) use the Internet to provide links to sites within the organization, commuters, and mobile workers. Organizations use security protocols to keep their IP VPNs secure from hackers.

> NOTE The term "IP VPN" is not used consistently to mean the same thing. Some organizations refer to it synonymously with MPLS. They might refer to VPNs that operate over the Internet simply as VPNs.

Using IP VPNs between Offices

Organizations use IP VPNs to link sites together so that remote offices are able to share resources such as centrally located e-mail servers, Internet access, and applications. A particular difference between IP VPN and MPLS networks is that organizations that use IP VPNs only pay for Internet access. This is a major cost advantage in favor of IP VPNs. Some companies do pay carriers for security services to screen incoming traffic for viruses. However, IP VPNs do not offer Quality of Service (QoS). This makes them somewhat problematic for transmitting group video conferences over the Internet.

Organizations can add capacity to their access lines, but they have no control over the Internet itself. If an organization experiences congestion on its access circuits, it has the option of adding access lines or increasing the capacity of its existing access circuits. It can add T1 lines, upgrade its T1s to T3, upgrade Carrier Gigabit Ethernet to higher speeds, or add Carrier Gigabit Ethernet and cancel the T3 service.

However, IP VPNs do not guarantee QoS. IP-based networks such as the Internet are *connectionless*. With connectionless networks, each packet is transmitted as a separate entity. A path is not saved in the network for the entire transmission. Rather, every packet can take a different route, and if there is congestion on a particular route, packets are dropped. The router at the receiving end reassembles packets into their original form, minus the dropped packets.

Dropping parts of voice or video streams can result in poor quality. As more video traffic is sent over the Internet from mobile devices and landline facilities, the likelihood of congestion and dropped packets increases.

Avoiding Congestion on IP VPNs

The most common points of congestion in IP VPNs are the access lines connecting organizations to the Internet and points in the Internet where carriers connect their networks together. In addition to monitoring and upgrading access circuits, where possible, organizations lease Internet access from the same provider at all of their sites to limit the number of connections between their carrier and other carriers. This is not possible in remote and international areas where the primary carrier does not provide coverage.

SECURING TRANSMISSIONS SENT VIA THE INTERNET

Most organizations deploy their Internet Protocol Virtual Private Networks (IP VPNs) for remote access as well as site-to-site links. When used for remote access, IP VPNs enable employees who are traveling or working from home to remotely access e-mail messages, place orders, check order status, and check inventory levels from the road and from home computers. With the growth of Voice over Internet Protocol (VoIP), some employees also receive phone calls directed to their office extensions on their laptops or mobile smartphones.

Because the Internet is open to users from all over the world, organizations deploy security software designed to protect transmissions sent over the Internet. The security software is also used for IP VPNs and MPLS networks that link sites together.

Secure Access to IP VPNs

Improvements in security software have led to advances in creating safe remote access procedures. These improvements encompass ease of use as well as protection from hackers. However, seemingly as quickly as security software improves, hackers find vulnerabilities and develop new ways to break into systems. Customers and developers find they must remain vigilant and diligently update their security software for protection against new viruses and types of attacks.

Security protocols designed for IP VPNs all create a *tunnel* for their transmission. Tunnels are special bits at the beginning and end of each packet. In essence, the tunnel encapsulates messages so that others cannot see what is being transmitted.

Tunneling protocols establish a secure connection between the corporate Local Area Network (LAN) and the remote user by encrypting and tunneling the bits and hiding the IP header in each packet. This ensures privacy. Tunneling prevents hackers from learning corporate LAN IP addresses. Specific protocols encrypt packets to further protect their privacy. *Encryption* is the use of a complex mathematical algorithm to reorder bits so that only the receiving end with matching encryption is able to decipher and read them. Other protocols require a different protocol for encryption.

To access the corporate network, customers with broadband services log on to the public Internet. From there, traffic is routed to the Internet and then to the T1 or other dedicated line connected to their place of business. For organizations with Multi-Protocol Label Switching (MPLS) service, the user is routed via the Internet to the provider's private IP-managed network, and then the organization's access circuit, as indicated in Figure 5-5.

The most common security protocols on access networks are the following.

- **Internet Protocol Security (IPsec)** This is an older security protocol that requires software to be installed in every computer that accesses the network remotely.
- **Point-to-Point Tunneling Protocol (PPTP)** This is a less secure protocol installed in Microsoft operating systems and often used with IPsec.
- **Layer 2 Tunneling Protocol (L2TP)** This protocol evolved from PPTP; it has stronger authentication security for screening devices that access the network. L2TP is also used with IPsec.
- **Secure Sockets Layer (SSL)** This is a newer access method that does not require client software.

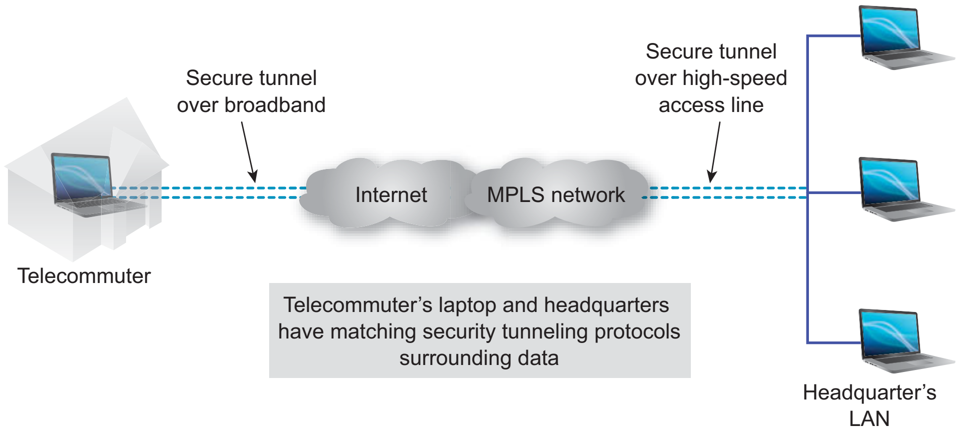


Figure 5-5 *Secure access to MPLS using an Internet Protocol Virtual Private Network (IP VPN) tunneling protocol to protect data transmitted over the Internet.*

The Complexities of Using VPNs with IPsec

To support IPsec remote access, IT staff members distribute software to each person's computer. (They also handle calls from employees who are having trouble logging on to the VPN or who have lost their laptop or smartphone.) Employees can only access their e-mail and other applications from their own computer or supported mobile smartphone, such as a BlackBerry, Android, or iPhone.

Users work with IPsec *client software* installed on their computers to launch remote access. Client software enables access to applications located on other computers or servers (usually in data centers). It is supplied and licensed by the organization that develops the IPsec security software. The client software is a special program written to interact with security software located in the data center. Security software at the user's organization issues prompts for usernames, passwords, and token ID (identification) numbers, if they're used. See the section "Token Identification: Another Layer of Protection" for secure access using token IDs.

To prevent remote users from passing viruses from the Internet to corporate networks, the client software will often not function if there is an open connection to the Internet while the user is logged on remotely.

Point-to-Point Tunneling Protocol

Point-to-Point Tunneling Protocol (PPTP) is a Microsoft protocol. It does not have encryption capabilities described in the protocol standard. It can be used with IPsec, which does include encryption. PPTP is included in many Microsoft and some Apple operating systems. Because of its known vulnerabilities, authentication—the process used for secure access—is performed by a different protocol in conjunction with PPTP.

Layer 2 Tunneling Protocol

Layer 2 Tunneling Protocol (L2TP) evolved from PPTP, and just as with PPTP, it too does not provide encryption. There is a new version of L2TP that has improved its tunneling. Like PPTP, it is also used with IPsec for encryption. In addition, IPsec has stronger authentication than L2TP.

Secure Sockets Layer

Secure Sockets Layer (SSL) is a newer VPN protocol than IPsec. SSL is a clientless protocol; that is, it does not require the installation of client software on each computer that's used for remote access. Rather, SSL works from within standard browsers on computers and smartphones. This makes VPNs easier to use and requires less administrative support from IT personnel. The simplified login results in fewer user errors. Recent releases of SSL are referred to as *Transport Layer Security* (TSL). For added security, SSL is frequently used with tunneling protocols.

Because it is a higher-level security protocol, SSL installed on *appliances* can enable access to particular applications based on privileges granted to classes of employees. An appliance is a specialized computer that is dedicated to a particular task.

It's possible for remote computers to pass viruses to corporate networks, so some SSL appliances have the capability to scan remote computers for antivirus software and automatically download patches to computers that don't have the latest security updates. Other appliances have the capability to remotely wipe out passwords and corporate data from shared computers in public areas such as libraries. This eliminates the possibility of computers in locations such as kiosks to store and pass on private information and passwords.

Token Identification: Another Layer of Protection

Tokens are small security devices; small enough, in fact, that they can be attached to a user's key ring. Tokens randomly generate six to eight-digit numbers at regular intervals (usually every 60 seconds). When prompted by the associated software on their computer, users enter the token-generated number. These numbers are generated by a combination of factory-set matching numbers in the user's device and a central server set to an external clock. To be authenticated, the number the user enters must match that generated by the central computer.

Token identification is used with both IPsec and SSL. It provides a second layer of *authentication* at logon in addition to the password. If a person's password is stolen, the hacker will not be able to access the network without the token. Authentication refers to the requirement that users prove to computer systems that they are authorized to log on to the network.

VPN Aggregation

Some organizations that support hundreds or even thousands of remote access employees worldwide use network aggregators to manage their remote access. Network aggregators are also referred to as *virtual network operators*. A network aggregator makes agreements with carriers worldwide, including those at hotels and airports, so that customers have Wi-Fi wireless, cellular, and landline access, all through one provider. The virtual network operator runs a clearinghouse that performs billing settlements. In essence, the aggregator pays network operators a fee and bills the corporation, which receives only one bill.

Users receive the aggregator's client software which establishes a session with the aggregator when it is activated. The aggregator passes the transmission on to the corporate firewall and security server after authenticating the user and checking that she has up-to-date firewall and virus-protection software.

Using an aggregator means the enterprise does not need to make agreements with multiple carriers and Wi-Fi operators for worldwide remote access. In addition, aggregators supply another level of security. Some companies use aggregators for people who work from home as well as those who travel. Large carriers as well as independent companies supply aggregation services.

Protecting against Malicious Attacks by Using Firewalls

A firewall is a device, software application, or set of devices at carriers, enterprises, and homes that screens incoming and internal traffic to prevent hackers from accessing files. Firewalls deny hackers access by allowing only designated users to access networks. In an organization's network, firewall software is installed on routers and appliances. For additional protection, organizations that use their carrier's firewall protection have onsite firewall protection, as well.

Firewalls provide networks partial protection against Denial-of-Service (DoS) attacks and intrusion. They use various techniques including *address filtering*, which looks at a user's IP address and accepts or rejects messages based on that address. Important applications might contain their own firewalls for extra protection.

Communications can also be restricted to certain addresses. Firewalls contain hundreds of ports and can filter on a port-by-port basis. In addition, they can be programmed to recognize applications and content that can be programmed to pass through the firewall by using a specific port. However, even with these filtering capabilities DoS attacks can congest access to the organization's files.

Firewall ports can be virtual as well as associated with physical equipment within the firewall. A virtual port is programmed to allow certain traffic such as Voice over Internet Protocol (VoIP) calls to pass through the firewall to its destination.

Because employees use their laptops at home to surf the Web and then bring them into work, corporations monitor internal transmissions as well as communications from the Internet. The goal is to avoid contamination from either source.

Firewalls don't protect against viruses and other threats such as e-mail spam. Corporations often subscribe to security services that keep them posted about new software attacks. The software monitors their networks for unusual amounts or types of traffic and downloads software patches for protection against new types of attacks.

Safeguarding Privacy and Intellectual Property by Employing Property Data Loss Management

Organizations are legally obligated to protect the privacy of their employees. There are privacy statutes that prohibit enterprises from sharing employee and customer personal information such as Social Security numbers, license numbers, credit card data, and data collected by human resources. In addition, companies need to protect their strategic plans and product designs from leaking. These assets are considered *intellectual property*.

To accomplish these goals, organizations use property data loss management software to scan outgoing e-mail. The software is programmed to flag specific words relating to their products or services as well as key phrases or formats which indicate that credit card data or license numbers are included in a message. Flagged messages can be manually scrutinized.

MANAGED SERVICES

In addition to their broadband services, carriers offer a variety of managed services. Examples of managed services include management of Local Area Networks (LANs), Wide Area Networks (WANs), and software applications, including security software. One such application is used to manage secure, remote access from the mobile devices used by employees, partners, and customers. Carriers develop solutions as cloud-based applications located in their networks.

The Rationale for Providing Managed Services

Many carriers view broadband offerings such as T1 and Gigabit Ethernet (GigE) as commodities available from other providers. Managed services are one way that carriers differentiate themselves from smaller competitors. Moreover, managed services provide an additional monthly revenue stream for carriers and help to cement the relationship between themselves and their customers. This is because it is complex and potentially disruptive for international enterprises to change both their network and their security provider or data center service across all of their sites. Thus, supplying this wider range of services creates a “stickier” relationship with customers, and a sticky customer is one that is less likely to change vendors.

In addition, carriers such as Verizon and AT&T have the resources to build international data centers and hosting facilities as well as hire consultants with specialized skills in developing applications for vertical markets such as healthcare and insurance.

Furthermore, carriers develop partnerships with organizations such as Cisco, Novell Technologies, and Akamai Technologies that supply complementary products and services that the carriers can sell along with their own network services. Some carriers offer Cisco’s Voice over Internet Protocol (VoIP) solution as hosted telephone and Unified Communications (UC) and Akamai’s application acceleration. Application acceleration services decrease possible delays when remote users access centralized applications and files. These delays are caused by common protocols employed by applications accessed over Multi-Protocol Label Switching (MPLS) networks.

Managed Services for Small and Midsize Organizations

In conjunction with managed services, carriers are placing more emphasis on small and midsize organizations. Large carriers have often assigned newly hired, less knowledgeable salespeople to smaller customers. In addition, fewer resources were allocated to resolving any billing issues for these customers. Consequently, many small organizations, lured by the promise of lower prices and more attention to their requirements, switched to smaller, regional providers, such as Windstream Communications, Level 3 Communications, and tw telecom. In contrast, most large multi-site organizations such as universities, financial institutions, and major hospitals stayed with the largest carriers which they felt had the resources to support their needs. This is particularly true for international and multisite organizations, which often want a single carrier to support all or at least most of their sites.

However, large carriers are now making a renewed effort to attract small and midsize organizations as well as multinational companies. One reason for this is that small organizations have embraced cloud computing because they don’t always have the resources to manage their own IT services. Cloud computing is in many respects similar to, and often the same as, managed services. Cloud computing is the substitution of Internet-based computing services for onsite computer applications such as e-mail and VoIP-based telephone service. Managed services include cloud computing along with management of broadband facilities.

Thus, carriers see a potential way to win back small and midsize companies with the combination of managed services, Internet access, and voice calling. This offers the opportunity of enlarging a carrier's customer base while simultaneously increasing total revenue. Although each small company produces less revenue than large organizations, the sheer number of them creates a large potential. Gaining traction with smaller organizations is also a way to spread the cost of adding resources for managed services across more customers.

Complex and Varied Managed Services

Carriers have long offered managed services in conjunction with the networking devices connected to broadband services. These services include managing the T1 multiplexers, routers, and modems connected to a customer's broadband circuits. Carriers now offer more complex, varied services in the hopes that customers will be attracted to the possibility of one provider managing their wide area, mobile, and computer networks. These offerings include the following:

- Hosting applications in carrier data centers
- Storing files remotely
- Developing software applications to be run in carrier data centers
- Operating video conferences
- Managing mobile devices
- Consulting on virtualization
- Managing outsourced data centers at carrier facilities

In conjunction with managed services, carriers have hired personnel who have expertise in particular managed services for wireline as well as mobile networks. These include experts in enterprise mobile devices, video conferencing, security, data centers, contact centers and wireless LANs (Wi-Fi networks).

Many carriers that own mobile and landline networks recognize the potential of mobile services. Their sales staffs—who were previously dedicated to only landline or only mobile products and services—now sell products and services for both mobile and landline networks. They actively promote mobile managed services that improve productivity such as developing applications for service organizations that dispatch technicians to homes or businesses. When a carrier's account staff determines that there might be a mobile application to increase productivity, it brings in experts to meet with its customer. After learning about the customer's needs, these experts propose a consulting service to develop a software application to address those needs.

For example, one carrier developed an application that improves the efficiency of remote technicians by eliminating the requirement for a dispatcher to create a preset schedule that might be changed by longer or shorter than estimated repair jobs. Rather, when the technician informs the system of his availability, a message is sent to him with the details of his next appointment. This is more flexible because the software determines which technician to dispatch, as required. Other applications are targeted at vertical industries such as insurance where Global Positioning System (GPS) technology is used to locate vehicles requiring estimates for repair.

In addition to managed services for large and small commercial organizations, carriers also offer services designed specifically for government agencies. One application might enable police departments, fire departments, and other public safety personnel to communicate via wireless devices that are not inherently compatible with the mobile handheld devices of other municipalities. This is because their devices often operate over different portions of the radio frequency (RF) spectrum than those of other departments or cities. Departments within large municipalities and the federal government have not always been able to contact other public safety personnel because of this issue. This has been a huge problem during widespread national disasters (the problem gained particular notoriety during the aftermath of the attacks on September 11, 2001). To solve this problem for agencies taking advantage of this service, the carrier performs the compatibility conversions by using equipment in its network.

Managed Services and Telepresence in Conjunction with MPLS

Because of the end-to-end prioritization capabilities and network monitoring that MPLS provides, it is particularly suitable for certain managed services. Telepresence, a high-end video conferencing service, requires priority service on all network points over which it travels for guaranteed high quality. Rather than manage their own conferences, multisite and international organizations often outsource their video conferencing to their MPLS network provider.

Most of the enterprise sites have their own conference rooms, specially equipped with video equipment. Staff members in other sites can participate in video conferences at public rooms connected to the carrier's MPLS network. In addition to managing the video conference, the carrier often provides the bridging equipment needed to connect more than two sites together in a video conference. The carrier sets up the conferences and monitors audio and video quality during the conference. This eliminates the need for customers to train people on how to use the equipment. It also does away with the need to purchase and maintain bridging equipment.

This is particularly useful for companies where sites might use incompatible video equipment, and international sites where training staff members is difficult. It has become increasingly common for carriers with an international presence to offer telepresence-equipped rooms in countries such as India so that they can provide international customers service on a global basis.

USING DIGITAL SUBSCRIBER LINE FOR INTERNET ACCESS

BellCore, the former research and development arm of the local telephone companies, developed Digital Subscriber Line (DSL) technology in 1986. It quickly recognized the advantage of a technology that could operate over the existing voice copper cabling. The local telephone companies were eager to avoid investing in new cabling to each subscriber's premises; thus, in 1989 they began deploying DSL throughout the United States.

Worldwide, DSL service is the most prevalent wireline Internet access service. In fact, as Table 5-1 reveals, in 2009 in most areas of the world, the number of DSL subscribers was growing. Residential consumers use it when Internet access is not available via traditional cable TV modem. In addition, traditional telephone companies that don't install fiber to the residence use high-speed DSL service for the short distance between each customer's home and the provider's fiber at a nearby utility pole or neighborhood cabinet. Although investments in DSL gear and bringing fiber cabling closer to customers are significant, it is less than running fiber to each customer.

Table 5-1 *Worldwide DSL Subscriptions by Region for 2008 and 2009 (Courtesy Point Topic, Ltd.)*

	2008 Q4	2009 Q4
Region	**Total**	**Total**
Asia-Pacific	27,611,795	25,994,583
Eastern Europe	13,783,762	17,052,236
Latin America	18,057,850	21,099,026
Middle East and Africa	11,191,794	12,660,821
North America	35,743,199	36,888,881
South and East Asia	71,819,963	94,991,984
Western Europe	87,495,117	94,004,901
Worldwide Total	**265,703,480**	**302,692,432**

However, in countries such as Japan, South Korea, and Hong Kong, where government policies that include subsidies have made it cost effective for carriers to install fiber-optic cabling, the number of DSL customers shrank from the fourth quarter of 2008 to the fourth quarter of 2009. According to the Fiber to the Home Council, by year-end 2009, there were more than 50 million homes and buildings connected to fiber-optic cabling worldwide. In contrast, according to UK-based market research firm Point Topic, Ltd., by year-end 2009, there were 303 million DSL subscribers. This is more than those connected directly to fiber. Interestingly, the overall number of both fiber and DSL customers grew between 2008 and 2009. Currently, the number of DSL subscribers is shrinking in locations such as North America and Scandinavia. It is generally expected that in the future, either fiber or high-speed wireless services will replace additional DSL.

DSL as a Backup Option for Business Customers

Midsize and large commercial and business customers in most developed countries lease DSL services primarily as a low-cost backup service in the event that their primary Internet access circuits fail. Many of these primary circuits are installed on fiber-optic cabling. The large volume of revenue generated by enterprise customers makes a carrier's investment in fiber-optic cabling for business customers viable. Fiber cabling supports higher speeds than the copper cabling used for DSL. It also requires less maintenance by providers than copper cabling. However, the lower cost of DSL makes it a more affordable backup option than, for example, redundant T1/E1 circuits or laying extra fiber.

IP Addressing and Symmetric Speeds for Business Customers

Very small business customers—those with fewer than 25 employees—still use DSL as their primary link to the Internet if fiber or low-priced T1 is not available to them. Because of the more complex requirements, business customers often choose more expensive DSL options than consumers. These options include higher speeds and symmetric transmission, which means that they can send data at the same rate as they receive it. By contrast, most consumer DSL service is asymmetric, with upload speeds typically being slower than download speeds.

Business customers also usually select a different form of e-mail addressing. Although consumers generally opt for the lower-cost dynamic IP addressing, business customers most often choose static IP addressing. IP addresses use a numerical format such as 123.555.46.329 that is translated into words such as ABCcompany.com. With static IP, customers select their own unique fixed-IP address using their domain name (such as ABCcompany) for their e-mail address. Customers with dynamic IP service use their carrier's domain name; for example, Mary@providername.net.

The use of dynamic IP addresses enables carriers to assign IP addresses on-the-fly from a pool of addresses as each e-mail message is transmitted. In this way, they don't use up as many scarce IP addresses.

DSL as the Predominant Worldwide Wired Internet Access Technology

In June 2010, Point Topic CEO Oliver Johnson said the following in an e-mail message:

> *DSL is still the lowest subscription cost (and lowest deployment cost) wireline access technology and is very popular in many markets with relatively low per capita income. Very few of these deployments are under .5Mbps.*

In most of the world, carriers are slow to invest in fiber-optic cabling all the way to homes. This is not solely due to the high costs for the fiber itself. Rather, the expenses for digging trenches are prohibitive. Moreover, the investment for existing copper cabling has usually long since been recuperated; it is a *sunk cost* that still generates steady cash flows from monthly customer fees for non–Voice over Internet Protocol (VoIP), analog telephone service. (Sunk costs are those that are fully depreciated and thus don't impact profits.)

Asynchronous Digital Subscriber Line (ADSL) is the prevalent type of DSL service. (See Table 5-3 in the "Appendix" at the end of this chapter for information on the types of DSL.) ADSL2, the second generation of ADSL, supports 40Mbps on short loop lengths of less than 3,000 feet. These speeds are only possible on unimpaired cabling. Impairments include bridge taps, where a second cable is spliced (connected) directly to the cable. Impairments are less likely to occur on short cable runs.

Worldwide, most carriers offer slower forms of ADSL. Rather than invest in new DSL gear, carriers that own mobile as well as wired facilities invest more heavily in mobile services and fiber-optic cabling to business and commercial buildings. These are more profitable and have a higher potential for revenue than wireline services for individual homes. Certain DSL deployments are considered an intermediate solution until fiber and/or high-speed wireless services gradually replace them.

Advances in DSL Technology

Advances in DSL technology have made it suitable to use the same copper cabling for last-mile TV and data services as well as for voice. New DSL gear supports high-definition TV, voice, and high-speed Internet access over short lengths of copper cabling. The most advanced DSL service, Very-High-Data-Rate Digital Subscriber Line (VDSL2), supports 200Mbps on cable lengths up to 1,000 feet. The copper cabling transmits these signals between a user's premises and a provider's fiber-optic cabling in cabinets or neighborhood nodes. (See Chapter 4, "Carrier Networks," for more information on DSL in conjunction with broadband deployments.)

One reason new DSL modems can be used for "triple-play" services (TV, Internet access, and voice calling) is their ability to eliminate noise. On copper cabling, background noise intrudes, or "leaks," from adjacent copper wires (crosstalk) or a nearby electric motor (electromagnetic interference). To prevent transmission degradation and speed loss, advanced DSL services constantly monitor the line for noise. This is complex because noise can change over time.

Crosstalk is a common impairment on DSL circuits. When crosstalk is detected by specialized equipment, it is eliminated by injecting a matching signal to cancel it. Matching the signals in crosstalk refers to a method of exactly replicating these extraneous signals to eliminate them. Noise from other sources such as AM radio transmissions can be eliminated by injecting signals into each cable pair that have certain opposite characteristics of the noise. According to Bhavani Rao, product marketing manager at Alcatel-Lucent:

> *Manufacturers have improved methods of detecting and measuring noise. They continually monitor for noise from sources such as crosstalk, electric motors, and lightening storms. It is extremely difficult to distinguish noise surrounding the signals (ambient noise) from the actual data signals. Improvements in detection and cancellation have resulted from years of work and experience, and are a key reason that DSL is able to support TV, high-speed Internet access, and packetized voice.*

The other major improvement is DSL's capability to transmit signals over higher frequencies. High frequencies carry more bits in shorter time spans than lower frequencies. Think of it in terms of a commuter subway system: If the trains don't come very often (low frequencies), fewer people are moved in a given span of time; if the trains arrive more often (higher frequencies), more people will be moved through the system in the same time period. Copper cabling and wireless services carry signals that are made up of wavelengths (frequencies). Low frequencies have longer wavelengths that can carry signals over greater distances. High frequencies have shorter wavelengths that do not travel as far, but they can squeeze more bits into each transmission.

Thus, to achieve greater capacity, DSL must use high frequencies. However, the shorter wavelengths render high-frequency signals more vulnerable to damage from environmental sources such as magnetic interference. At the same time, vulnerability to attenuation (weakening and fading) means that high speeds are supported only on short lengths of copper cabling. The terms *megahertz* and *gigahertz* express types of frequencies on DSL and in cable TV networks. Hertz refers to cycles per second. DSL service that supports 30 megahertz (or as commonly expressed, 30MHz) has greater capacity than DSL at 12 megahertz (12MHz).

HIGH-SPEED ACCESS VIA CARRIER GIGABIT ETHERNET

Carrier Gigabit Ethernet (GigE) is a site-to-site and Internet access high-speed service. When used by enterprises, Gigabit Ethernet is intended to increase network access speeds so that they more closely match the speeds in local area networks (LANs). While Gigabit Ethernet operates mainly over fiber-optic cabling, new Ethernet services are becoming available that operate over copper cabling. GigE transmits data, video, images, and packetized voice (VoIP).

> **NOTE** Employees at carriers use the term "Gigabit Ethernet" or "GigE" when they refer to Gigabit Ethernet broadband service. However, to distinguish carrier broadband service from Gigabit Ethernet on LANs, IT personnel might use the term "Carrier Gigabit Ethernet." Some Gigabit Ethernet switch manufacturers use the term "Carrier Gigabit Ethernet" and others use "Gigabit Ethernet." Both terms are correct and are used in this chapter for the broadband service.

A key advantage is that Carrier Gigabit Ethernet uses the same protocol used within buildings in LANs, making it less complex to connect to a customer's network and simpler to upgrade to higher speeds. Ethernet does not require a CSU/DSU device (used for T1-type service) as an interface between the LAN and the carrier's network. A CSU/DSU is used for network diagnostics and clocking. Clocking keeps T1-type services synchronized with a carrier's network. See the section "Channel Service Units and Digital Service Units," later in this chapter, for information on CSU/DSU equipment.

Carrier Gigabit Ethernet was first introduced in the late 1990s. At that time, it was not widely available both because it required fiber-optic cabling to the customer and because the central offices of providers were not widely equipped with Gigabit Ethernet switches. In contrast, carriers now offer Gigabit Ethernet services to small and midsize organizations as well as large ones. These services start at speeds of 10Mbps and some can scale up to 10Gbps. In addition, Gigabit Ethernet is more widely available because more central offices have been equipped to support it and fiber is more widely deployed to business customers. A newer, slower-speed Ethernet service that operates over existing copper cabling will also increase its prevalence. Ethernet over copper is capable of transmitting at 2Mbps to 100Mbps. To quote an anonymous carrier employee: "I've heard 2010 referred to as the year of GigE; which is to say that I've seen extraordinary bandwidth demand."

Bandwidth demand by all types of organizations has created the impetus for carriers to invest in gear that will meet this demand. Customers that previously used T1 service now have either multiple T1s or T3 services at their disposal. And organizations with T3 links are now upgrading to Gigabit Ethernet. Moreover, smaller organizations can order the slowest Ethernet service with the option to easily upgrade later.

Carrier Gigabit Ethernet Offers Flexibility and Scalable Speeds

Gigabit Ethernet is offered by carriers for accessing the Internet, Multi-Protocol Label Switching (MPLS) networks, and connections to other sites within cities. When used for accessing these networks, enterprises might use Ethernet over copper or Gigabit Ethernet at their headquarters. At remote sites, depending on the level of traffic at each site, T1 often is used.

Organizations with many buildings within cities also use it for point-to-point private lines within the metropolitan area. These organizations include large hospitals, universities, and government offices that use GigE to transfer large files between sites. One example is the connection between hospitals and the facilities where patient records and imaging files are stored. It is also used for connections to storage area networks (SANs) that hold backup files. Access to the backup files is via either the Internet or private lines.

Carrier Ethernet over Copper in the First Mile

The availability of high-speed carrier services for business and commercial customers in Europe, Latin America, and the Middle East has been held back by low availability of fiber-optic cabling. This is also generally true worldwide outside of metropolitan areas; however, this is starting to change. Ethernet in the first mile (EFM) is now available at speeds from 2Mbps up to 100Mbps over copper cabling. Using existing copper cabling increases the availability of Ethernet by eliminating the expense and delays of deploying new fiber-optic cabling.

Ethernet over Copper is based on an Institute of Electrical and Electronics Engineers (IEEE) standard 803.ah, which was ratified in 2004. This standard specifies bonded pairs of copper cabling. Bonding is the use of equipment called *inverse multiplexers* to increase bandwidth by combining two or more circuits or pairs of copper cabling such that they act as a single circuit. Figure 5-6 presents an example of bonding on Ethernet over Copper. The inverse multiplexing function is included in Ethernet-over-copper gear. Bonding requires the availability of extra pairs of copper cabling at the customer's buildings.

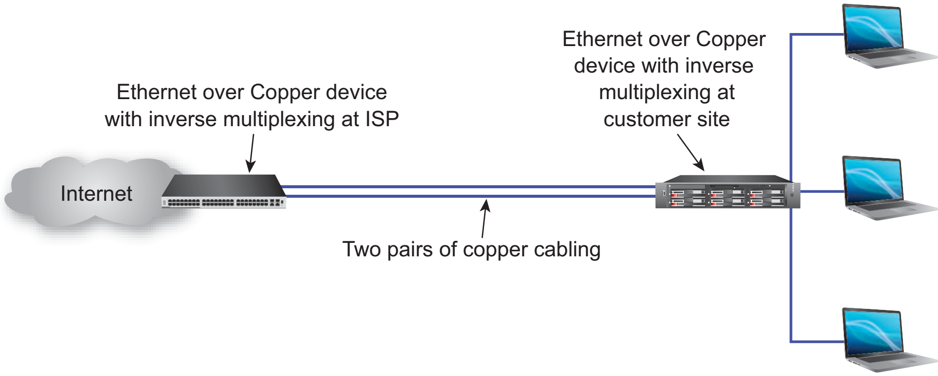


Figure 5-6 *Bonding two or more pairs of copper cabling together increases capacity. Ethernet over Copper overcomes cabling impairments.*

Extra pairs of copper cabling are often available because telephone companies commonly deploy cabling it in bundles of 25, 50, or 100 pairs upon installation. This is done to avoid the expense of adding new cabling later if customers want more lines. Adding additional cabling afterward can involve labor and material for digging trenches and adding new conduit if existing conduit or trenches are already at capacity.

Mitigating Interference to Achieve Higher Capacity

An important innovation in the Ethernet over Copper standard is its ability to mitigate interference caused by noise from transmissions on other cables within the same bundle. In a similar fashion to the noise cancellation techniques described earlier, in the section, "Advances in DSL Technology," Ethernet decreases the impact of interference by continually monitoring the circuit and eliminating noise caused by other cables in the bundle.

Ethernet over Copper provides more bandwidth and costs less than multiple T1 circuits. Thus, it is marketed to small and midsize customers that now use multiple T1 circuits, and customers wanting the greater flexibility that Ethernet provides. If a customer initially uses a 2Mbps Ethernet service, it can later increase it to 5 or 25Mbps by requesting an upgrade from its provider. Upgrades do not require hardware changes at the customer's site; thus, they can be implemented faster than new T1 circuits.

However, attainable speeds do depend on factors that include the distance from the telephone company's central office and the condition of the cabling. Customers need to be within 20,000 feet (3.72 miles) from the central office. Increasing the number of pairs of cabling bonded together overcomes some of these distance limitations and impairments. (See the section "DSL as the Predominant Worldwide Wired Internet Access Technology," earlier in this chapter, for a description of impairments.)

Providers That Offer Ethernet over Copper in the First Mile

Incumbent telephone companies, those that own last-mile cabling, and competitive carriers offer Ethernet over Copper. Incumbent telephone companies include AT&T, Verizon, Telefónica in Spain, and Telstra in Australia. Ethernet is less complex, can be implemented faster, and has more flexible capacities than traditional T1 circuits. Ethernet gear is also less costly for carriers than equipment required to interface with T1 circuits.

Examples of carriers that offer Ethernet over Copper include AT&T, Windstream (the fifth largest incumbent carrier in the United States), and MegaPath. MegaPath also resells services to other, non-incumbent providers who then sell Ethernet over Copper to their own customers. Competitive carriers such as MegaPath install the Ethernet equipment in the central offices of incumbent telephone companies. It also supplies compatible Ethernet devices at customer locations. Hatteras Networks is one manufacturer of Ethernet over Copper equipment. Many of its switches are multiplatform. It also supports other services such as T1 circuits.

T1 AND T3: THE FIRST BROADBAND SERVICES FOR BUSINESSES

T1 service is a digital broadband technology that utilizes a Time-Division Multiplexing (TDM) scheme which enables one circuit to carry 24 voice, video, or data channels. The entire circuit runs at 1.54Mbps. T3 is also able to carry a variety of traffic types but operates at 44Mbps. TDM divides the T1 and T3 circuits' capacity by assigning each channel to small slices of time. When T1 was introduced, it had many times the capacity of the fastest modems available and was more efficient than managing the individual analog copper lines that it replaced.

T1 service was first used in the United States to connect telephone company backbone switches to one another over copper cabling. It was made available commercially to large financial services companies in downtown areas in 1983. An impetus for its wider availability was competition in the late 1980s from new providers who offered it at lower prices and in more locations than the incumbent telephone companies.

Manufacturing efficiency, sharp increases in bandwidth demand, and wider availability have led to more affordable T1 service. With some exceptions, T1 and T3 services are used worldwide. T3, another service based on TDM, operates at 44Mbps in North America.

A Comparison of T1 and E1

T1 technology is used only in North America and Japan. The rest of the world uses E1, which operates at 2.048Mbps on 32 channels—30 channels for voice or data, one channel for signaling, and one channel for framing (assigning bits to channels and maintaining synchronization with external clock sources) and remote maintenance. T1/E1 and T3/E3 depend on strict adherence to timing.

Each individual channel is referred to as a digital signal zero (DS-0). A DS-0 runs at 56Kbps or 64Kbps on T1 and E1 circuits. The DS-0 speed of 64Kbps is the same worldwide. (See Table 5-2 in the "Appendix" section at the end of this chapter for various digital signal levels.)

Organizations that link a T1 or E1 in the United States to an office in Europe need rate adaptation equipment so that the carrier in the United States can connect the domestic T1 to the European E1 line. Rate adaption equipment converts E1 signals to those compatible with T1, and vice versa. Carriers supply rate adaptation equipment in their networks.

A Comparison of T3, J3, and E3 Worldwide Standards

DS-3 speeds differ internationally.

- The T3 North American speed is 44Mbps over 672 channels ($28 \times 24 = 672$)—the equivalent of 28 T1s.
- The Japanese "flavor," J3, operates at 32Mbps over 480 channels. This is the equivalent of 20 T1s.
- The E3 speed is 34Mbps over 480 channels. E3 is the equivalent of 16 E1s.

T3 services are also offered at fractional speeds. For example, fractional T3 is offered at speeds of 10Mbps. However, customers who want fractional T3 often opt for the lower-speed Carrier Gigabit Ethernet, where it's available. This provides a more scalable solution and is not limited to 44Mbps.

T1/E1, T3/E3, the Internet, and Public Switched Telephone Network Access

T1/E1 and T3/E3 services are used mainly for network access. Access to the Public Switched Telephone Network (PSTN) for an organization's voice traffic is a common application for TDM. Quality is guaranteed because a time slot is saved for each conversation. T3 trunks are often used by call centers to access a provider's networks because of their higher call volumes.

Headquarters often use T3 service and smaller remote sites use T1 for access to the Internet and Multi-Protocol Label Switching (MPLS) networks. Increasingly, large firms install multiple T3s at their headquarters for their growing bandwidth requirements. Organizations frequently locate e-mail servers centrally at headquarters so that the main IT organization is able to manage the server and its security for all sites. This is an example of a *hub-and-spoke* configuration, in which the headquarters acts as the hub for smaller sites.

A Comparison of T1 and T3 Media Requirements

T1 is media agnostic. This means that it can operate over any medium, including fiber, copper, and microwave. However, because of its higher speeds, T3 requires fiber, terrestrial microwave, or satellite-based microwave. The term "terrestrial" denotes that the microwave service is transmitted from land-based towers, not satellites.

Telephone companies use T1 and T3 over microwave for hard-to-cable areas such as across rivers and canyons, and cellular providers use microwave as one choice to link together their antennas and data centers with centralized switches. These links are referred to as *backhaul links*.

T1 on fiber is more reliable than T1 over copper because fiber is a nonelectric medium. External noise and interference from radio stations does not impair service. Because it is nonelectrical, signals do not fade as quickly as those sent over copper. Thus, less equipment is required to boost signals. In many countries, fiber is commonly in place directly to midsize and large business premises in metropolitan areas. When fiber is brought into a user's premises, the end user must supply the electricity for the equipment on which the fiber terminates. If there is no backup power, customers lose their T1/E1s and E3/T3s when they lose power.

T1 and the Inefficiencies of Time-Division Multiplexing

All T carrier signals (for example, T1, E1, E3, and T3) are based on Time-Division Multiplexing (TDM). Each device that communicates over a T1 line is assigned a time slot. If there are eight telephones contending for a T1 circuit, a time slot is saved for each telephone for the duration of the particular telephone call. Telephone 1 might be assigned slot A; telephone 2, slot B; and so forth. Figure 5-7 shows an example of TDM on T1 circuits. During pauses in voice conversations, the slot is not assigned to another computer. The assigned time slot is transmitted without any information. This is why TDM is not efficient on a Wide Area Network (WAN). Pauses in data

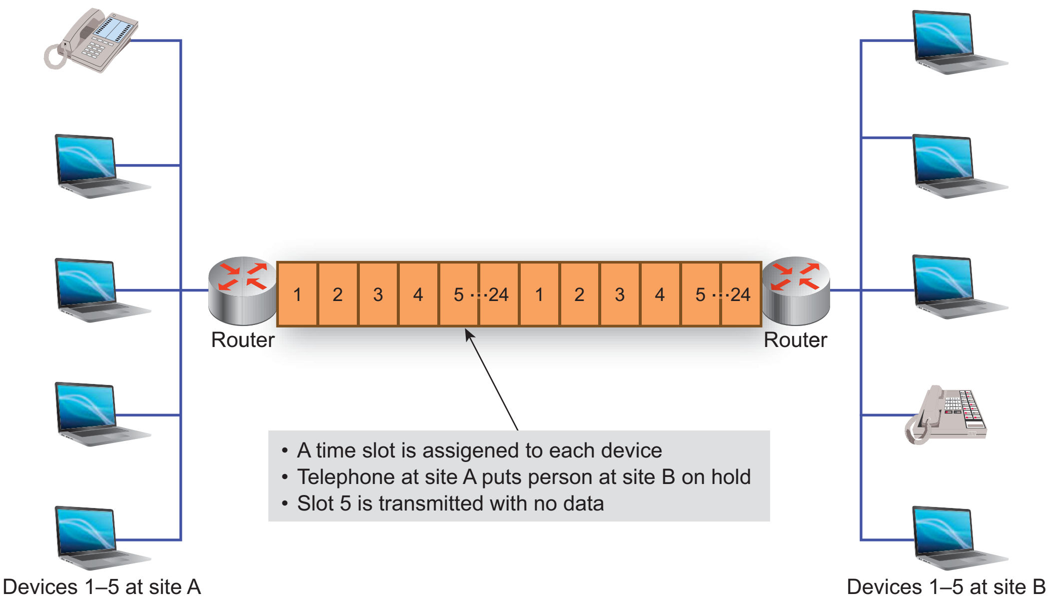


Figure 5-7 *Wasted network capacity on the Time-Division Multiplexing (TDM) used in T1/E1 and T3/E3. TDM multiplexers are located in the routers.*

transmission result in idle time slots. In a network with millions of time slots, this can result in many idle time slots and wasted bandwidth.

Channel Service Units and Digital Service Units

When customers order any type of T1/E1 or T3/E3 service, they also need to order a Channel Service Unit/Digital Service Unit (CSU/DSU). These devices act like modems and are situated between the outside network and the customer's equipment. They serve as a point to troubleshoot service and ensure that the T1 service is compatible with the outside network. CSU/DSUs are generally cards within multiplexers, routers, and Private Branch Exchanges (PBXs) rather than stand-alone, external devices.

Maintenance and performance tests are done from the CSU/DSU to determine if a repair problem is in the equipment, the CSU/DSU, or the telephone line. The CSU also provides clocking and signal reshaping. The clocking function is responsible for sending out bits in an evenly timed fashion. If the clocking is off, the transmission will not work. In this case, the technician might say, "The line is slipping," or "The timing is off."

CSUs use mainly *extended superframe* (ESF) so that T1 and T3 circuits can be monitored while a line is in service. Network service providers have ESF CSU/DSUs in their networks that connect to the circuits of multiple customers.

PRIVATE LINES, NETWORK TOPOLOGY, AND FRAME RELAY

Private lines and frame relay services have been largely replaced by newer, less costly and easier-to-maintain and configure Multi-Protocol Label Switching (MPLS) Virtual Private Network (VPN) offerings. Private lines are still used by large organizations such as financial firms that need to maintain a high level of security. Frame relay, which is a VPN, is rarely implemented. Network topology refers to how devices and sites are connected to one another in networks. It is essentially the "view from the top." Topologies include straight lines, hub-and-spoke designs, and mesh designs.

The Costly Solution of Dedicated Private Lines

Dedicated services, also known as private lines, are circuits leased by enterprises for their exclusive use. Private lines are expensive, and the number of them used by commercial organizations has decreased dramatically. For all but the largest organizations, MPLS and IP Virtual Private Networks (IP VPNs) have replaced private lines. These are less costly to maintain and boast lower monthly lease rates. However, large enterprises, utilities, and financial services organizations still use high-speed private lines for applications such as money transfers because they are the most secure method of transmitting data. Most of these organizations have the expertise for the initial design and sizing of the dedicated network, ongoing maintenance, and redesign for new applications.

Dedicated Services for Wide Area Networks and Metropolitan Area Networks

Dedicated, private lines are available for the exclusive use of the customer that leases them from a network service provider. Large organizations such as the Department of Defense, large cloud computing organizations, and pharmaceutical companies connect their multistate sites via circuits running at 155Mbps (OC-3) and greater speeds.

Metropolitan Area Networks (MANs), which are a type of Wide Area Network (WAN), consist of private lines that connect buildings within a city or metropolitan region. Large hospitals transmit customer records, research files, and radiology images over MANs; major universities also use them.

Private lines have the following characteristics.

- **Fixed monthly fees** Private, dedicated links are priced at flat monthly fees. The fees are not based on minutes used or the amount of data transmitted.
- **Fixed, inflexible routes** Dedicated lines are not flexible. Calls and data can only be sent between the fixed points to which the lines are connected. Thus, communication with a site that is not on the network is not possible.
- **Exclusive use** Only the organization that leases private lines can use them. For example, companies with dedicated connections to video conferencing equipment can only hold video calls with organizations that are a part of their private network.
- **Voice, video, and data** Dedicated lines are suitable for transmission of video, voice, and data. These services can share the same dedicated services or they can use completely different dedicated lines. Firms often lease T3 lines that comprise 672 channels to tie locations together. They might use 24 of the paths for voice and the rest for data and video.
- **Fixed capacity** Dedicated services are leased or built from carriers such as AT&T, Verizon, or CenturyLink with a fixed capacity or bandwidth. These speeds range from a low 19.2Mbps to T1 and T3 up to OC-3 (155Mbps), Gigabit Ethernet, and higher.
- **Security** T3/E3 are used in large, private networks operated by entities such as financial firms and the military for data communications between sites. Some organizations feel that the extra fees and maintenance are justified. Private networks are more secure than even MPLS networks for transmitting sensitive military information and financial transactions.

An important factor when deciding to use dedicated services is the desire for secure transmissions. Some firms believe that public network services such as MPLS are too public or prone to hacking for confidential applications such as funds transfer. They want to control their own networks and have staff members available to monitor transmissions over these facilities. Additionally, encryption is used to further ensure privacy and security.

Local and Inter-exchange Channels

Rates for private lines are based on distance and speed. Higher-speed lines that run over longer distances cost more than slower circuits that run over shorter distances. A T1 line at 1.544Mbps is less expensive than a T3, 44Mbps line.

Pricing for dedicated, private lines consists of two items.

- **Local channels** Local channels run from a customer's premises to the carrier's equipment. One local channel is required at each end of the private line in a point-to-point circuit. Local channels are also referred to as *local loops*. The incumbent telephone company often supplies local channels. Because of limited competition for this service, pricing on these short links is often close to the same as that for the longer inter-exchange circuit. Local channel fees are also charged for circuits used to access the Internet and MPLS networks.
- **Inter-exchange miles** Inter-exchange mileage is the portion of the circuit located within a carrier's network. The mileage runs from the access point, where it enters the carrier's network, to the egress point, where it leaves the carrier's switch.

Organizations that lease T1 circuits for Internet access also pay for the local loop that connects their site to their carrier. The local loop is a private, dedicated service from the customer to the local provider. When traffic reaches the Internet, it is carried over a shared network. The same is true for access lines to VPNs.

Network Topologies

Topology on private lines is a consideration in the following circumstances:

- Carriers design networks.
- Organizations design internal networks.
- Large enterprises lease or build their own private, dedicated line networks.

The shape of the network (the configuration in which lines are connected to one another), impacts cost, the ability to scale (add or delete sites), reliability, and accessibility.

Consider the multipoint configuration in Figure 5-8. An application for multipoint design is one used by utilities for communications to monitor the control equipment in their plants. They run fiber-optic cabling on their existing rights of way, over which

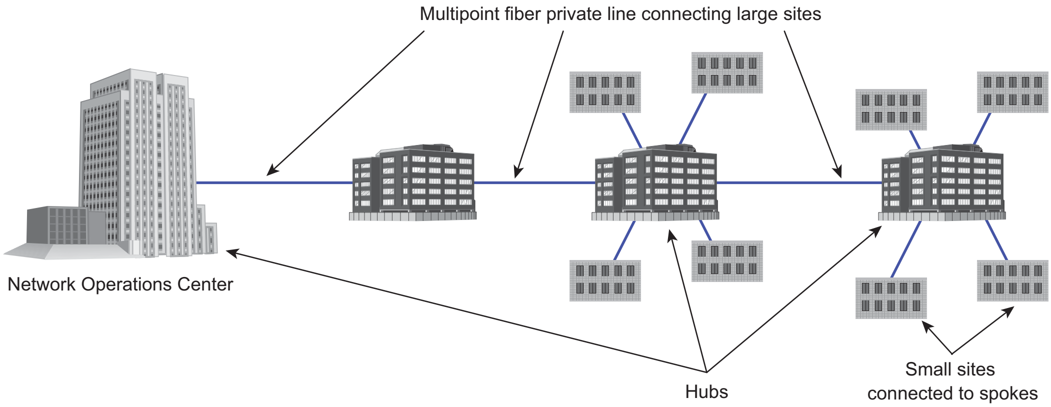


Figure 5-8 *Multipoint private lines connecting large sites. A hub-and-spoke design is used to connect small sites to large sites.*

signals are sent. If the link to one of the large sites is out of service, the other sites cannot reach the main location. However, recall from the mesh configuration presented in Figure 5-3 that if one link is out of service, traffic can be rerouted over other links. There is a trade-off between designing and constructing the more reliable mesh networks that are more costly and simply using a less reliable multipoint configuration.

The following are common network configurations.

- **Point-to-point** One line connects two locations. An example is a hospital with a private line to a medical office where hospital doctors see patients.
- **Multipoint** One line connects more than two sites together. This is also referred to as *multidrop*.
- **Star (hub-and-spoke)** All locations connect to, or “hub into,” a central site. Data switches in Local Area Networks (LANs) are configured in star topologies. Another example is a corporation with centralized e-mail, financial, and sales applications. If the central site, the switch, or headquarters crashes, all sites connected to it are also out of service. This is illustrated in Figure 5-9.
- **Mesh design** All points on the network nodes connect to one another in a flat or nonhierarchical manner. Peer-to-peer networks for music sharing are examples of mesh networks. Carriers often design their core, backbone networks in a mesh configured with multiple failover routes.

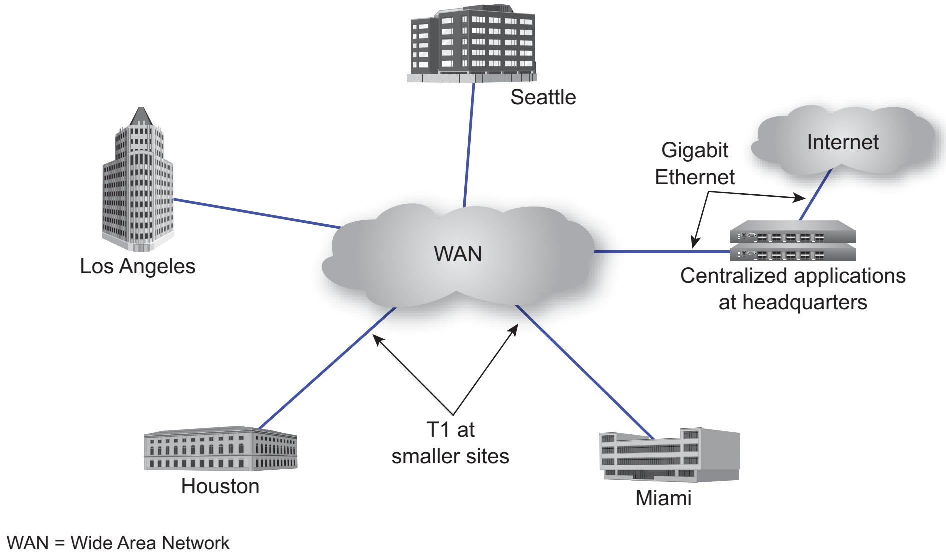


Figure 5-9 *A hub-and-spoke design for centralized applications such as e-mail. The disadvantage here is that if e-mail or another application at the central site crashes, all sites lose access to it.*

Integrated Services Digital Network

Integrated Services Digital Network (ISDN) is a worldwide public standard for sending voice, video, data, or packets over the Public Switched Telephone Network (PSTN) in a digital format. There are two "flavors" of ISDN: Basic Rate Interface (BRI) and Primary Rate Interface (PRI).

However, manufacturers implemented some forms of ISDN differently from one another. This resulted in some incompatibilities between ISDN in Europe, North America, and Japan.

PRI ISDN is used mainly in enterprise call centers and for other incoming calls to commercial organizations. The use of BRI ISDN is declining. When it is used, it's mainly deployed for videoconferencing. PRI and BRI ISDN use out-of-band signaling to carry dialed digits, caller identification, dial tone, and other signals. ISDN works over existing copper, fiber-optic, or satellite media. ISDN is gradually being replaced by IP services because of their greater efficiency, capacity, and flexibility.

The Similarities between PRI ISDN and T1

PRI has twenty-four 64-kilobit channels in the United States and Japan and 30 elsewhere in the world. PRI lines are similar to T1 because they both have 24 channels; however, PRI ISDN has *out-of-band signaling* on the twenty-fourth channel. This is different from T1 circuits in which signaling is carried in-band along with voice or data on each channel. On data communications, the signaling channel leaves each of the bearer channels "clear" capacity for all 64,000 bits. PRI does not require any bearer channel capacity for signaling such as call setup or teardown of signals.

Using PRI Trunks for Caller Identification

Many corporations use PRI ISDN for incoming voice traffic. The local telephone company sends the caller's name and phone number over the signaling channel. The telephone system captures the information and sends it to the display-equipped telephone. Figure 5-10 illustrates a PRI line for transporting caller ID. Employees who receive heavy volumes of calls from vendors or who prefer to only take calls from certain callers use ISDN to screen calls. Unanswered calls are automatically forwarded into voice mail.

Large call centers use PRI ISDN to receive the telephone number of the person calling. With ISDN, the telephone number is sent at the same time as the call. However, it is sent on the *separate D*, or *signaling channel*. This is significant because it enables the telephone system to treat the telephone number information differently than the call. It can send the telephone number to a database that matches the telephone number to the customer account number. The data network sends the account number to the agent's terminal to which the call is sent, which saves agents time by eliminating the need to key in account numbers.

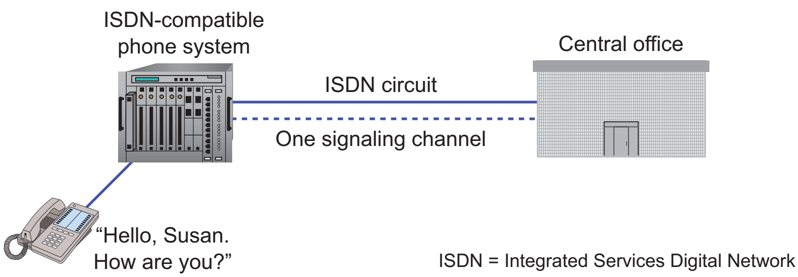


Figure 5-10 *PRI ISDN is typically used in an organization to identify callers' names and phone numbers.*

Sharing Signaling Channels to Enable Circuit-Switched Video

Companies with multiple PRI trunks can share the twenty-fourth signaling channel among a group of PRI trunks via *non-facility-associated signaling* (NFAS). An organization with six PRI trunks might have four of them equipped with 24 channels for voice and data. Two of the six would have 23 channels for user data and one signaling channel each with NFAS to support all six PRI trunks. Having two PRI circuits with signaling provides a backup in case one signaling channel fails. PRI lines don't work without a signaling channel.

Frame Relay

Frame relay is an older, slower Virtual Private Network (VPN) that has largely been replaced by Multi-Protocol Label Switching (MPLS). Frame relay is a public network offering with which customers can transmit data between LANs at multiple locations. It also is used to access the Internet. Frame relay was first promoted as a lower-priced substitute for private lines. By using frame relay, organizations do not have to plan, build, and maintain their own duplicate paths to each of their sites. Multiple users share the frame relay networks.

Frame relay requires defining links between sites in advance. This can be cumbersome for large organizations that want to connect each of their many sites to every other site. Falling prices on MPLS service and frame relay's unsuitability for voice are other reasons why organizations have largely migrated to MPLS. In addition, carriers do not want the expense of supporting separate frame relay networks. MPLS operates over a provider's private IP data networks.

APPENDIX

Table 5-2 An Overview of Broadband Network Services

Network Service	Places Typically Used	How Used
T1: 24 voice or data channels 1.54Mbps E1: 30 voice or data channels, 2Mbps plus one channel for signaling and one for framing and remote maintenance	Commercial organizations	Internet access, connections to long-distance and local telephone companies for voice and data, private lines between company sites. Each channel = 64Kbps. E1 is the European version of T1.
T3: 672 voice or data channels, equivalent to 28 T1s E3: 480 voice or data channels	Large and midsize organizations	Access to long-distance companies, Internet access, high-speed private lines between company sites. This is the European version of T3.
BRI ISDN: Two voice or data channels and one signaling channel	Being supplanted by other technologies Organizations	Video conferencing; but new systems mainly use IP.
PRI ISDN: 23 voice/data channels and one signaling channel in the United States 30 voice/data channels and one signaling channel in Europe	Business and commercial customers	Call centers, videoconferencing, voice links to local and long-distance providers; PRI ISDN has different speeds in the United States and Europe.
Digital Subscriber Line (DSL): 128Kbps to 44Mbps	Residential consumers, small and midsize businesses Telecommuters	Internet access, television. Remote access to corporate files and e-mail.

Table 5-2 *(Continued)*

Network Service	Places Typically Used	How Used
Frame relay	Commercial customers Most customers now use Multi-Protocol Label Switching (MPLS)	56Kbps to 45Mbps access to data networks for LAN-to-LAN communications and Internet access.
Carrier Gigabit Ethernet 1Mbps to 10Gbps over fiber	Midsize to large commercial customers	Access to the Internet, connections to storage area networks, and LAN-to-LAN connections; data only.
	Carrier networks and cable TV core and metropolitan networks	To aggregate traffic in metropolitan networks and send it as a single stream to central offices or cable headends.
Carrier Ethernet over Copper 5Mbps to 100Mbps	Small to midsize organizations	Internet access and access to MPLS networks.
Asynchronous Transfer Mode (ATM): Up to 2.5Gbps	Telephone companies	To transmit voice, video, and data traffic on small and rural carrier fiber connections to the Internet.

Table 5-3 *Digital Signal Levels*

	North America		Japan		Europe	
Level	User Chan.	Speed	User Chan.	Speed	User Chan.	Speed
DS-0	1	64Kbps	1	64Kbps	1	64Kbps
T1 (DS-1)	24	1.544Mbps	24	1.544Mbps	24	2.048Mbps
T2 (DS-2)	96	6.312Mbps	96	6.312Mbps	120	8.448Mbps
T3 (DS-3)	672	44.7Mbps	480	32.06Mbps	672	34.368Mbps

Table 5-4 Digital Subscriber Line Standards

Digital Subscriber Line Service	Upstream Top Data Rate	Downstream Top Data Rate	Voice	Comments
ADSL (Asymmetric DSL)	800Kbps	7Mbps	Yes	Offered to residential customers. Uses one pair of wires.
ADSL2	1Mbps	8Mbps	Yes	Most common standard worldwide for Internet access.
ADSL2plus	1Mbps	24Mbps	Yes	Supports video on demand on short cable runs.
ADSL2- Reach extended	1Mbps	8Mbps	Yes	Increases reach of ADSL2+.
SHDSL	5.6Mbps	5.6Mbps	Yes	Single or two pair. Two pair speeds higher than single pair.
VDSL (Very-High-Bit-Rate DSL)	1.5Mbps 2.3Mbps	13Mbps 52Mbps	Yes	
VDSL2—12MHz	30Mbps	55Mbps	Voice	Requires short cable length; TV/data/voice.
VDSL2—30MHz	100Mbps	100Mbps	Yes	Requires short cable length; TV/data/voice.

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6 The Internet

In this chapter:

INTRODUCTION

The Internet is a set of complex interconnected networks that was developed in the United States, and then spread around the world and evolved into what we so commonly use today—thus, the term "Internet," which is an abbreviated version of the word "internetwork." High-speed, terabit (1,000-gigabit) routers connect these networks to one another and transmit packets over the Internet *backbone*. The backbone carries the greatest concentration of Internet traffic. However, the edges of the networks that make up the Internet are critical. Edge routers direct traffic to their destinations, are responsible for security, and must be compatible with many different protocols.

As traffic on the Internet increases, capacity will continue to grow, and complex legal and societal issues will emerge. This includes network neutrality, which is the ability of users to access content from any site regardless of protocols at the site and whether the site's provider also owns broadband services over which the site operates. This is a thorny issue that is currently being hashed out by governments and providers. Broadband wireless and wireline providers are concerned that they will not be adequately reimbursed for continuing to upgrade their network facilities. Broadband providers want to be compensated for transmitting services from other companies such as video streaming and online games that consume large amounts of their networks' capacities.

The Internet has materially altered the way business is conducted. The high speeds and expanding availability of the Internet are the main reasons that impromptu, low-cost video conferences on laptop, desktop, and tablet computers occur with ever-increasing frequency. It is no longer necessary to equip a separate room with specialized video equipment to conduct video conferences. High-quality video conferences are now regularly held over the Internet between employees who might be at their desks or traveling practically anywhere around the globe; thus, remote employees, partners, and customers are able to conduct business with organizations in real time from distant locations.

The Internet has spawned entirely new industries and caused others to shrink dramatically. Music sales are no longer distributed mainly through retail stores. Rather, many consumers download individual songs of their choosing instead of buying an entire CD. Online book sales are the major reasons that many bookstores have closed and Amazon has flourished. Book sales are continuing to change. Increasingly, people are choosing to purchase lower-cost e-books that they can download directly to their tablet computers or e-readers. As the volume of e-book sales grows, this will impact authors and publishers, most of whom will earn drastically lower revenues on these lower-cost books.

The trend of distributing movies and television shows over the Internet also has the potential to disrupt an established industry. Streaming these products via the Internet rather than over cable TV networks offer opportunities for online providers to profit, but it has the potential to diminish revenues for cable TV and content providers.

Surveys already indicate that an increasing number of people under the age of 25 watch less television every year. Rather, they watch programs online and spend time on computers, participating in social networks and in services such as online games.

However, unlike music and books, for which content is readily available for electronic distribution, studios that distribute movies and TV shows to cable providers at high prices are often reluctant to make all of their content available to Internet-based distributors such as Netflix and Google. This is because cable TV companies are in a position to pay more for content than Internet-based distributors whose customers pay lower subscription fees. In addition, advertisers pay lower rates than those charged for TV ads.

In the early days of the Internet, search engines and other sites that provide free service to consumers concentrated on attracting as many visitors as possible to their sites. Once the Internet achieved critical mass, the emphasis turned increasingly to highly profitable advertising revenue. Advertising revenue now underwrites many sites, including social networks, travel-related sites, and search sites. New display ads have integrated video and often pop up in the middle of the first page of retail and news sites. Advertisers are attempting to attract users to ads that are amusing and appealing so that viewers will pay attention to the ads.

Google now earns the lion's share of Internet advertising revenue. Its purchases of software companies including AdSense, DoubleClick, and AdMob have provided Google with the tools to manage advertising placement and creation. It now has ad networks that receive bids for ads and place them instantly in a great many sites. Ad networks are an attractive feature for advertising agencies that manage their customers' marketing campaigns by placing ads in the network. Ad networks are a major advantage for Google over smaller Internet companies such as Yahoo! and AOL (America OnLine) that do not have ad networks with as large a reach.

The Internet is an integral part of the daily activities of many people. The following is a quote from a college student in Massachusetts that expresses the increasing dependence of young people on the Internet for much of their social life, for shopping, and as a source of information:

> *I am a totally Internet person. I cannot live without the Internet. I depend on the Internet to search for information, to study, to connect with other people, to go shopping, and to do anything.*

However, the Internet is not yet ubiquitous, nor can it be accessed by people universally. In developing countries, less than five percent of the population utilize the Internet. Interestigly, these people typically do not have advanced, high-speed infrastructure available, but many of them do have mobile phones, which they use for e-mail. Thus, there is still a potential for a great deal of growth in Internet traffic worldwide as more countries build out infrastructure capable of supporting high-speed mobile Internet access.

THE GROWTH OF THE INTERNET..........................

When it was first developed in 1969, the Internet was used initially by the government and universities. Access to files on remote computers and e-mail was cumbersome and slow, and required arcane computer commands. Beginning in 1993, browsers such as Netscape Navigator and Internet Explorer did away with the requirement to learn computer commands to navigate the Web. The development of browsers marked the beginning of large-scale consumer access to online services.

However, for most consumers, Internet access was limited to dial-up services, which initially supported speeds of only 19.2Kbps. This made using the Internet excruciatingly slow and cumbersome (certainly by today's standards), and thus, early adopters primarily used little more than e-mail. Technologies such as Digital Subscriber Line (DSL), T1, and cable modems gradually became more widely available and affordable for consumers and small businesses. These broadband technologies replaced dial-up access and created a less cumbersome, more consistent, "always-on" Internet experience. *Always-on* services enabled web page graphics to fill the screen faster, making browsing more convenient.

Improvements in broadband services and development of other technologies have made the Internet an integral part of everyday life and business in Western Europe, North America, and many parts of Asia and the Middle East. The criticality and availability of the Internet was triggered by technologies such as fiber-optic cabling and the supporting electronics connected to it; lower-cost, smaller memory and processor chips for wireless handsets and laptops, and faster computers; as well as improved compression to support multimedia streaming and high-speed content downloads. These improvements increase speed and capacity and, along with search engines, have yielded our modern Internet, which is easy to navigate and search.

Technological advances enable the Internet to carry various forms of entertainment and support important commercial undertakings. Higher-speed broadband access enhances the user experience for consumers and businesses, alike, as do improvements in site designs.

However, there are still vast parts of the world's population that do not access the Internet. According to Wendy Cartee, vice president of Technical Marketing at Juniper Networks:

> *We work with the largest carriers, worldwide. Globally, most of the world is still not connected to the Internet. Worldwide, roughly 25 percent to 30 percent of people are connected today. The majority of the population has not experienced the Internet. Over time more people will be getting connected to the Internet by a PC, or more likely it will be from a cell phone of some kind. We're seeing that trend already in Southeast Asia and Africa.*

Using Search Engines to Unleash Vast Stores of Information

A key development that followed the introduction of browsers was the development of sophisticated search engines by organizations such as Google, AltaVista, and Jeeves. These early search engines promoted browsing by organizing the enormous amounts of information available on the Internet. Search engines from Google, Microsoft, and Baidu in China earn revenue from advertising on their sites. Moreover, their services have grown beyond mere searching to include offerings for mobile devices, such as location services, Voice over Internet Protocol (VoIP), cloud computing, and e-mail.

Google not only earns the highest search-engine-based advertising revenue, but because of its many acquisitions, it has the potential to skew results of searches toward its own sites. When search results are returned, search engines such as Google can rank their own sites higher than those of competitors. Over the years, Google acquired many software companies, including the following:

- Zagat (Restaurant and hotel reviews)
- Keyhole Technologies, Zipdash Inc., and Where2 LL2 (Software that forms the basis of Google Maps)
- ITA (Airline flight aggregation information)
- Motorola Mobility (Mobile devices; patents for mobile services)
- YouTube (Videos)

Competition from Social Networks

Traditional search companies now face competition from social networks that have developed new methods for search. Search firms such as Google face competition mainly from Facebook, which has developed new ways for users to search while on its site. Google and other traditional search firms such as Yahoo! use algorithms that analyze keywords, titles, site structures, and descriptions to determine which sites fit the search terms specified by Internet users. These terms are located in Hypertext Markup Language (HTML) code not visible to users.

By contrast, Facebook searches are based on the purchases and preferences of friends. Social network searches also take into account how often a person follows an individual friend's "likes." Thus, whereas Google searches are scientific and analytical, searches on Facebook are more personal and perhaps more likely to result in purchases. These searches have the potential to be more valuable to advertisers, and therefore, will likely attract advertising revenue away from Google.

Internet Access via Mobile Devices

Escalating advancements in technology are propagating the growth of the Internet at a faster pace than ever before. Many experts see the greatest potential for expansion in mobile services in developing countries. In developed countries, particularly in Western Europe, consumers not only browse the Internet from mobile devices, but they also download video on these handsets. However, Internet use in developing countries, which include many in Africa and Latin America, is limited. Residents in these countries already use wireless devices but mostly for e-mail and texting. As prices for video and Internet-enabled handsets decrease and mobile networks are upgraded, Internet browsing in these areas is expected to increase dramatically.

Machine-to-machine transmission is anticipated to spur another major growth sector in mobile-services-based Internet traffic. Machine-to-machine mobile traffic is that in which mobile devices transmit directly to one another. Many machine-to-machine transactions are automated messages that are scheduled for set intervals or triggered by equipment malfunctions. An example of machine-to-machine communications is in Denmark, where automobile charging stations are equipped with routers. The routers wirelessly connect charging stations to central monitoring equipment.

The Impact of Video

In developed countries, experts expect video to be the main driver of increased Internet traffic. Downloading entertainment from the Web to televisions is a key application that is expected to grow. The use of portable devices as well as game consoles is taking the complexity out of transmitting video from the Internet to computers and connecting computers to televisions. This is because it often requires special cables and technical know-how to connect a computer to a television and configure the settings.

Video downloads and streaming to tablet computers such as the iPad is simpler. Video can be streamed over mobile networks or over high-speed home Wi-Fi networks. Sales of computer tablets are growing and are expected to increase as their prices decrease. Video downloads and streams from the Internet to game consoles such as the Wii and the Xbox are also easier because game consoles are usually already connected to a television. Two examples of this phenomenon are Netflix and Hulu movies and TV shows, which have been made compatible with game consoles so that they can be streamed directly to them.

In addition, sales of Internet-enabled televisions are expected to increase. Televisions are already available with menu-driven options for surfing the Internet and selecting programming. Consumers can use the remote controls for these televisions to explore and click Internet menu options, including sites from which movies and television shows can be streamed to the TV. At some point, most new televisions will be Internet enabled. These televisions can connect to the Internet via home wireless networks or high-quality Ethernet cabling via routers and cable modems.

The impact of traffic from mobile devices and video on the Internet will require adequate core, metropolitan, and access capacity. Congestion in any one of these links will result in slow downloads and choppy, unsatisfactory streaming video on mobile and landline devices. Carriers worldwide analyze current and past traffic patterns to predict growth. However, predicting traffic levels can be a challenge in areas with little or no high-speed access history on which to base projections. This has proven to be the case when carriers in developed countries promote attractive smartphones which add unexpected amounts of Internet and e-mail traffic that networks are not prepared to handle. It takes enormous investments and long lead times to add capacity to complex, modern networks.

THE STRUCTURE OF THE INTERNET ....

The Internet is made up of routers that direct traffic based on addresses contained within the headers of data packets. In an effort to reduce delays, Content Delivery Networks (CDNs) install servers at their own locations and that of the carrier's site at the Internet's edges, thus placing content closer to the end users that request it.

Edge Routers

Edge routers are located at the edge of a carrier's network where they connect to customers and to other routers. They are often located at Points of Presence (POPs) where multiple providers connect to the Internet.

The edge of a network needs to support complex applications, protocols, and video. Edge routers must support multiple protocols, including Internet Protocol version 6 and version 4 (IPv6 and IPv4), Multi-Protocol Label Switching (MPLS), and complex accounting software to track packet usage per customer. On MPLS networks, edge routers attach labels as described in Chapter 5, "Broadband and Wide Area Network Services," that include information regarding addresses, protocol, and Quality of Service (QoS). For more information about IPv4 and IPv6 addressing protocols, see the section "Address Structures," later in this chapter.

In addition, edge routers commonly handle aggregated Digital Subscriber Line Access Multiplexer (DSLAM) traffic in various formats such as older Asynchronous Transfer Mode (ATM) and Time-Division Multiplexing (TDM); therefore, routers need to support both newer and older variations of IP. ATM protocols use complex asynchronous multiplexing technologies to transmit voice, data, and video. They are more costly and complex to operate and less flexible than networks based on IP; they are typically used in a carrier's older networks. See Table 5-2 in the "Appendix" section of Chapter 5 for a description of ATM services.

Edge routers also use addressing information to determine how to handle the data. Figure 6-1 presents a detailed look at a router that can be used at the edge or in the core portion of networks.

Services on edge routers include the following (if a router is used in the core, it does not require the extensive services listed here).

- Authentication that verifies the sender is indeed who he identifies himself to be when he logs on to networks.
- Protected session setup that confirms that each multimedia session conforms to the features and QoS allowed to the computer making the request. This protects against fraud and ensures accurate billing.
- Network Address Translation (NAT) addressing that translates external IP addresses to internal IP addresses, and vice versa.
- Support for IPv4 and IPv6 addressing. IPv6 is designed to replace IPv4; it supports many more IP addresses than IPv4.
- Layer 2 switching for creating Virtual Private Line Service (VPLS) to communicate directly with databases and applications in data centers. (See Chapter 5 for a description of VPLS.)
- Firewall software that protects networks from hackers.
- Accounting to track subscriber packet usage in the event that carriers charge for usage.
- QoS per application and per user for VoIP and video.

In addition to more intelligence, there are requirements for greater capacity in routers. This is caused by increasing use of video conferencing, greater demand for video by residential customers, access to cloud-based services, and growth in mobile smartphone Internet browsing. Router ports now commonly support 1Gbps as well as speeds up to 10Gbps. Total capacity of edge routers ranges from 1 to 3 terabits per second (Tbps). A terabit is the equivalent of 1,000 gigabits.

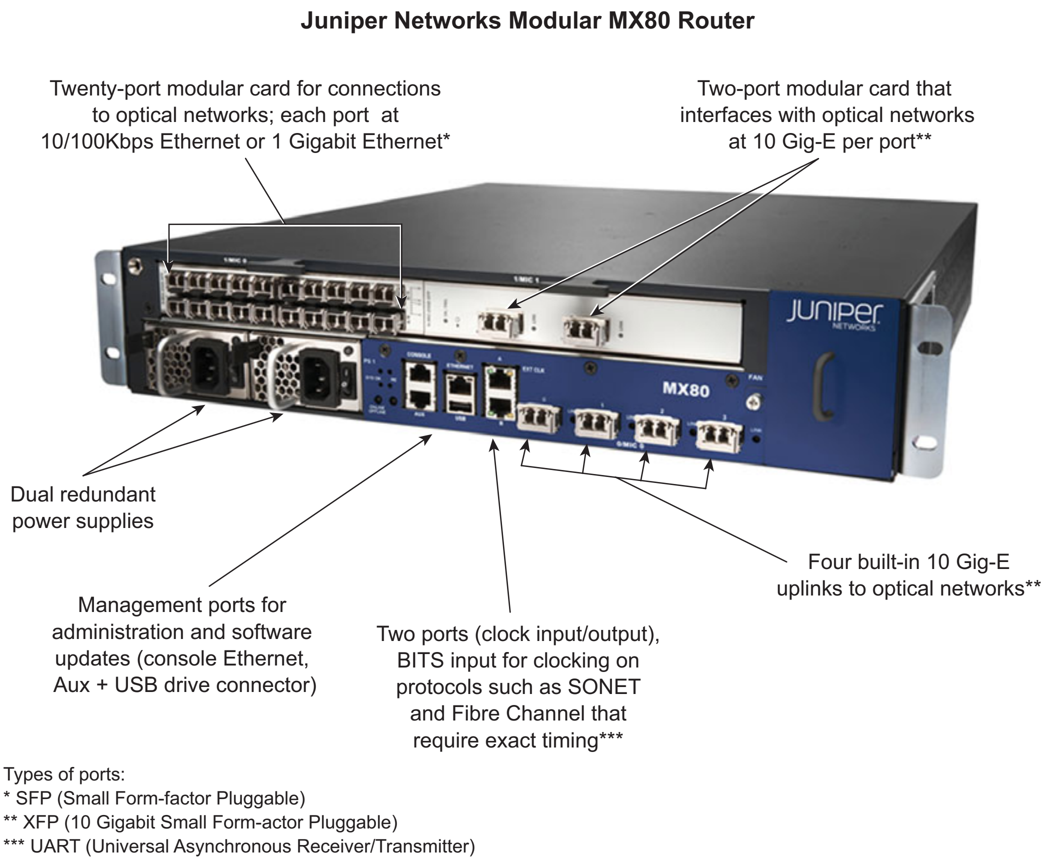

Figure 6-1 *When routers are used in a network's edges, carriers use the services described in this illustration. These services are not implemented in core, aggregation routers. (Courtesy Juniper Networks)*

Core, Aggregation Routers

Core routers carry the highest concentration of traffic. A single core router connects to multiple edge routers, aggregates traffic from these edge routers, and then sends it to distant cities and countries. If a single router doesn't have the capacity to handle this aggregated traffic, multiple routers can be networked together. When this is done, the networked routers function as a single entity with a single management interface. This simplifies the carrier's operations, upgrades, and remote diagnostics.

Networking routers together is commonly done through virtualization. (See Chapter 1, "Computing and Enabling Technologies," for information on virtualization.) Virtualization enables multiple servers or computers to appear as one device. In addition, traffic is balanced among all of the networked routers. If one router fails, the others absorb its traffic.

Ensuring Reliability in the Core and Edge

Routers sold to carriers and to large web sites such as Google and Amazon are designed for "*five 9s*" of reliability. This means that they offer 99.999 percent uptime. They are sold with *hot-swappable cards* that connect to other services and networks. If a card fails, it can be replaced without taking the router out of service. They are also offered with options for duplicate processor cards and often come standard with dual power supplies. Power supplies connect to sources of electricity. It's also common for carriers to install duplicate routers that can be seamlessly brought on line in the event of a failure. Duplicate routers are crucial at the edge, where if the router fails, all other networks and customers connected to it lose service.

Enhancing Internet Performance by Using Content Delivery Networks

Content Delivery Networks (CDNs) provide a number of services at the edge of the Internet that alleviate congestion on the Internet's backbone. In its simplest form, a CDN reduces congestion by decreasing the distance that the traffic must travel. One way they accomplish this is by storing frequently requested web pages at their servers, nearer to the end users, often in a service provider's location. This is referred to as *caching*. Many enterprises with large web sites use CDNs to replicate their web content at many edge locations to prevent delays at their web or e-commerce sites. For traffic that traverses the Internet backbone, CDNs use mathematical algorithms to map out the best paths for traffic to take.

CDNs are also key enablers of quality video on the Internet. Specialized servers are used to optimize video. In addition, some CDN providers, including Cambridge, Massachusetts–based Akamai Technologies, partner with companies such as Brightcove, Inc., which is a provider of cloud content services that transmit video in formats compatible with the many devices (including mobile handsets) that use different methods of displaying video. Brightcove equipment is located with Akamai servers.

As the amount of data on mobile networks increases, CDNs will place a growing number of their servers close to cell towers to enable mobile providers to handle their data and video traffic. CDNs provide other services, as well, including security, cloud computing, and wide area network (WAN) acceleration, wherein specialized compression and protocol optimization decrease delays. See Chapter 1 for more information on WAN acceleration.

Exchanging Data at Peering Points

Large multinational carriers are referred to as Tier 1 carriers. Tier 1 carriers own the majority of the high-speed lines that make up the Internet backbone. These carriers, all of whose networks are international, include Nippon Telegraph and Telephone Corporation (NTT) in Japan, Telefónica in Spain and Latin America, Deutsche Telekom in Germany, France Telecom in France, and AT&T and Verizon in the United States.

Regional carriers—which are referred to as Tier 2 carriers—also own core, backbone facilities. Comcast and tw telecom are considered Tier 2 carriers because their networks do not cover the entire country and they purchase backbone capacity from Tier 1 carriers. These Tier 1 and Tier 2 carriers interconnect with other carriers in places where they do not have coverage. These interconnections are referred to as peering points.

Network service providers transfer Internet Protocol (IP) traffic among one another at peering sites. Peering sites are also referred to as Internet exchanges and Network Access Points (NAPs). ISPs lease ports on the routers of other providers as a means of transferring IP traffic between networks. This enables carriers to send traffic that originated from their own customers to areas where they do not have network facilities, as demonstrated in Figure 6-2.

NOTE The terms "ISP" and "carrier" are used synonymously.

Carriers that own peering points charge other carriers for connections to ports on their routers. However, traffic at these peering centers has the potential to create delays in the Internet if carriers lease too few ports from one another in an attempt to save money. If carriers exchange about the same amount of traffic, they often don't charge one another under this arrangement. Security, routing, traffic policing, and Network Address Translation (NAT) take place at peering points.

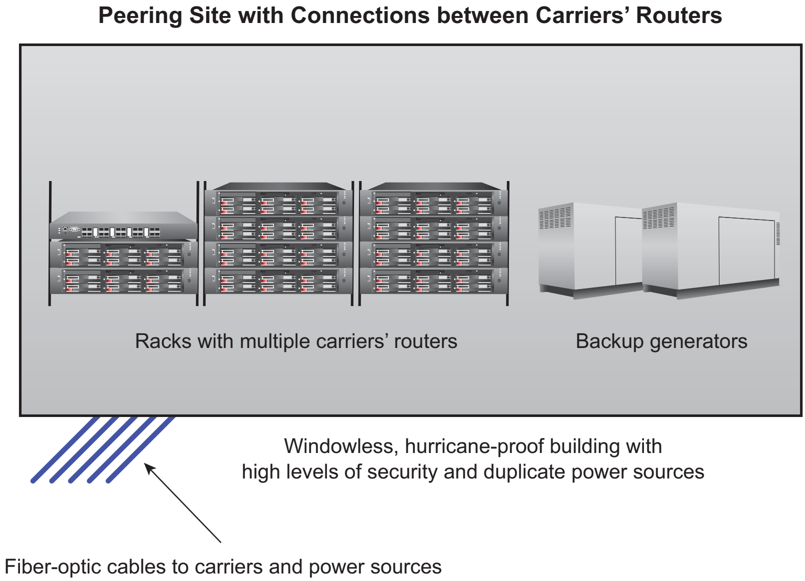

Figure 6-2 *Traffic at peering points is routed between the facilities of multiple network operators.*

Address Structures

Two universal addressing schemes, Internet Protocol versions 4 and 6 (IPv4 and IPv6), are used to transmit messages from computers, smartphones, and tablet computers worldwide. The system of routing messages based on IP addresses is managed by 12 organizations that administer 13 clusters of servers, called *root servers*.

The Criticality of Root Servers

The root name server system was implemented in the 1990s. The Internet cannot function without root servers, which route messages to the correct organization. Root servers are critical for the sustainability, capacity, and survivability of the Internet. To lessen the system's vulnerability to malicious actions such as Denial-of-Service (DoS) attacks, wherein millions of fake messages bombard a site, root servers balance incoming messages among multiple servers within each root. If one server within the root is brought down, other servers within the root handle the traffic. Ensuring protection against hackers is an ongoing endeavor.

The 13 Root Servers Worldwide

The *Domain Name System* (DNS) is the umbrella name of the Internet's capability to translate alpha characters to numeric IP addresses within root servers. Carriers and organizations send traffic addressed to locations outside their networks to one of the 13 sets of root servers, usually the one nearest to them, to determine where to route these messages. The root servers, which are massive databases, translate alphabetic hostnames (gmail.com) into numeric IP addresses (193.22.1.126), and vice versa. Of the 12 organizations that operate the root servers, eight of them have root servers located in multiple cities or countries.

Tracking and Managing Top-Level Domain Names

The Internet Corporation for Assigned Names and Numbers (ICANN) is the organization responsible for managing the technical aspects of the databases of domain names in root servers. In a web or e-mail address such as name@companyname.com, the .com portion is the *top-level domain name*, and *companyname* is the domain name, which is also referred to as the *secondary-level domain name*. Every country has a top-level domain name. For example, for China, it's .cn; for Russia, it's .ru. In the United States, some top-level domain names include .edu and .mil for educational and military institutions, and.gov for the government.

Voting ICANN board members are appointed by the United States Department of Commerce. Until 2009, the Department of Commerce had sole responsibility for these policies. However, increasing criticism by other countries regarding what they feel to be too much control by the United States of major aspects of the Internet has led to the establishment of international review and policy determination. Currently, the United States continues to control ICANN even in the face of mounting pressure from countries such as Russia and China to cede control to the United Nations.

The Inclusion of Non-Western Domain Names

Initially, addressing systems used only the Roman alphabet character set (A–Z, a–z, the digits 0–9, and the hyphen). However, pressure from countries that use other character systems eventually led to the inclusion of other alphabets for addresses. These non-Roman languages include Arabic, Persian, Chinese, Russian, Japanese, and Korean. China, South Korea, and Arabic-speaking nations had already started assigning non-Roman domain names. These addresses introduced the possibility of duplicate domain names because they were outside of the root system. This created pressure for ICANN to alter their addressing requirements and move forward with making the technical changes in the root system that translations from other alphabets require.

Transitioning to IPv6

The main addressing scheme used on the Internet is IPv4. It was developed in the 1970s and is only 32 bits long. On January 31, 2011 the Internet Assigned Numbers Authority (IANA), which manages the central supply of Internet addresses, gave out the last of their IPv4 addresses to each of the five regional Internet registries. By April 2011, the Asia Pacific region had given out all of their addresses, and the remaining four registries are expected to distribute all of their addresses within the next few years, Capacity is being depleted by the addition of new Internet-enabled wireless devices and the growing number of Internet users, particularly in Asia. To ensure that they will be able to get new IP addresses, most organizations are now transitioning to the newer 128-bit IPv6 protocol, which is capable of accommodating billions of additional addresses. Most carriers have transitioned to IPv6. The IPv6 IEEE standard was published in 1998.

Most new routers, web browsers, and computers are compatible with both IPv4 and IPv6. However, many organizations are still using IPv4 in some of their networking equipment. The transition to IPv6 can be complex because it means assigning new addresses to every device with an IP address, including routers, firewalls, network management software, and all servers, including e-mail servers. In addition, it's not a simple matter to determine which applications and devices are compatible with IPv6. Enterprises that transition to IPv6 often need to be able to handle messages that are still in the older IPv4 scheme. Encapsulating IPv6 addresses within IPv4 can address this problem. There are also software packages that support both protocols.

SECURITY THREATS FROM INTERNAL, EXTERNAL, AND INTERNATIONAL SOURCES............................

Prior to the advent of the Internet, organizations kept important documents secure by putting them into locked file cabinets, accessible only to authorized individuals. In contrast, strategic information and databases with client information are now widely available from a multiplicity of devices. They can be accessed from mobile devices, remote offices, home offices, and business partners. Organizations and governments attempt to keep their information and infrastructure secure with a combination of software, passwords, and secure entry to data centers where much of this data is stored.

Cyber Terrorism

In the past, countries engaged in spying and sabotage by planting agents in other countries. They hoped to learn strategic information about their enemies and potential enemies through networks of spies who often disguised themselves as friendly citizens.

Some spies went beyond gaining information to planning acts of sabotage that damaged property, such as roads, bridges, and factories. These same countries also used networks of agents to ferret out spies trying to infiltrate their own institutions. All of these strategies still exist, but they are supplemented by cyber terrorism. Most cyber terrorism is conducted via the Internet.

Acts of cyber terrorism can also be implemented by using *sneaker attacks*, whereby inside employees are co-opted by foreign governments or terrorist groups to learn government secrets or sabotage weapons systems by planting software bugs in computer-controlled weapons systems or copying strategic information inside the organization. This strategy is used to circumvent security measures whereby strategic departments such as armed forces or defense departments attempt to shield themselves by bypassing the Internet for all data communications. Entities such as these communicate to other locations on private lines that they lease or build. These networks only connect to other trusted departments or perhaps suppliers.

Cyber terrorists use the Internet to gain information and damage key infrastructure remotely by deploying software programs disguised as friendly messages and nonthreatening packets. Targets can include water supplies, electrical grids, military plans, nuclear reactors, and remotely operated weapons. Foreign governments as well as individuals and groups of individuals originate these attacks. A common strategy in many attacks is to look for weaknesses in computer systems and use them as a way to access information or plant software bugs.

Cyber terrorism attacks not only cause computers systems to malfunction; they can also disable computer-controlled weapons systems. This is what happened in September 2010 when a worm dubbed *Stuxnet* attacked one of Iran's weapon control systems. A *worm* is a software bug programmed to be activated at a later time. The Stuxnet attack was so sophisticated that many security experts thought a government, not an individual, planned it.

Attacks on Enterprises

Both enterprises and governments are under siege from hackers. All multinational businesses have been the targets of security attacks. In some attacks, credit card numbers and personal identification are stolen for financial gain. Other hackers steal information for insights on competitive strategies and product plans. Both the government and private sector acts of sabotage can involve planting delayed software bugs that damage networks and databases.

There are many types of security breaches. Distributed Denial-of-Service (DoS) attacks involve sending millions of packets to a site simultaneously. This has the potential to disable entire sites by making it difficult for the site to handle legitimate traffic. Organizations use a variety of strategies to thwart hackers and prevent data breaches. These include routing traffic through carriers and security company networks to screen incoming traffic, purchasing a variety of security hardware and software, training end users on the importance of keeping information private and secure, and hiring outside consultants.

However, as security methods improve, hackers eventually become familiar with them and devise new ways to breach them. It is a constant battle between improving security and keeping up with new ways that hackers devise to break through an organization's defenses.

Cyber Countermeasures

In 2010 and 2011, Adobe, AT&T, Google, Facebook, Sony, and Twitter all experienced security breaches. These attacks focused on private data in some cases; in other cases, they rendered the target companies unable to conduct business for a period of time. Although most organizations recognize the importance of security, investments in these areas compete for resources needed for product development, marketing, and other endeavors. Too frequently, if an organization has not been the victim of a data breach, spending money on security is not recognized as having a return on investment when compared with the introduction of a new product.

The military and industries such as financial services and pharmaceutical firms place a high value on keeping information safe. The lifeblood of pharmaceutical companies is the development of new drugs. If the intellectual property of research is leaked, a great deal of damage can be done. These companies, as with most organizations, screen incoming messages for *malware*, which is a catch all term for viruses, worms, and other software threats. Furthermore, they screen outgoing e-mail for keywords related to drug development and strategy.

A major challenge to IT security personnel is utilizing security software and practices that don't slow down or hinder employee access to applications and information. There might be resistance to the necessity of changing passwords on a regular basis or of being required to use long passwords that are difficult to remember. Employees are often tempted to write down these passwords and keep them out in the open, where they can be easily stolen.

Mounting Defenses via Firewalls and Security Software

Firewalls are used to screen incoming messages for known viruses, worms, and *Trojan horses*. Trojan horses are computer programs that appear to have useful functions but actually contain malicious code. A video sent from Facebook can have a Trojan horse embedded within it. Some firewalls can also detect anomalies that are indicative of an attack, including packets that are too short.

Other types of security can be embedded in servers containing applications or installed in a stand-alone appliance (a computer with a dedicated application). There is a trend to embed security in multifunction devices. Routers are often equipped with firewalls, and Local Area Network (LAN) switches also contain optional security software.

To prevent hacker attacks, many organizations use Intrusion Detection System (IDS) software or devices to monitor traffic. These systems monitor packets for malware and report them. Intrusion Detection and Prevention Systems (IDPSs) attempt to stop these attacks as well as identify and report them.

As security programs become more sophisticated, hackers analyze these defenses and build increasingly sophisticated malware to defeat them. It is an ongoing challenge to respond to every new type of security breach with improved defense measures. This is a particularly difficult challenge because there is generally a lag between when a new software bug or worm is discovered and a software patch is created to guard against it. It's also time-consuming to add patches to not only software security but also application programs such as browsers that might also introduce security holes.

There is also specialty security for e-mail and other applications. Security software can be used to encrypt files containing passwords. Encryption is the use of mathematical algorithms to make files unreadable except to authorized users who have the software necessary to decrypt the files or e-mail messages. Encryption is used also on transmitted files to keep them private. This is important because so many employees, contractors, and business partners now access files remotely.

In addition to all of these practices, firms hire outside organizations to conduct a security audit to identify weaknesses that leave the organization vulnerable to attacks. Auditors might identify out-of-date software that needs to be patched, or they might find unauthorized wireless devices.

Most security software and hardware products and services offer software that generates audit trails. These printouts and software records display indications of security breaches. Paying attention to them is an aid to identifying network weaknesses. In IT departments with large workloads, this does not always happen.

Intentional and Inadvertent Security Breaches by Insiders

The Verizon 2010 Data Breach Investigations Report, conducted in collaboration with the United States Secret Service, found that in 2009, insiders were responsible for 49 percent of breaches. In particular, employees who have been fired or those who feel entitled to access information are frequent causes of these incidents. An employee with high-level authorization to sensitive data can copy it or corrupt it in some way. The employee might then provide the sensitive data to competitors or cyber criminals.

Employees who change jobs are often in the position to copy entire files and use them in their new positions. They might use information such as lists of customers to help them succeed in their new job.

In other instances, employees inadvertently open infected e-mail attachments. They might unknowingly insert infected storage devices such as USB flash drives into network-connected computers. These viruses can then spread through a corporate network. To prevent this from happening, organizations often purchase security software that automatically screens e-mail attachments, laptops, and external devices for known malware. They can also install software that prevents USB devices from being inserted into LAN-connected computers.

Other inadvertent security lapses caused by insiders include lost laptops, smartphones, tablet computers, backup disks, and flash drives with files such as medical and demographic patient data or other private or strategic information.

Combatting Security Threats with User Training

User training is an important strategy toward preventing inadvertent security breaches and in gaining the cooperation of employees in adhering to corporate practices. If employees understand the crucial nature of lost data, they might take extra precautions to protect it. This can include measures as simple as not taking strategic information out of the organization, reporting losses immediately, and not leaving passwords on sticky notes under keyboards. They will also be more careful in not allowing unauthorized outsiders entry into the organization. This can be something as fundamental as not allowing people without badges to walk into secure areas behind them. Another point that should be stressed is not leaving unattended computers active so that other users have access to strategic information and e-mail messages. To prevent this, some organizations configure their computers to time out and enter a password-protected standby mode if they are inactive for a specified amount of time, or they institute rules that all employees must shut down their computers at night.

Training end users on how to recognize online e-mail scams and warning employees to never give out passwords online are effective tools in guarding against social-engineering-type scams. Social engineering involves gaining people's trust so that they will provide strategic information or information such as passwords, account numbers, and private client data.

PRIVACY

Information about consumer buying habits is a key advantage for advertisers who purchase ad space on the Internet. However, it can also create issues for people concerned about privacy. New, sophisticated software is able to add small software files to browsers. These software files track which sites an individual visits. For example, if a user clicks an ad containing video that uses Adobe's Flash or HTML5, the advertiser can compile a list of sites that she visits after clicking the ad. With this information, it can display ads based on what these habits suggest about her interests. For instance, advertisers might display ads about sporting events to people who visit sports-oriented sites.

If a user fills out forms at any of the sites she visits while being tracked, the tracking software has access to the information on the form. This allows advertisers to gather more detailed demographic information. Information gathered in this manner from sites such as social networks is a powerful way to attract advertisers. In turn, advertising networks that place ads at many different sites are able to amass large databases of demographic information about a user's browsing and purchasing habits. Mining this data and tailoring it for ad campaigns is referred to as behavioral advertising.

Another way that marketers collect information about users is from online games on social networks such as Facebook. Every time a Facebook member downloads a game application, the game developer acquires information about the game player. Developers track the user's data, compile it into lists along with information about other users, and then sell the data to marketers.

Marketing firms and manufacturers who purchase these databases use the information to show ads to people based on metrics such as age, gender, circle of friends, interests, and income. The software that tracks a user's browsing habits is becoming increasingly sophisticated and difficult to remove. A major problem with tracking software is that unlike older *cookies*, which only gathered information from a single location, tracking software follows users from site to site, monitoring their behavior while online. It is somewhat straightforward to delete cookies from browsers. This is not the case with tracking software. There are currently no menu commands in browser software to delete tracking files.

Privacy versus the Bottom Line

Large search, social networking, and e-commerce providers are under pressure from advertisers and investors to allow marketing firms to place tracking software at their sites. Another pressure on these web site owners is competition from other sites for advertising dollars.

Giants such as Facebook and Google face competition for advertising revenue generated on mobile devices as well as from broadband, landline-connected devices. Mobile devices based on Google's Android operating system and search software compete for advertising revenue with mobile devices that use Microsoft's operating system and its search application, Bing. This competition for advertising dollars motivates site owners to allow advertisers to use tracking software and other tools to enhance the revenue-generating value of their sites.

Privacy threats exist from additional sources. E-commerce sites compile massive databases of past purchasing information that can potentially be made available to advertising partners. One way purchasing histories are used is to target people with ads based on past purchases. Amazon might target e-mail campaigns with messages about photography equipment to people who have purchased books or equipment related to photography. Google and Yahoo! as well as other companies provide free e-mail. Some advertisers place brief text ads at the end of these messages, based on keywords within messages. They state that they do not actually read the content in these messages. However, the potential for abuse is there.

The Stricter European Privacy Rules

The European Union, currently composed of 27 countries, has more-stringent rules governing Internet privacy than does the United States. It has mandated that each country must enact laws requiring web sites to offer visitors the choice of opting in before allowing the site to gather information about them. Thus, if a person does not explicitly agree, the web site is prohibited from gathering any information.

In addition to warning users about privacy risks, web sites must not use behavioral marketing to target advertising based on a visitor's race, religion, or other such categories. Furthermore, social networking sites cannot keep personal information after a user deletes her account or after an account is idle for a long period.

Different rules in the United States and Europe make it complex for organizations to operate web sites in both areas. These varying rules force web-based companies to custom-program different versions of their sites to accommodate the various countries. The use of marketing programs can also be limited. The European regulations do protect citizens' rights more fully than those in the United States. It's not clear, however, what the impact is on e-commerce and revenue from online advertising. Currently, advertising revenue underwrites the cost of operating many Internet services. While there have been lawsuits and vocal complaints about privacy infringement in the United States, it's not known how much most people are concerned about possible privacy infringement or how much privacy they're willing to give up in exchange for low cost or free access to online material.

VIDEO STREAMED FROM THE INTERNET TO THE FRONT ROOM

For years, the only way to watch television was through broadcast, satellite, or cable technology. Now viewers can access the Internet to view movies and television shows on a variety of devices including mobile tablets, smartphones, Blu-ray players, a variety of set-top devices (such as those from Roku, Boxee, and Apple), and Internet-capable televisions. Video-on-the-Internet providers such as Netflix, Apple, and Google face challenges obtaining rights to the most recent movies and TV series from media conglomerates such as Time Warner, The Walt Disney Company, and Viacom.

Cultural, Economic, and Technological Factors

Technological and economic factors enable TV shows and movies to be easily streamed or downloaded from the Internet to consumer devices. The emerging video market enables major shifts in the entertainment industry. Just as online music streaming and electronic books impacted CD and book publishing profits, online video might trigger major shifts, as well. New video distributors such as Netflix, Apple, Amazon, and Google might drain revenues from cable TV providers and movie theaters, causing their profits to shrink.

The availability of lower-cost entertainment content on the Internet has led to people dropping cable TV or subscribing to lower-cost, basic tiers rather than premium video-on-demand (VOD) cable TV. These subscribers are willing to delay seeing prime time entertainment in exchange for saving money by using alternative services. In addition, there is an appeal to the possibility of getting entertainment on a variety of mobile devices and TVs at the times and locations that are convenient for individual viewers.

Cultural factors also play a role in interest in video on the Internet. There are many families in which both parents work. This phenomenon combined with longer work hours has reduced leisure time and increased the desire for people to spend more time "nesting" on weekend evenings rather than going to a movie theater.

Finally, as technologies mature, people become more comfortable using them in new ways. In time, technologies that were initially cutting-edge become accepted and easier to use. This phenomenon is occurring with online video that is streamed and downloaded to televisions, mobile devices, game consoles, and set-top devices dedicated to supporting streaming video.

Ease of Use and Technological Enablers

In addition to cultural and economic factors, it has become easier to watch content on television and mobile devices via the Internet. It is no longer necessary to connect laptops to high-definition televisions to stream movies from the Internet to the TV. Dedicated set-top devices such as the Roku and Apple TV are easily linked to flat-panel televisions via the High-Definition Multimedia Interface (HDMI) and RCA (coined by the former Radio Corporation of America) video and audio interfaces on the back of these TVs.

Significant technological improvements have occurred that enable multimedia streaming on the Internet in homes and consumer equipment that simplifies streaming to mobile devices and TVs. These innovations include the following.

- Dedicated electronic devices, such as set-top boxes from Apple TV and Roku, that connect directly to televisions for streaming TV shows and movies from the Internet.
- Adaptive bit rate streaming software on servers that dynamically alters the speed of video streams to match consumer devices and bandwidth. This provides a more consistent video stream with fewer disruptions.
- Improvements with respect to in-home wireless networks.
- The availability of Internet-connected televisions.
- The attractiveness, sound quality, and lower prices in home entertainment systems and high-definition, flat-screen televisions that make home viewing attractive.
- Wireless tablet computers with large screens and enhanced resolution that make wireless viewing of entertainment more attractive.

Over-the-Top Competitors versus Cable Operators

Cable providers and telephone companies that own local broadband facilities now compete with companies such as Netflix, which offers a less costly service. This is because they provide streaming over the broadband infrastructure of the very same telephone and cable companies with whom they're competing. This eliminates the significant capital investment in building a network, which in turn lowers the barriers to entry into the market. Competitors such as these are referred to as *over-the-top* (OTT) providers. Other companies that offer lower-priced streaming TV and movies include Amazon, Apple, and Google, through its YouTube subsidiary.

Cable companies, which are concerned about losing customers to lower-priced services, have created strategies to counter OTT providers. For example, Time Warner, which no longer owns Time Warner Cable, coined the term and implemented a strategy called *TV Everywhere*. TV Everywhere refers to the ability of subscribers to watch full-length movies and television shows on devices and at times of their choosing.

Time Warner's HBOGO.com division makes HBO content available online to the subscribers of cable TV providers. Subscribers of cable TV providers that have signed up for HBOGO.com can watch any HBO content on the Internet that their subscription allows them to watch over the cable provider's wired broadband infrastructure. Comcast and other cable companies have begun to embrace the TV Everywhere strategy as a means to retain profits and subscribers for their pay television services in the face of competition from OTT providers. They are at various stages of implementation.

To date, Netflix has had the most success with its streaming service in competing against the on-demand TV and movie content offered by cable providers. Unlike other OTT providers, Netflix does not sell any hardware for playing content. Instead, its online streaming service is compatible with more than 100 formats on devices such as the Apple iPad and iPod, mobile handheld devices, Roku devices, and game consoles such as the Microsoft Xbox, Nintendo Wii, and Sony PlayStation.

Some OTT providers sell set-top devices that are compatible with televisions. This equipment makes it easy for customers to receive streamed video from the Internet. Set-top devices have interfaces that connect to home networks as well as televisions. The most common way to interface with home networks is via high-speed Wi-Fi wireless networks. These devices usually also have an Ethernet interface for connections to a residential network's cabling. Blu-ray players with Wi-Fi and Ethernet interfaces can also be used to stream content from the Internet, as can Internet-connected TVs.

The Quest for Current, Quality Content

The biggest challenge for OTT competitors is access to current content including television series, sports events, and movies. Content providers such as Warner Bros. (part of Time Warner), Viacom, NBC Universal (majority-owned by Comcast), and Sony earn 60 percent to 70 percent of the approximately $4 rental fees charged each time a subscriber rents a movie from pay TV services offered by companies such as Verizon, AT&T, and Comcast. This is less than what is possible from OTT providers. This is because there are lower fees for these services, leading to less revenue to share with content providers.

Content providers, which typically receive large fees from agreements that allow cable operators rights to their TV shows and movies, are reluctant to jeopardize these fees by licensing rights to the competitors of operators. HBO, the largest premium cable channel, does not currently license its shows for streaming to companies such as Netflix until a year after their debut. A content provider's revenue from streaming services is lower than its fees from DVDs and cable TV.

In addition, content providers earn revenue from sales of DVDs and movie theaters, both of which are declining. With fewer people going to movie theaters, content providers have made new movies available for video-on-demand (VOD) sooner than in previous years. They now provide them exclusively to movie theaters for periods shorter than the previous norm of 120 days.

The issue of content is also complicated by the fact that some cable TV providers also own rights to movies and TV series and/or national broadcasters. In January 2011, Comcast received approval from United States regulators to purchase a controlling stake (51 percent) in NBC Universal, which owns Universal Media Studios and

Universal Pictures' Focus Features; the NBC broadcast network; and cable networks USA, Bravo, and CNBC. It is part owner of the Weather Channel and majority owner of MSNBC.

Major content providers and a partial list of what they own include the following.

- Time Warner owns the most content in the United States and Canada. Some of its properties are HBO Films, CNN, New Line Cinema, TBS, Turner Entertainment, and Warner Bros. Animation.
- News Corporation, under its Fox Filmed Entertainment division, owns 20th Century Fox Films, Fox Searchlight, and the Fox television shows, and is part owner of National Geographic Channel.
- Viacom owns Comedy Central, MTV, Spike, Nickelodeon, BET, and VH1, as well as others.
- Sony, through its Sony Pictures Entertainment Division, owns Columbia Pictures, TriStar Pictures, Sony Classic Pictures, and Sony Pictures Animation. Sony also manufactures Bravia TVs, Blu-ray players, and the PlayStation game console. It is able to offer this content through its Internet-connected televisions, Blu-ray players, and home entertainment systems.
- The Walt Disney Company owns ABC, ESPN, Marvel Entertainment, and Pixar. It is part owner of Lifetime Entertainment, the History Channel, and A&E TV Networks.

Content Providers Fight Back with Hulu

ABC, NBC Universal, and Fox started Hulu jointly as a response to free TV available on the Internet at sites such as YouTube. Knowledge@Wharton published an article quoting a 2010 Wharton Leadership Lecture by Jeff Zucker, former NBC Universal president and CEO. The remarks refer to the formation of video content site Hulu. Zucker commented on the 2005 Saturday Night Live music video parody "Lazy Sunday" that went live on YouTube.

> *Lazy Sunday aired on a Saturday night. By the next morning, it was on YouTube, and by Monday morning it was a worldwide phenomenon. A couple of months later, YouTube [was] sold to Google for $1.6 billion. That was our content. They stole it and that was continuing to happen, so we thought we needed to control our content and be able to profit from our content.*

Hulu initially made its TV series available online at no charge. It now offers different levels of subscription-based services for which viewers pay monthly fees to watch additional content. Hulu also receives revenue from advertising that plays on its lower-priced subscription services when subscribers watch TV programs at Hulu.com.

Technical Challenges

Chris O'Brien, founder of Motionbox (now part of Snapfish, a Hewlett-Packard company) and SoftCom (now part of Interactive Video Technologies), stated in a telephone interview that "the challenge today is keeping up with the incredible diversity of tablets, mobile phones, and other devices. All of these different devices are creating an enormous challenge for video publishers, which convert the video into formats compatible with all the different screens and display capabilities."

This is complicated by the fact that there is no single format that can be displayed on devices from different manufacturers. Tablets from companies such as Apple, Samsung, and Dell all use a different format, as do mobile devices that use different operating systems and are connected to mobile networks based on differing protocols.

Even using the same type of compression is no guarantee of compatibility. If otherwise compatible audio and video codecs are stored in a different container (file) format, the video cannot be played. Desktop computers with the same type of audio and video compression as iPods won't be able to play the same video if the container format in which the compression is stored is different.

There are a number of audio/video container formats (QuickTime, Windows Media Video (WMV), ASF, AVI, and more), and each of these can contain a variety of different audio and video codecs. So, for example, H.264 video with AAC audio in an MPEG4 container might play on your desktop player but not on your iPod, even though they both support H.264 video with AAC audio. Again, this is because they are stored in different containers.

Conversion and Distribution Engines to Process Video

Because of challenges in distributing video content to match the many formats used worldwide, specialized companies such as Brightcove and Ooyala manage the conversion and distribution of video for many online video distributors, including cable TV operators. Other examples are media companies such as online newspapers and magazines, pay TV operators, and broadcasters.

Authentication and Reporting

Video processing engines perform other tasks associated with distributing video. When cable subscribers watch programs from televisions connected to broadband, the authentication software built into a set-top box automatically sends messages to the cable provider's networks verifying that this is a legitimate customer with a subscription for particular services such as video-on-demand (VOD).

Authentication is more complex when subscribers attempt to view content from other devices such as a tablet computer. The authentication software needs to determine if this device belongs to a legitimate subscriber. Authenticating a set-top box associated with a particular subscriber is simpler because it involves only a single set-top box, at a fixed location.

ELECTRONIC COMMERCE

Social networking, video, and search sites are key generators of e-commerce revenue. Additional drivers are dating sites, massively multiplayer online games, online gambling, pornography, and virtual worlds such as Second Life. Advertising adds substantial revenue at most of these sites. According to market analysis company eMarketer, Inc., Internet advertising revenues in the United States grew 30 percent from June 2010 to June 2011. Google earned the largest amount of ad revenue.

Total online advertising revenue is expected to increase as more people use tablet computers, smartphones, and Internet-connected televisions to browse, shop, and view content over the Internet. Use of these devices is in early phases in most countries. However, as such use proliferates, advertising revenues will continue to grow, underwriting the costs for content, which will lead to lower prices or possibly no fee at all on the Internet.

The demographic information collected about people's interests by tracking which articles they read and which sites they visit enables marketers and advertisers to target ads to narrowly defined groups. They can target women older than 55 who are interested in women's health issues, shopping, or travel. Or, they can focus on 18- to 35-year-olds interested in specific health issues and sports.

Another advantage of online ads is that they are less costly than those on television. They also provide a great deal more information about who's viewing them than either television or billboards. Advertising on the Internet—particularly video ads—are often better able to hold the attention of viewers by being entertaining, brief, and interactive. These ads can ask people to fill out a survey in exchange for being entered into a contest to win a prize.

The Attraction of Online Services

Online services provide convenience. People can access them at any time of day and from anywhere they have a broadband wireless or wireline Internet connection. Web site owners can also enhance their sites with photographs, video, and links to other locations. Eye-catching, easily navigated sites that attract large numbers of people are a draw to advertisers, and thus earn more revenue.

Social Networks

Social networks have materially affected how people socialize. In general, people make fewer telephone calls. Instead, they often stay in touch and keep others posted through social networks, Twitter, and e-mail. In particular, they can stay in touch with friends and family in other cities and countries. A quick message on Facebook is all it takes to keep people current on personal news. While e-mail also lets people stay in touch regardless of distances, social networks are more suitable for updating larger groups of friends simultaneously. They are also used to exchange information about travel and shopping, and to share experiences with others.

Relatives and friends update one another through photos and videos uploaded to social networks. This is a powerful draw and one reason why social networks, originally used only by college students and teenagers, have grown so quickly. Photos, and in particular video uploads, provide a way for grandparents, relatives, and close friends to feel close to children as they grow up.

Examples of large social networks include Facebook, LinkedIn, Baidu in China, Orkut in India, and Friendster in Asia and the Pacific islands. Other social networks are established around special interests such as music or particular sports.

One specialized social network, LinkedIn, is designed for business people. Professionals use it to network with others in their field. It is international in scope with more than half of its members based outside of the United States. LinkedIn was established in 2003, earlier than Facebook, which was started in 2004. LinkedIn is a forum for people to offer services such as training in new technologies and discuss issues pertinent to particular fields. It is not unusual for posts offering services based on new technologies to attract hundreds of responses. In addition, recruiters post job openings and people explore employment opportunities by using these posts, which are organized by specific careers.

Social networks are adding applications such as games to boost revenue. There are currently 1,500 online games in a dedicated section for social games on Facebook. These include FarmVille, FrontierVille, and Texas HoldEm Poker from Zynga. Other companies such as RockYou develop games created specifically for social networks. In these games, people compete with other participants by adding to their frontier area or farm. In FarmVille, participants pay for virtual goods, including farm equipment and crops, to expand their farm. Game developers share a portion of their revenue with the social network.

Twitter is another form of social networking. People use Twitter to broadcast microblogs, or "tweets," of not more than 140 characters to others who "follow" them. Many celebrities and most businesses have a presence on Twitter. They use it to post timely information about their business and for public relations purposes. Interestingly, Twitter is used more by people older than 25 than by teens who rely more on texting on mobile devices, which is more private and not as easily seen by adults.

Commercial organizations use both Facebook and Twitter to promote their products and to monitor people's reactions to their products and services. In addition to public relations benefits, feedback on social networks enables businesses to react more quickly to complaints or to learn how to improve their products. It also enables non-profits to conduct fund-raising efforts and candidates for public office to gain a following.

Online Games

Massively Multiplayer Online Games (MMOs) such as World of Warcraft, Eve, and Everquest require software downloaded from the game site instead of a game console. Thousands of people can play these games simultaneously. Game software is made up of complex video and audio, and the action revolves around themes including science fiction, fantasy, sports, and real life. There are some free online games, but the more complex ones require monthly subscriptions.

Gamification

Gamification is the use of games and contests posted on web sites to engage and attract users. Sites that use gamification might have simple games such as choosing between options and voting for their favorite sport or TV celebrity. Web gamification is a tool that can be used to collect data about group attitudes and preferences. The data collected is sold to organizations such as marketing companies, sports leagues, and political organizations. Startup company Wayin, which is headquartered in Denver, Colorado, incorporates features of social networks on its site, which is geared to mobile devices. Wayin-registered users can chat with friends about sports, their favorite TV shows, and other topics, and create their own pages dedicated to topics of their choosing. Other sources of revenue for sites that incorporate gamification are advertising, licensing of gamification software, data collection software, and retail sales of products on their sites.

Online Gambling

The attraction of online gambling is the allure of winning money without leaving home. At casinos, people can play at only one table at a time. By contrast, online gamblers can play at multiple windows simultaneously. Participants gamble using money deposited from their credit cards. Online gambling is legal in many countries and boasts large global participation. Currently, the use of credit cards for gambling is banned in the United States; however, online gambling site owners get around the credit card rules by using offshore accounts for credit card payments.

Travel and Retail

Travel and retail sites enable people to compare prices and see other consumers' reviews. Jeff Bezos, the founder of Amazon.com, was a pioneer in e-commerce and added online reviews to his then one-year-old site in 1995. He was inspired to let buyers write reviews as a competitive advantage to traditional bookstores and as a way to create a community at Amazon.com. He later expanded from books to music. In 2001, he leveraged the company's billing, delivery, and reputation for good service to attract other retailers. He also added many types of merchandise such as electronics and clothing.

Other online retailers and lodging sites such as TripAdvisor followed suit, giving customers the ability to write reviews about products they purchase. Consumer reviews, the ability to compare prices, and convenience are reasons that many consumers have shifted their purchasing and travel-related booking online. This has radically changed the travel industry. Airlines need fewer agents to book flights, and revenue at travel agencies has dropped dramatically.

Travelers can easily log on to the Internet at sites such as Kayak.com and Bing Travel (owned by Microsoft) to compare prices for specific routes at various airlines. Travel sites include categories for car rentals, vacation packages, and adventure travel, as well as travel advice. The majority of sites charge no fees, instead depending on advertising for revenue.

E-textbooks for Colleges—Less Costly, More Functional

The convenience of new multifunction tablet computers, combined with the rising costs of college textbooks, are driving the increasing adoption and availability of e-textbooks. Textbook price increases are outpacing inflation and represent a sizable burden for students struggling to pay tuition. Textbooks now cost much more than $100 each and sometimes more than $200 each. These high prices are driven by the cost to produce the supplemental material authors prepare for teachers and students, including CDs, quizzes, and lesson plans.

E-textbooks are about half the cost of hardcopy textbooks and offer other advantages, as well. They are often offered as 180-day rentals at even lower costs. Moreover, e-textbooks will decrease the number of used books purchased. The National Association of College Stores estimates that used books account for one-third of total sales of college textbooks. Publishers receive no royalties on used-book sales.

Another advantage of electronic formats is that they lend themselves to interactive features and other enhancements. For example, new tablet computers support full-color and interactive graphics that students can manipulate; for instance, they can edit the inputs of pie charts and bar graphs to see how the outcome changes. In addition, publishers are thinking about other creative ways to offer information online, such as selling single chapters of books on particular topics.

Publishers receive lower royalties on e-textbooks because of the lower overall prices. However, they will gain material savings on printing, warehousing, and distribution, which are major cost considerations. In addition, authors will be able to more easily edit their books for the inevitable errors that show up after a book has been printed. Some publishers allow professors to customize books for their classes by reorganizing or deleting chapters and uploading syllabuses, notes, equations, and illustrations. Textbook publishers have long been planning and implementing their online strategies. The popularity of tablet computers along with rising costs for printed books are major enablers of this trend.

ONLINE COMMUNITY FORUMS ....

Not all web activity is designed with a profit motive. Many blogs, mailing lists, and wikis are started to further social causes or provide support to the community. Numerous online forums generate no revenue; they simply disseminate information on topics of interest. For example, new mothers living in Brooklyn, New York, organized a neighborhood mailing list using the Google Group application to set up the mailing list and invite people to join. The list quickly grew to 120 mothers who all had babies around the same time and who live in the same neighborhood of mostly townhouses and a few apartment buildings. The following is an anonymous quotation from one of its members:

> *It's a list-serve of moms who gave birth around the same time in my neighborhood. It's a great social and educational resource. Initially, it was mostly useful as a way to coordinate get-togethers right after all the babies were born and everyone was on maternity leave.*
>
> *Eventually, it also became an important resource/advice outlet. So if someone had questions about how to wean a kid, or that their kid wouldn't sleep, they would send an e-mail to the group, and people would write back with advice. We still coordinate some social outings using the list. I actually took an infant/child CPR class with one of the moms, who is an ER doctor. And another mom recently organized a talk about preschools with a leading local educator. I also just joined a babysitting co-op that was formed through the list-serve; 15 moms out of the about 120 moms on the list decided to join.*

Town E-mail Lists Can Keep Communities Informed

Other examples of e-mail lists that provide a community forum are those organized around town issues and local services. One New England town, Framingham, Massachusetts, maintains an e-mail list called Frambors (short for Framingham Neighbors) to which residents can subscribe to hear news and announcements about local government and schools as well as opinions about ordinances up for a vote. The list additionally provides a place for people to ask for recommendations for service providers such as plumbers, contractors, electricians, beauty shops, and nearby restaurants. Subscribers often let others know about services with which they are happy as well as those that they feel are unsatisfactory. The service providers often respond on Frambors to these comments. Frambors has more than 1,700 subscribers.

The following is a quote from Steven W. Orr, who established Frambors, about why he founded it and about the policies he established in relation to posts:

> *After moving to Framingham, I felt that there were too many decisions made at Town Hall, about which too many people were uninformed. The Framingham Neighbors mailing list was created to give people an easy way to be more informed and to participate in the discussion. After a decade, the list is seen as an integral part in why the town is different*

today than it was ten years ago. More people still need to be better informed, but their options and their access is better than it was. In the end, the higher the degree of community involvement, the better that government operates.

Creating a mailing list is far less complicated than the design and implementation of the policies that govern it. One of many examples of such a policy decision is that all messages must be signed in the body of the message. This is different from the comment sections of newspaper articles where virtually all messages are anonymous and people feel free to say anything that's on their minds, often with little consideration. On the one hand, signing will inhibit those people who are uncomfortable with the loss of their anonymity, resulting in lowered written participation. On the other hand, signing messages has resulted in changing the whole tone of the conversation; civility, care in detail, and a number of other subtle characteristics all contribute to a marked degree in integrity of the list as a whole.

Community Wikis

Wikis are web pages that the public is able to modify and update but not delete. Some e-mail lists include wikis as adjuncts to their messaging, with recommendations that list subscribers add to web pages started by the e-mail list organizer. In Framingham, Massachusetts, the Frambors list has an adjunct wiki to which residents can add the names of services and restaurants that they recommend.

The term "wiki" comes from the Hawaiian word for *quick*. Wikipedia is the most famous wiki site. It is supported solely by donations and accepts no advertising. Wikipedia has an enormous following and is a factor in making paper encyclopedias obsolete.

NETWORK NEUTRALITY

Legal rulings regarding the Internet directly impact consumers, established carriers, and startups alike. In fact, frequently it's startup companies that develop innovative services and often offer them at low or no cost over a carrier's mobile and wireline broadband infrastructure.

Network neutrality is the concept of broadband providers treating all traffic equally. It applies to people's ability to access the content they choose from wired as well as mobile devices. The following are the basic tenets of network neutrality.

- Treat all users' traffic in an equal manner.
- Prohibit blocking content from any provider.
- Prohibit blocking access to any content or service.

The United States Federal Communications Commission (FCC) has enacted network neutrality rules for wireline and mobile companies.

Background Events

Prior to 2010, the FCC enforced rules on network neutrality. In 2008, it attempted to fine Comcast because it restricted, or *throttled*, BitTorrent traffic of largely illegal music downloads. (BitTorrent is a peer-to-peer file sharing protocol that was developed by the BitTorrent company.) However, Comcast sued the FCC over the fine and eventually won. The courts ruled in April 2010 that the FCC had no authority to regulate the Internet because it is an information service and not a telecommunications service. Under the Telecommunication Act 1996, the FCC's jurisdiction only covers telecommunications services. Telecommunications services are those used purely for transmission, sending, and receiving, not for storing content or applications in providers' networks.

In conjunction with its review of network neutrality, the FCC is currently considering classifying only the transmission, not the content or rates on the Internet, as a telecommunications service. This would allow it to regulate access to the Internet.

The Issues Surrounding Network Neutrality

Carriers that provide broadband and/or mobile network infrastructure are often in disagreement with application and content providers, such as those selling Voice over Internet Protocol (VoIP) services and entertainment over the Internet, about network neutrality policies. These content providers compete with broadband providers such as Comcast, Verizon Communications, and AT&T Mobile for VoIP and entertainment on the Internet. Examples of competitors' sites include Hulu, Netflix, Skype, iTunes, and Pandora.

Network neutrality proponents are concerned that network service providers have a monopoly or near monopoly on infrastructure and might slow down (throttle) the traffic of competitors in favor of their own customers. This would put competitive services at a disadvantage against the services offered by broadband providers and might lock consumers out of new, possibly lower-cost, offerings. This will be a problem for both content providers and their customers if there are no adequate rules and compliance mechanisms in place to ensure network neutrality.

The major carriers, however, want to be compensated for upgrades to their networks to accommodate increased traffic. When carriers upgrade their networks to support video streaming, subscribers transmit more bits over their Internet connections. Currently, most wireline access in the United States is an "all you can eat" offering for residential customers. Thus, most of these customers pay a flat fee even when using more broadband capacity. Network providers fear they will be relegated to providers of dumb pipes without profits from potentially lucrative applications.

Web site owners and content providers such as Netflix, Amazon, and Facebook profit from services they sell over the Internet. However, most don't compensate carriers for the infrastructure over which their services are transmitted. Rather, they pay for connections from their site to the Internet. When these carriers transfer traffic to other networks needed to reach customers, neither the other network owners nor the carrier connected to the subscriber are compensated. (See Figure 6-3.)

Proposed Modifications to Network Neutrality

Most large carriers that own broadband infrastructure connecting subscribers to the Internet would like to see modifications to parts of network neutrality. On August 9, 2010, Google and Verizon issued a joint statement for legislation. They stated that they agreed to most, but not all, facets of network neutrality for wired broadband networks. An exception on wireline networks is for new, differentiated applications for which carriers would be allowed to provide special treatment. The statement listed the following possible exceptions: healthcare monitoring, gaming options, advanced education services, and new forms of entertainment. The rationale is that these applications, with

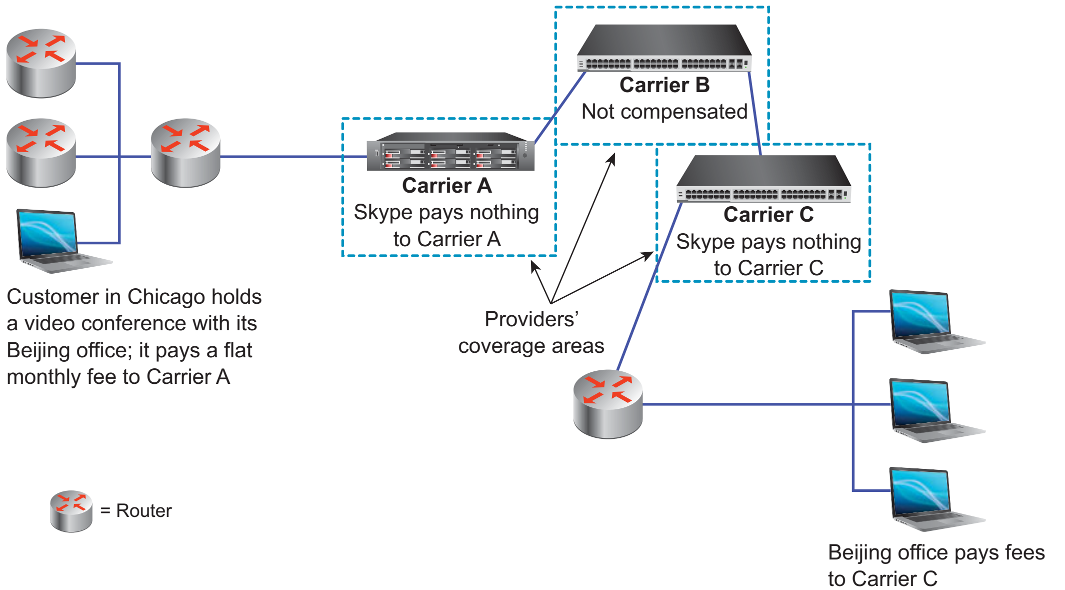

Figure 6-3 *With network neutrality, Internet application providers do not pay fees to long-haul carrier B for transmitting video or other high-bandwidth applications.*

their high-bandwidth requirements, might require Quality of Service (QoS) or other special treatment to operate smoothly.

The Google and Verizon joint statement took additional exceptions to applying network neutrality rules to mobile networks. They further stated that mobile networks are still developing and that wireless networks are already competitive. This was contradicted in May 2010 in the FCC's annual report on the state of competition in the wireless industry.

For the first time, the FCC did not state that there is competition. In comments afterward, one of the commissioners stated that competition had decreased because of consolidation in the industry. The four largest mobile providers—AT&T, Sprint Nextel, T-Mobile, and Verizon—each announced several purchases in the two years prior to the report. Verizon purchased the mobile assets of Alltel Corp., and Sprint Nextel Corporation. combined its advanced-generation network with that of Clearwire.

Network neutrality for mobile networks is a particularly difficult issue. Capacity is finite and wireless networks are being built up to handle large amounts of data and video, which can easily overwhelm them. Providers have stated that a shortage of spectrum, over which wireless services operate, makes it necessary to more tightly control traffic carried on mobile networks.

Most providers do agree that both wireless and wireline carriers should adhere to rules on transparency. Transparency should apply to network management and disclosure in understandable language about conditions and characteristics of their networks. Network management applies to a carrier's efforts to handle congestion and security threats.

The Haves versus the Have Nots: First Class and Everyone Else

Many consumer watchdog organizations feel that creating exceptions for certain, possibly lucrative, applications will in effect create two different Internet classes of network services. They fear that the part of the network providing priority "first class" treatment for new applications will take increasing amounts of capacity away from ordinary applications and bog them down. Currently, applications that require special treatment operate over a carrier's private IP data Multi-Protocol Label Switching (MPLS) networks, where QoS is routinely applied and paid for by commercial customers. For information on MPLS, see Chapter 5.

Network neutrality is important to ensure that networks are able to accommodate additional multimedia traffic. Until now, wired backbone Internet networks have been over provisioned with adequate spare capacity to handle traffic peaks. This can change with the increasing amounts of traffic generated by video content, online multiplayer games, and video conferencing.

Prioritizing certain applications over others has the potential to increase congestion and slow down traffic that is not prioritized. It additionally has the potential to slow down innovation and competition by making it costly for startups to pay for specialized treatment for the traffic that they generate.

Open Internet Regulations

On December 21, 2010, the FCC issued its network neutrality order titled *Open Internet Regulations*. The order included three rules on transparency, blocking, and discrimination.

The following is a summary of the rules.

- Network operators are required to publicly disclose actual attainable speeds on their networks as well as reasonable network management practices and terms of service.
- Landline network operators are not allowed to block lawful content, applications, or services, subject to reasonable network management. Operators of wireless networks are not allowed to block access to lawful web sites, subject to reasonable network management. Wireless operators are additionally not allowed to block applications that compete with their own voice or video telephony services.
- Providers of fixed broadband are not allowed to discriminate in transmitting lawful network traffic over a consumer's broadband access service.

The FCC stated that rules are not as stringent on wireless networks because these networks are at earlier stages of development and might be subject to additional capacity constraints. The FCC additionally provided a definition of reasonable network management. This includes allowing carriers to ensure network security and integrity and reduce or mitigate the effects of congestion on the network.

Critics of the Open Internet Regulations have expressed concern that network management will be used to slow down competitor traffic. The ability to treat traffic from different sources uniquely is provided through technology known as *Deep Packet Inspection* (DPI). DPI enables carriers to analyze traffic to determine information such as its source and whether it's video or e-mail. You can read more about DPI in Chapter 1.

The Open Internet Regulations resemble some of those suggested in the 2010 Google/Verizon joint statement. However, the joint statement urged legislative action, not FCC regulations. Verizon stated its intention to file a lawsuit requesting that the FCC's order be overturned. Verizon argues that the FCC does not have jurisdiction over the Internet or broadband networks.

In 2012, AT&T Mobile announced a plan to shift some of its data network costs to developers whose customers generate the traffic. Under the plan, developers will have the option of paying fees to AT&T Mobile for mobile traffic produced by their applications. Traffic from applications for which developers pay usage fees will not count toward customers' data plans. Critics of the plan charge that it favors established developers that can afford the fees, which results in free usage for their customers.

THE DIGITAL DIVIDE: BANDWIDTH, SKILLS, AND COMPUTERS

Most middle- and high-income residents in urban and suburban areas have Internet access with adequate capacity. This is not always the case with residents in rural areas where, if broadband services are available, they are often costly and slow compared to service in more developed regions. The slow speeds discourage users from signing up for these services because services such as video depend on a higher capacity to work well.

Low-income residents and minorities might have either limited or no Internet access. For these groups, costs for computers and broadband can be prohibitive, given their limited resources. These circumstances contribute to what has been termed the *digital divide*, by which segments of populations do not have access to Internet and computer services. These populations are essentially locked out of online educational services, the ability to apply for and look for jobs on line, and other services such as instructional materials and electronic training for their children.

The digital divide is more than the simple measurement of whether or not Internet access is available. The digital divide is further identified by the following.

- **The amount of available bandwidth** This is the network capacity in terms of bits per second and cost per kilobit or per megabit compared to urban sections of a country.
- **The quality of computer equipment available to users** Is it compatible with the latest browsers and is it capable of handling video?
- **The availability of training** Do users know how to navigate the Internet to accomplish their goals?

Government policies and allocation of resources have a major impact on bandwidth availability. Countries can provide free computer training for the unemployed to open up new opportunities for them. Training can enable the unemployed to apply online, which opens additional opportunities. It might also enable them to apply for jobs requiring a higher level of skills.

Economic policies can make a difference in the availability of broadband. Tax credits for new networks encourage carriers to upgrade equipment and infrastructure. Outright subsidies are a more direct option for improving networks. Countries such as Australia, China, and Japan have underwritten the cost of building fiber-optic or advanced mobile networks in rural areas. Improved broadband is one step in bringing remote areas into the online economy.

Community resources can bridge some of the gaps in the digital divide. In the United States, public libraries provide free Internet access, computers, and often training in how to use them. This is particularly critical in areas where residents do not have up-to-date computers or the expertise to access the Internet.

A report funded jointly by the Bill and Melinda Gates Foundation and the United States government highlighted the role of libraries in bridging the digital divide. Research was conducted by Samantha Becker, Michael D. Crandall, Karen E. Fisher, Bo Kinney, Carol Landry, and Anita Rocha. The Institute of Museum and Library Services printed the report in 2010. The report, "Opportunity for All: How the American Public Benefits from Internet Access at U.S. Libraries," states the following:

> *The wiring of public libraries has transformed one of the nation's most established community resources into a critical digital hub, where patrons can compete more effectively for jobs, improve their health, find key government services, and manage their finances. Computer and Internet access allows librarians to go beyond library stacks to connect patrons to all of the resources, services, and tools available online. In a world increasingly defined by technology, the public library is one of the widest bridges to the Internet and computers, not only for those who cannot afford their own connection, but for those who find the library is an easier, faster, friendlier, or more effective way to use these tools.*

INTRANETS AND EXTRANETS ....

An *intranet* is the use of web technology for the sole, dedicated use of single-site and multisite organizations. Intranets are a way to distribute information, software, and other services within an organization using web-like software tools.

Extranets extend the reach of intranets from internal-only communications to sharing documents, fixing software bugs, and providing information for business-to-business transactions. Online banking is an example of an extranet.

Intranets

When they were first developed, intranets based on web technology served as repositories of centralized information. Intranets still serve as a single source of an organization's information. However, they have evolved to interactive sites with many functions that make organizations and IT staffs more efficient. An organization might post a time-limited "jam" session, during which employees are encouraged to enter ideas for new products or services. This can generate a plan that leads to the start of a new endeavor. Some additional intranet functions include

- Providing company-recommended software that employees can download to their computers
- Checking whether user applications need updating and that all security patches are in place when employees log on to the intranet
- Managing human resources functions such as accessing pay stubs and appraisals, making changes to tax forms, changing user addresses, and selecting benefits
- Submitting time cards and expense reports
- Supplying training courses that users can complete on the intranet
- Making available corporate documents, such as organizational practices, required documents, templates for résumés and sales proposals, technical magazines, and corporate directories
- Providing collaboration tools that facilitate the ability of employees who work at different physical locations to work together on joint projects
- Posting internal job openings
- Establishing wikis with information about particular technologies or work-related information

In addition, intranets at global organizations often mimic web functions by providing social networking functions. The directory might have fields in which people can list special interests such as trekking or music. Employees can form groups around these interests.

Customizable social networking software for enterprises contains security software and provides the benefits of social networks and microblogs without the risks. Employees can use these software packages to share ideas and exchange messages about customer orders and new products without risking the introduction of inappropriate content or computer viruses by opening compromised links to sites. Yammer is an example of social networking software for business and commercial organizations. It is a cloud-based application that customers access remotely.

Firewall and other security software control staff members' access to corporate information on intranets. Restrictions can be applied to prevent employees from accessing inappropriate databases and applications. Not everyone has access to all files. Rather, employees can be placed in groups based on the applications to which they are allowed access.

Potential Issues with Intranets

The most common complaints about intranets are the difficulties in finding information and the problem of outdated information. Organizing information into a coherent form is challenging, particularly when a new company has been purchased. The purchased company might use different protocols for services on its intranet, making it difficult to merge the two intranets into a uniform entity. Moreover, in large organizations such as the military and global companies, different departments might use different databases, which can make it complex or impossible for all employees to access them. Organizations such as Autonomy, Google, and Microsoft sell search applications that help companies manage their "information overload."

In some organizations, every department posts their own updates. If updates are cumbersome and time-consuming to make, they might not be posted in a timely fashion. To make it easier to update intranets, organizations can deploy software packages such as Adobe Dreamweaver and Microsoft FrontPage, both of which have user-friendly interfaces that make it easier to update intranets and extranets. Often, a centralized IT organization manages the intranet and sets technical standards for it. Having a single-password, single-sign-on procedure for a uniform intranet saves time on calls from users who forgot their passwords.

Time and attention devoted to organizing and updating information often depends on whether top management views the intranet as a priority. Organizations without either management support or tools to support automated or simple maintenance and implementation might have intranets do little to enhance employee productivity.

Extranets

Extranets use a web interface for partial, secure access by customers, business partners, and temporary employees. They limit access to applications more so than intranets because they are used with outside individuals and organizations. Individual vendors or partners have access to only specific applications. Access to extranets is generally password protected or password-plus-token. A token is a small device (about the size of a large house key) that generates random numbers at predefined intervals. Users key in the number displayed on their token plus their password to access applications.

Online banking is an example of an extranet service. Customers transfer money between accounts, pay bills, and gain instant, graphical interfaces to the status of their accounts. This is highly advantageous to banks because it saves money on financial transactions and they can use their sites as an opportunity to offer customers services such as loans, home mortgages, and other financial instruments. Banks and other organizations also offer customers online bank statements and electronic bills through their extranets. These electronic services save mailing expenses and printing costs.

Because of security concerns, many extranets are located at web hosting sites. The hosting company's customer has his own computer at the hosting company. High-speed T3 or Carrier Gigabit Ethernet speed lines connect the hosting company to the Internet backbone. Companies often remotely upload or download information to their host-located computer via T1/T3 lines, or Carrier Gigabit Ethernet. Online learning is an example of an extranet service. It provides web-like access to educational material for school staffs and students. In addition to supplying extranet software, online-learning companies offer to host the application at their own site.

SUMMARY

The Internet is more widely available than ever before in an increasing number of regions worldwide via high-capacity mobile and wireline networks. The availability of these networks has resulted in an explosion of applications that can instantly reach millions of consumers and businesses. In turn, developers, governments, and marketing companies have the ability to collect information about consumer behavior through features in Internet applications.

Businesses that offer web-based applications have a large stake in being able to collect and sell demographic information about people who visit their sites. Often entire business plans are based on the ability to collect and sell this information. Many Internet businesses have a financial stake in privacy regulations which they might view as detrimental to their interests. They are in a position to influence the outcome of these regulations by hiring lobbyists to advocate for their position. Governments are faced with balancing consumer and business interests without alienating either group.

The Internet has a major impact on political, economic, and social conditions. Information is available instantly and broadcast globally. Governments, businesses, and consumer groups spend billions of dollars attempting to shape news favorably. Political candidates and parties as well as businesses are discovering ways to use the Internet to promote their interests, services, and products.

Consumers, too, have helped spread news and information through web sites such as Baidu, Twitter, and Facebook, where they often offer news about regional conflicts and political views. Powerful tools enable governments to track this online behavior and detain or arrest people who spread what they deem to be subversive activities or activities that threaten their country's stability.

The Internet has spawned sites that greatly improve communications. These same sites can be used to compromise privacy, confuse users with the rapidly changing offerings, and enable governments to monitor online behavior. The spread of the Internet has had an impact far beyond what the developers of the original Internet protocols, fiber-optic networks, and high-speed switches envisioned.

Social networks have added a new dimension to how people stay in touch, make business connections, and share photographs and videos. Competition from the Internet has caused many "bricks-and-mortar" businesses to shut down or change the way they operate. Innovative Internet businesses continually evolve and offer increasingly sophisticated ways to access and store music and movies, documents, and large databases.

The development of innovative Internet-based businesses depends in large part on open access to broadband networks. Broadband providers that favor their own services or charge prohibitive fees to start-ups for access could potentially inhibit this growth.

Part IV

Mobile Networks and Mobile Carriers Worldwide

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7 Mobile and Wi-Fi Networks

In this chapter:

INTRODUCTION

Mobile networks are critical during personal and national emergencies as well as for day-to-day communications. Worldwide, large percentages of populations that don't have access to affordable wireline broadband services are able to access e-mail with low-cost mobile devices. In addition, mobile networks are becoming an integral part of commercial transactions, and businesses that develop new applications and infrastructure for mobile networks contribute to economic growth by generating revenue and creating employment opportunities. And to a large degree, international enterprises depend on mobile communications to conduct business with mobile staff members and remote customers.

Mobile networks are made up of vast landline networks, switches, and databases. The only portions of these networks that are actually wireless are between a user's device and the mobile network's antennas. Signals to and from antennas are transmitted over landline networks to a carrier's centralized core network.

In addition to their wireless interfaces, mobile providers maintain complex wired networks as well as equipment and databases in core networks. Equipment in the core provides connections to billing systems, various databases, voice switches, and *gateways*. Gateways convert protocols in mobile networks to those compatible with public data networks and the Internet, and vice versa. The mobile core acts as a central site within which these functions are consolidated.

Cellular technology has been transformed from the initial analog systems that were first installed in 1984 to the new, high-capacity digital networks that we use today. Each successive generation has higher capacities, can cram more signals on given amounts of spectrum, and supports additional functions. Mobile networks are primarily based upon second-, third-, and fourth-generation standards. Additional interim standards that are transitions between generations are 2.5, 3.5, and pre-fourth-generation services. The following are the main protocols in mobile networks.

- The second generation, which is still the most common service worldwide, is digital and supports features such as caller ID, voicemail, and Short Message Service (SMS) for texting. Two examples include Code-Division Multiple Access (CDMA) and Global System for Mobile Communications (GSM).
- Third-generation services, which not all carriers have implemented, support higher speeds and packetized data. Wideband Code-Division Multiple Access (WCDMA) and CDMA2000 are among these services.
- When they are fully implemented, fourth-generation protocols will support higher data capacities capable of displacing Digital Subscriber Line (DSL) and cable modem-based broadband Internet access. These protocols include Long-Term Evolution (LTE) and Worldwide Interoperability for Microwave Access 2 (WiMAX 2).

Building, upgrading, and maintaining cellular networks are highly capital-intensive endeavors. Mobile networks require cell sites, switching equipment, and connections to other networks. They also depend on peripheral billing, operations and maintenance, and enhanced services components such as servers that support SMS and e-mail. Further, as a result of the high costs for spectrum needed for new-generation services and additional capacities, usually only the largest carriers have the resources to bid on and purchase spectrum.

Mobile services have already displaced a large percentage of home telephone lines. In the near future, particularly in rural areas and in developing countries, mobile services will be used instead of landlines for Internet access, as well. They are currently replacing DSL Internet access in Scandinavian countries that have high-capacity fourth-generation (4G) mobile networks.

For mobile service to have the capacity to carry this additional traffic, additional spectrum—the portion of the public airwaves over which mobile signals are transmitted—needs to be made available by governments worldwide. However, much of the spectrum is already used for other purposes or for earlier generations of mobile services. Government agencies, broadcasters, and others using this spectrum do not always want to give it up. Freeing up spectrum for next generations of cellular service is often a political issue facing government agencies that control spectrum allocation.

When spectrum is made available at public auctions, governments use the money to supplement tax revenues. High prices for spectrum often shut out smaller, less cash-rich carriers, making it more difficult for them to upgrade their networks. This often makes them less competitive against large, multinational mobile carriers. Availability of spectrum and the ability to use spectrum more efficiently are important issues. Using spectrum more efficiently often depends on having state-of-the-art equipment based on new standards that are better able to carry the large quantities of video and e-mail that are transmitted to and from smartphones and tablet computers.

One way that carriers add capacity to existing networks is by adding additional, smaller cell sites in densely trafficked metropolitan areas. They can also supplement capacity on mobile networks by using Wi-Fi services both within hot spots and in outside areas. (Wi-Fi is is an abbreviated form of the term "wireless fidelity.") Wi-Fi networks have the advantage of operating on unlicensed spectrum that governments make available at no charge. Determining cost-effective ways to add capacity and upgrade networks is the major challenge facing mobile carriers. Maintaining complex infrastructure with many thousands of cell sites is difficult and costly. Moreover, in countries where there are many competitors, prices tend to be lower, resulting in less capital available for carriers to invest in infrastructure.

FIRST-GENERATION ANALOG TECHNOLOGIES........

A wireless telephone network with connections to the Public Switched Telephone Network (PSTN) was first implemented in 1946 in St. Louis, Missouri. One transmitter and receiver covered the entire area, and all users shared the spectrum. This meant that only a limited number of simultaneous calls (25 to 35) could be placed on each city's mobile system. In addition to limited capacity, the quality of service was spotty, with considerable static and calls breaking up. Local telephone companies in each city later deployed this type of mobile system throughout the United States.

These services were replaced by analog cellular services, which evolved into advanced generations of digital mobile services capable of carrying data as well as voice. The popularity of mobile service created a demand by carriers for rights to more spectrum to handle the growing traffic.

Analog Cellular Service

Analog cellular service, which was put into operation in 1984, uses spectrum more efficiently than earlier, noncellular systems by enabling networks to reuse the same frequencies in different cells within cities and towns. The reuse of frequencies within nonadjacent cells was a creative innovation that added capacity to cellular networks. AT&T's Bell Laboratories (now part of Alcatel Lucent) created this first generation of cellular service.

The United States Federal Communications Commission (FCC) set aside radio spectrum for cellular service and decided that each metropolitan and rural service area was to have two cellular providers. The local wireline telephone company was assigned, at no charge, to one block of frequencies; a nontelephone company got the other block. The FCC hoped to foster competition by having two providers in each area.

Frequencies in the nonwireline block were allocated by an FCC lottery to qualified operators such as McCaw Cellular (later purchased by AT&T). Two network operators in each city proved not to be a competitive enough environment; thus, high per-minute rates resulted.

Cellular, Wireless, Cordless, and Mobile

The terms "cellular," "wireless," "cordless," and "mobile" have different meanings. Some services fall into multiple definitions. For example, services can be cellular, mobile, and wireless. The following are definitions of each.

- **Cellular** Any service in which the spectrum allocated to a carrier is broken up into geographic areas called *cells*. Cells next to one another use different frequencies. Noncontiguous cells reuse the same frequencies.
- **Wireless** Any service that uses radio waves instead of wires or fiber optics to carry electrical signals.
- **Cordless** A service that uses unlicensed spectrum and is restricted to a small coverage area within a home or private premises.
- **Mobile wireless** A service that can be used over a wide distance as people move around on foot or in cars and public transportation.

FINITE SPECTRUM FOR WIRELESS NETWORKS ....

On wireless networks, spectrum consists of the invisible electric energy used to transmit signals. The spectrum over which signals are carried is a critical asset that carriers require to operate their mobile networks. Governments regulate the allocation of spectrum because the availability of mobile networks in national defense and public emergencies is vital. They also designate uses for each portion of spectrum and set the terms of use by carriers and other entities that use spectrum.

The Division of Airwaves into Frequencies

Spectrum is divided into and allocated by frequencies. A *frequency* is the number of times per second that a radio wave completes a cycle. A cycle can be imagined as a letter *S* lying on its back, such that it appears similar to looking at a cross-section of an ocean swell. A cycle is complete when energy passes through an entire radio wave from the highest to the lowest portions of the wave. For a visual depiction of a complete wavelength cycle, see Figure 7-1. Frequency is measured in *hertz*, which refers to the number of complete cycles per second. Thus, for a frequency of 30 million hertz—or *megahertz* (MHz), as it is called—energy passes through 30 million resting *S*'s in one second.

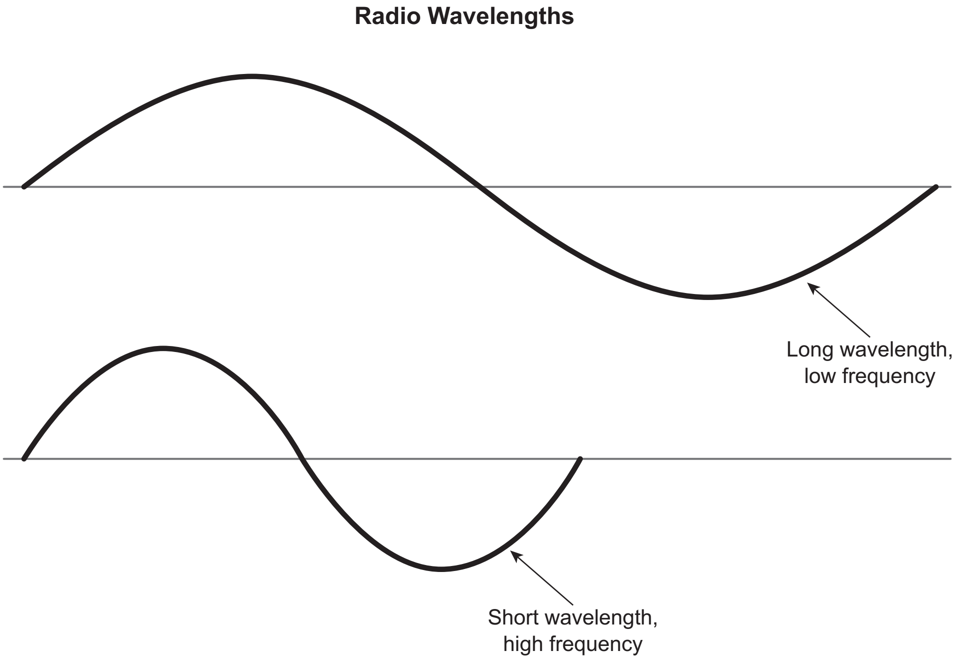

Figure 7-1 *A comparison of short, high-frequency wavelengths and long, low-frequency wavelengths.*

The Characteristics of Short and Long Wavelengths

Spectrum is divided into frequency ranges from low ranges of frequencies of about 30MHz to 300MHz allocated to government agencies, local police, highway, and state police to high frequencies such as 38 to 40 gigahertz (GHz) for fixed, point-to-point wireless service. Each range of frequencies is measured by the wavelength in the range. Wavelengths in low frequencies, such as AM radio at 100 kilohertz, measure 9,000 feet (3,000 meters) long. Higher-frequency 10-gigahertz wavelengths measure 1.78 inches (3 centimeters).

Because of their longer wavelengths, low-frequency signals travel farther than higher-frequency signals. Their longer lengths allow them to better withstand physical barriers such as rain and other solid materials. Thus, low frequencies can penetrate walls, buildings, and similar obstacles better than high frequencies. For these reasons, broadcast services such as those for traditional TV and for TV broadcasts designed for mobile devices typically use lower frequencies.

In the United States, analog TV, formerly in the 700MHz band, was relocated to another portion of the spectrum for digital TV. Most of the 700MHz frequencies were allocated to mobile carriers to build high-capacity Long-Term Evolution (LTE) mobile networks. High-speed mobile data networks operate over a variety of spectrum, such as 700 MHz, 2.1GHz, and 2.6GHz. Higher frequencies require more closely spaced antennas because these signals fade over shorter distances.

Spectrum Blocks

Governments allocate spectrum in chunks of frequency bands that are measured in ranges of, for example, 12-, 15-, 22-, and 30MHz. The size of the spectrum band is determined by subtracting the lowest frequency of the range from the highest frequency (highest frequency minus lowest frequency). For example, if an organization is granted the rights to use the spectrum band from 785MHz to 800MHz, it has the right to a 15MHz band (800 – 785 = 15).

Spectrum bands, which are set aside for specific services, are divided into blocks designated by letters of the alphabet. For example, within the 700MHz band (between 700MHz and 799MHz), the A block refers to a different block or range of frequencies within this larger range of frequencies than the B Block. The A Block might be allocated to one carrier in a region and the B Block to a different carrier to offer competing services in the same region.

The Federal Communications Commission (FCC) auctioned a 700MHz block in 2008 to a variety of carriers for higher-capacity, higher-data-rate services. Verizon Wireless won regional licenses to spectrum in the A and B Blocks, and AT&T Mobility won rights in the B and C Blocks. AT&T's B Blocks are in a different region than Verizon's. None of the licenses cover the entire country. The auction raised $19 billion for the federal government. All of the auction winners are required to use this spectrum to build networks capable of supporting higher-speed data on next-generation LTE networks.

Using Numeric Designations for Roaming Compatibility

In addition to alphabetic designations for blocks of spectrum, numeric ranges are designated for particular portions of spectrum within blocks. Standards bodies designate the numeric bands of spectrum for *uplink* and *downlink* transmissions. Uplink transmissions are those from subscribers to carriers' antennas, and downlink transmissions are those from the carrier to the subscriber. The goal is to enable equipment compatibility so that carriers can more easily make roaming agreements with one another. Mobile devices have preset designations for which frequencies are used for uplink and which are used for downlink communications. Thus, they only work on networks that use these same frequencies.

These bands are specified by numerals. For example, the 3rd Generation Partnership Project (3GPP) designated band 13 spectrum of the 777–787MHz range for uplink transmissions. The 3GPP specifies other bands, such as 12 and 17, for either uplink or downlink transmissions. Not all technologies require separate frequencies for uplink and downlink communications. In these instances, numeric designations are not required. The 3GPP established third-generation Wideband Code-Division Multiple Access (WCDMA) standards, and some LTE standards. It is in the process of agreeing on additional LTE standards for voice and data.

Using Auctions to Allocate Spectrum

Because it is finite and critical to industry, security, and emergency preparedness, all governments allocate spectrum for particular uses. Portions of the public airwaves and frequencies are allocated for satellite, broadcast TV, or fourth-generation mobile service.

Prior to 1993, the United States government authorized the FCC to make some spectrum available at no charge. Thus, television broadcasters received free spectrum over which they broadcast TV signals. Early cellular providers also received free spectrum in the 1980s for analog cellular service. In exchange for free spectrum, broadcasters agreed to provide air time for certain public service announcements and programming.

The allocation process changed in 1993, when Congress passed legislation enabling the FCC to auction off spectrum. The first auction was held in 1994 when the FCC auctioned off spectrum to the highest bidders for digital mobile cellular services. Later, auctions were held for additional spectrum for prefourth and fourth-generation data networks. Governments often provide spectrum at no charge when they believe it is in the national interest to foster development of new services. This happened in some Asian countries such as Japan where the government felt it was in the national interest to foster construction of higher-capacity wireless networks.

The Ramifications of Reallocating Spectrum: A Political Issue

Rules about spectrum allocations are argued about in the courts, before the FCC, and in Congress. The rights to these blocks are strategic assets that enable carriers to offer new, competitive services. Experts predict that a worldwide shortage of spectrum might hamper growth of data services for mobile devices. For example, a shortage of spectrum might hinder implementation of fourth-generation, high-capacity wireless because in many countries some of these bands are used for analog television.

In 2010, the FCC issued a National Broadband Plan in which it was predicted that the United States will require 500MHz of additional spectrum over the next ten years. It cited the estimate made by Cisco Systems in its *Global Mobile Data Forecast 2009–2014* that smartphones consume 30 times more data than basic phones. Smartphones generate hundreds of megabytes per month; and tablets and laptops consume gigabytes of data monthly.

In the United States, all of the spectrum bands suitable for mobile communications are already used by mobile carriers or have been allocated for other purposes. Thus, in order to free up spectrum for high-capacity mobile networks, organizations and government agencies already using these bands must be moved to other bands. The National Broadband Plan listed steps that should be taken to free up this spectrum for new mobile technologies.

There is a concern that inefficiencies in allocating spectrum will create delays and an inadequate supply of spectrum. In the past, allocating spectrum for new uses has taken an average of ten years.

Once an organization has rights to spectrum, it might not want to give it up because of its potential future value. For example, the D Block of the 700MHz frequencies was allocated for public safety to build a nationwide network designed with compatible protocols on 700MHz spectrum. This would enable devices to communicate with one another during national emergencies. Public safety organizations consist mainly of police, fire, and highway departments.

The D-Block allocation was triggered by the September 11, 2001 attacks on the World Trade Center in New York City and the Pentagon in Washington, DC In the immediate aftermath of the attacks, police and fire departments often had difficulty communicating with neighboring departments for assistance because they used devices that were incompatible with one another. To be compatible, each device must be manufactured to operate on the same spectrum and use the same protocols.

Using Incentive Auctions to Speed Up Spectrum Availability

Although they have rights to nationwide spectrum in the 700MHz D Block, to date the public safety organizations have not begun construction of a nationwide network. When the FCC offered the D Block spectrum in the 2008 auction, no one submitted an adequate bid to build out a network. The FCC has expressed a desire to move the planned emergency network to other spectrum that the public safety organizations already own. However, the public safety organizations claim that they need the spectrum they own in other bands and it cannot be used for a nationwide network. They currently have spectrum in multiple bands including the 32MHz, 33MHz, 154- to 156MHz, 158MHz, 458MHz, 460MHz, 821MHz, and 866MHz bands.

Public safety organizations had conducted a successful lobbying campaign to keep their 700MHz spectrum and for government funding for construction of a nationwide network. Thus, in February 2012, Congress allocated $7 billion for the build-out of a nationwide public safety network.

Prior to 2012, in an effort to fund the construction of the nationwide public safety network and to make spectrum available for mobile high-capacity networks, the FCC suggested holding *incentive auctions*. In these auctions, proceeds would be put into a trust so that public safety groups could contract to build a new, compatible nationwide network.

The FCC would like to hold incentive auctions for other spectrum currently held by government agencies. One purpose would be for raising money to move these agencies to other bands so that spectrum can be freed up more quickly for mobile data. Currently, the FCC has no authority to hold incentive auctions; this requires congressional approval.

Shared Access to Spectrum to Increase Efficient Utilization

Although mobile carriers are facing a shortage of spectrum due to the increasing use of smartphones to access the Internet, check e-mail, and watch video, other wireless networks use less than 50 percent of their spectrum at any given time. Shared Spectrum Company, located in Vienna, Virginia, hopes to increase the efficiency of spectrum utilization with its dynamic spectrum access software. This software enables networks to use unused spectrum in other networks and utilize the spectrum in their own networks more efficiently.

Dynamic spectrum access continuously monitors spectrum to determine availability. The available spectrum might be in an organization's own network, in unlicensed spectrum, or in other networks altogether. The spectrum monitoring can be used to prevent interference in an organization's own network. It can monitor the airwaves at a mobile carrier's cell site to ensure that its signals do not interfere with signals that *spill over* from its adjacent cell sites. (Frequency spillover is a particular issue at the edge of small cell sites in metropolitan areas.)

Dynamic spectrum access has the potential to make it possible for mobile networks to operate without interference on unlicensed spectrum in metropolitan areas. Currently, *white space* spectrum is planned for fixed Internet access in rural areas where there are fewer possibilities for interference. White spaces are unused bands of frequencies (guard bands) on either side of a channel that prevent wireless signals from adjacent channels from interfering with one another. (See the section "Unlicensed Spectrum for 'Super' Wi-Fi," later in this chapter, for more details on white spaces.) However, the continuous spectrum monitoring would enable new, more powerful Wi-Fi networks to be used for mobile e-mail and Internet access without interfering with other networks in busy metropolitan areas. These white-space-based networks would be operable over multiple spectrum bands so that if one band has traffic, devices would automatically switch to an available band.

Dynamic spectrum access could also be used with applications for which spectrum is used intermittently or only at certain times of the day. Utilities that have spectrum for meter reading and schools that use their wireless networks during the day could make their spectrum available to other organizations when it is idle. Another example of spectrum that is used intermittently is that of news broadcasters that have rights to particular spectrum that they use irregularly for remote broadcasts of special events (for example, crime scenes, fires) to which they dispatch specially equipped trucks to record and transmit the broadcasts back to the stations.

Shared Spectrum Company has spent ten years developing its unique shared-spectrum access software. The Defense Advanced Research Projects Agency (DARPA), which is part of the Department of Defense, funded the research with $25 million in seed capital.

The major challenge in developing its dynamic-spectrum access software was in distinguishing the many types of emissions from those of wireless transmissions. It is necessary to distinguish false positives such as background noise and engine noises (including those in automobiles) from wireless signals. An additional challenge was developing the peer-to-peer technology that enables all of the devices in a network to be synchronized together and continuously monitor the network. Synchronization is required for the devices to operate together on the same spectrum.

DARPA underwrote the research for military purposes. The intent is to take advantage of existing wireless networks in countries where the military is deployed so that its communications are up and running faster and at lower cost than setting up its own infrastructure. The military currently uses Shared Spectrum Company's software for mobile devices carried by soldiers. The software automatically tunes radios to available frequencies rather than using spectrum analyzers to manually tune a soldier's wireless device.

Shared Spectrum Company CEO Tom Stroup envisions its software being used for a wide variety of commercial applications. Its current emphasis is on cellular applications because of the demand for more data and video services. It's working with a major supplier to put its technology on *femtocells* (small cell sites for inside buildings) for access to multiple frequency bands.

Applications outside of cellular networks include technology to control non-military, unmanned airborne vehicles that transmit realtime, high-definition videos of border patrols back to controllers. Another is wildlife monitoring to track threatened bird and animal species. Stroup also foresees medical sensing applications such as monitoring blood pressure and transmitting readings to medical technicians. Other vertical applications include Wi-Fi for passengers in smart cars and various public safety applications for police, fire, and highway departments.

The FCC is also interested in furthering explorations of dynamic spectrum access as a means to improve spectrum utilization. To that end, on November 30, 2010, it issued a Notice of Inquiry about promoting the efficient use of spectrum through dynamic-spectrum access technologies. The FCC issues a Notice of Inquiry to gather information about broad subjects or to generate ideas on a specific issue. The following is a quote from FCC Chairman Julius Genachowski's statement on the goals of the inquiry:

> *I am a strong believer in the creative power of spectrum engineers and innovators–both inside and outside the agency–to help us use our system resources more intensively and efficiently. We need to hear from these experts as we move forward with our Notice of Inquiry–making sure we have a complete picture of the dynamic spectrum access tools available and doing what we can to encourage their development and use.*

If the FCC moves forward in approving this technology, the next step is for it to issue a Notice of Proposed Rule Making (NPRM). An NPRM solicits comments about proposed changes to its rules. This is a multiple-year process.

Enhancing Spectral Efficiency to Increase Capacity without Adding Spectrum

The ability to carry more traffic within a given amount of spectrum is crucial. This is called *spectral efficiency*. Each successive generation of wireless protocols is more spectrally efficient than the previous one. For example, fourth-generation (4G) wireless technologies are capable of carrying more high-speed wireless data and video than third-generation (3G) technologies, which are more efficient than second-generation (2G) and analog technologies. Unfortunately, many carriers worldwide still use 2G services.

When carriers purchase other carriers, the merger of different technologies can cause spectral inefficiencies. When Sprint purchased Nextel, Nextel used a different protocol for its push-to-talk voice and data services. This protocol is known as Integrated Digital Enhanced Network (iDEN), which was developed by Motorola Solutions. Sprint has announced its intention to phase out its iDEN service to gain more capacity without purchasing spectrum. Large "chunks" of networks using the same protocols enable carriers to transmit more traffic. This is because smaller "chunks" might not be used to capacity while the rest of the network is congested. This change enables Sprint to upgrade more of its network to newer, higher-capacity protocols.

In addition, carriers can add more capacity by increasing the number of cell sites in their territory. Carriers add cell sites because each one reuses spectrum used in non-adjacent cells. However, although additional cell sites equate to more spectrum re-use, this strategy is more expensive. It involves adding and maintaining new antennas and other equipment at each new base station.

Unused Spectrum on the Secondary Market

In addition to obtaining spectrum at auctions, carriers also purchase spectrum on the secondary market from organizations that purchased it at earlier auctions but either did not build a network on it or were unsuccessful in their service offerings. For example, AT&T Mobility, in addition to purchasing spectrum in the 700MHz range at the 2008 FCC auction, offered Qualcomm $1.93 billion for additional 700MHz spectrum in 2010. Qualcomm had used its spectrum for mobile TV, but it attracted few customers. AT&T received FCC approval for the deal in 2011.

Aloha Partners L.P. purchased 700MHz spectrum auctioned in 2001 and 2003 and later from other companies that also had acquired 700MHz spectrum at auction. It sold all of its 700MHz spectrum to AT&T in 2008. Aloha Partners II was formed in 2004 and many of the investors in Aloha Partners L.P. are investors in Aloha Partners II. It acquired spectrum in the 1.7- to 2.1GHz range at a 2004 auction and other spectrum from NextWave Wireless, which had obtained it in a 1996 FCC auction but subsequently entered into bankruptcy. NextWave still has spectrum that it has not used for wireless services.

Aloha Partners and NextWave both bid and won spectrum at FCC auctions on which they never built wireless networks. According to Aloha's web site, the FCC requires that Aloha Partners II provide substantial service on its spectrum by 2021. Aloha Partners is the twelfth-largest owner of spectrum in the United States. The FCC web site indicates that NextWave Wireless still holds spectrum.

Educational institutions also hold large swaths of spectrum. These are in the 2.495- to 2.69GHz range. The Kennedy administration granted them this spectrum in the 1960s for remote learning purposes. Schools in California and elsewhere have rented spectrum to commercial organizations as a way to earn revenue. In addition, an early investor in Clearwire, a mobile broadband provider, purchased some of this spectrum and merged his holdings into the Clearwire network. For the most part, schools access the Internet via wireline rather than wireless services for remote learning.

The FCC's National Broadband Plan made the following recommendation as a way to expand incentives and mechanisms to reallocate and repurpose spectrum:

> *The FCC should evaluate the effectiveness of its secondary markets policies and rules to promote access to unused and underutilized spectrum.*

Taxpayers currently receive no revenue from the sale of unused spectrum by nongovernmental organizations. In 2011, cable TV providers Comcast, Time Warner Cable, and Bright House Networks agreed to sell the spectrum that they purchased through their joint venture, SpectrumCo, to Verizon Wireless for $3.6 billion. If the government approves the purchase, the cable companies will earn a windfall of $1.4 billion on their $2.2 billion spectrum purchase. None of this will go to taxpayers. Moreover, at the same time that mobile carriers face a shortage of spectrum, other organizations hold spectrum that they do not use or that is vastly underused.

Regulating the Amount of Spectrum per Carrier by Using Spectrum Screens

Governments often establish policies limiting the amount of spectrum that any one carrier can have rights to in any single area. These limits, referred to as *spectrum caps*, are created to promote competition by splitting up air rights among carriers. At one time, the FCC had a spectrum cap of 55MHz per metropolitan area for mobile carriers. The federal government, under the Clinton administration, eliminated the cap in 2003.

In place of the 55MHz spectrum caps, the FCC instituted spectrum screens of 95MHz. The new rule applies only to spectrum acquired through proposed mergers between carriers. In cases where the proposed merger results in a merged carrier with more than 95MHz of spectrum in a single region, the FCC can determine if this creates an anti-competitive situation. If it does determine that the merger is anti-competitive, it can order that the dominant carrier divest itself of spectrum in areas where it exceeds the 95-MHz screen.

Eliminating the cap removed a stumbling block that would have prevented the merger of AT&T Wireless and Cingular (into AT&T Mobility) and the merger of Verizon Wireless with Alltel in the United States. It also eliminated rules which would have prohibited both Verizon and AT&T from leasing additional spectrum for certain regions at future auctions. Both Verizon and AT&T Mobility exceeded the 95MHz screen when they acquired 700MHz spectrum in 2008. This was approved because screen caps do not apply when spectrum is gained at auctions.

Synchronizing Spectrum Internationally

Spectrum allocation is administered on both an international and a national level. The International Telecommunications Union (ITU) manages the allocation of spectrum for services such as satellite and television that cross national borders. It also acts as the umbrella for other services such as determining spectrum bands for third- and fourth-generation services. These functions have become more critical as subscribers worldwide depend on their mobile devices when they travel for business and leisure.

In the United States, the International Bureau of the FCC, the National Telecommunications and Information Association (NTIA), part of the Commerce Department, and the State Department are working with the ITU. Generally, working groups comprising representatives from many countries hash out particular issues under the auspices of the ITU. Decisions are made at the ITU's World Radiocommunication Conferences (WRC), held every five years.

The FCC and the NTIA jointly manage spectrum allocation in the United States.

Geographic Licensing Schemes

In Europe as well as in many other locations, when governments offer spectrum to carriers, they offer it in country-wide swaths. However, in the United States, spectrum auctions for mobile service initially only covered portions of the geographic region. Part of the reasoning is that this encourages competition. In addition, it was felt that the United States is so large that purchasing nationwide coverage could be cost-prohibitive for entrepreneurs. As a result, no carrier's network provides complete geographic coverage across the entire United States.

This is starting to change. In the 2008 700MHz auctions, carriers were allowed to bid on large swaths of spectrum in Regional Economic Area Groupings (REAGs) that encompass more territory than the business economic area, metropolitan, and rural groupings. There are six regional groupings in the contiguous United States and others for regional groupings such as Alaska and Hawaii. The Gulf of Mexico also retains its own grouping.

Verizon Wireless and AT&T Mobility cover almost all of the metropolitan areas in the United States, but not all of the rural areas. No other carrier has such extensive coverage or the financial wherewithal to purchase spectrum to cover these large areas.

Mitigating Interference

When transmissions use the same frequencies in the same locations or even next to one another, they can interfere with one another. For example, if next-door neighbors install Wi-Fi wireless equipment and cordless telephones that both operate at 2.4GHz, they often experience operability problems. These problems are caused by interference. Newer wireless technologies have the capability to hop between channels when they sense that other signals are in the same channel. Concerns about interference often lead to political conflicts between factions. This can occur when new uses for spectrum or new technologies are proposed. This occurred, as illustrated in the next section, when it was first proposed that white-space spectrum be allocated for other uses.

Unlicensed Spectrum for "Super" Wi-Fi

Governments specify portions of the spectrum for unlicensed services such as Wi-Fi and Bluetooth. Unlicensed spectrum is available free to companies that do not have to apply for a license to use it. This significantly lowers the cost of deploying service, but it doesn't mean the government does not regulate unlicensed spectrum. Moreover, the government can designate bands of spectrum as unlicensed for public benefit.

In 2010, the FCC designated licensed spectrum formerly used in conjunction with analog TV as unlicensed spectrum to lower the cost of bringing new broadband services to rural areas. When the FCC parceled out digital spectrum to broadcasters in the 1990s, it was with the understanding that broadcasters would return their spectrum when it was no longer used to broadcast analog television. The FCC auctioned off most of this returned spectrum for Long-Term Evolution (LTE) use, but it did not auction off the 6MHz of that spectrum formerly used as *guard bands* for analog TV and still used for wireless microphones.

Guard bands, also called *white spaces*, are unused bands of frequencies surrounding each channel that prevent wireless signals from adjacent channels from interfering with one another. Wireless signals are not enclosed in cabling, and thus can leak or spread into adjacent spectrum. Analog signals leak more than digital signals. For this reason, when the FCC originally allocated spectrum for analog television, it set aside 6MHz of spectrum as guard bands between all adjacent TV channels. Only wireless microphones and other wireless equipment for public events such as Broadway plays were allowed to operate in white spaces.

When the FCC announced its desire to make these white spaces available because they were no longer used as guard bands, broadcasters and Broadway theater producers objected. They were concerned that new services in the spectrum might interfere with microphones and other equipment used at public events such as those in stadiums, concerts, and even churches. After extensive testing, including an experimental license granted in a small rural town, the FCC ruled that the former white spaces could be used as unlicensed spectrum. It ruled that it could be used for "super" Wi-Fi, a Wi-Fi standard whose signals could travel over longer distances than traditional Wi-Fi signals. "Super" Wi-Fi is the informal name for the 802.22 IEEE standard.

The FCC hoped that this spectrum would be used to bring high-speed Internet access to rural areas. Making the spectrum unlicensed further supported the goal of lowering the total cost to bring Internet access to rural areas. Because this spectrum is in the 700MHz range, which is a low frequency, the signals can travel the long distances required in rural areas. Using wireless obviates the need to lay fiber-optic cabling and install costly electronic equipment near customers or directly to premises.

Power-Level Specification for Unlicensed Spectrum

Because of the potential for wireless spectrum to cause interference, governments establish rules regarding issues such as signal spreading and power limitation to protect adjacent licensed spectrum bands against egregious interference emanating from unlicensed spectrum transmissions. All equipment used in licensed and unlicensed wireless networks must meet government specifications to receive certifications. That is why even a Bluetooth mouse is certified and assigned an FCC ID number. There are no assurances that congestion from many networks in the same unlicensed spectrum will not interfere with one another or overwhelm capacity.

SECOND-, THIRD-, AND FOURTH-GENERATION DIGITAL NETWORKS ....

Each successive generation of digital networks uses spectrum more efficiently and provides capabilities for additional features. Third-generation (3G) networks have improved capabilities to carry data. Fourth-generation (4G) networks support broadband services, and in the future they will replace fixed-line Internet access services such as Digital Subscriber Line (DSL).

Second-Generation Digital Service

Although second-generation (2G) digital cellular service was first deployed in the 1990s, it is still the most prevalent form of cellular technology, worldwide. 2G cellular service provides more capacity than analog mobile service and enables features such as caller ID, speed dialing, and voicemail message notification in the form of stutter dial tone. These features were not available on analog cellular service.

Digital wireless services use multiplexing access techniques to carry more voice traffic on the same amount of spectrum than the analog cellular service they supplanted. Mobile carriers introduced disparate, incompatible multiplexing techniques, referred to as *air interfaces*. The air interface in the customer's device must match the one used in the carrier's cell site. Thus, although all digital services have more capacity than analog cellular, the air interfaces added for additional capacity are not always compatible with one another.

Digital handsets include Digital Signal Processors (DSPs) to convert analog voice signals into a digital format. DSPs are specialized, very-high-speed computer chips. The DSPs code and decode the voice signals, converting them from analog to digital at the sending end and from digital to analog at the receiving end.

All digital cellular services improve privacy. Snoopers with scanners can easily listen in on analog cellular signals. Eavesdropping on digital transmissions is more difficult because the digital bits are scrambled before they are transmitted over the open air between handsets and an operator's equipment.

Because 2G service is designed for voice traffic, it is not efficient for transmitting data. Therefore, some carriers have started using spectrum on which 2G service operates for 4G service. This is referred to as *refarming*. They have decommissioned some 2G services and use the spectrum for 3G or 4G services. Refarming refers to changing the type of air interface deployed on particular spectrum bands.

The two most prevalent 2G air interfaces in the world, in order of worldwide subscriber use, are Global System for Mobile Communications (GSM) and Code-Division Multiple Access (CDMA).

GSM Service

GSM is the most widely used 2G air interface worldwide. Its strength lays in its widespread global penetration, which enables consumers to use their telephones when they travel. GSM phones have clip-on Subscriber Identity Module (SIM) cards. These cards contain a microchip that stores user identity and other information such as speed-dial lists. The SIM card encrypts voice and data before they are transmitted.

GSM is the digital cellular standard that was originally decided on by European governments and was first deployed in 1992. GSM divides channels of 200KHz spectrum into eight time slots. Seven of the time slots carry traffic and the eighth carries control signals. The control channel also carries Short Message Service (SMS), which is otherwise known as text messaging. GSM uses a form of Time-Division Multiplexing (TDM). T-Mobile USA and AT&T Mobility operate GSM networks in the United States.

Roaming Using Mobile Devices in Other Networks

Roaming is the capability to use voice or mobile data devices in another carrier's network. Outside of the United States, these networks are usually in other countries; within the United States, they might be in other states. Roaming is important because no one carrier has coverage everywhere. People with GSM service often obtain compatible Subscriber Identity Module (SIM) cards for countries to which they frequently travel in order to save on roaming fees. People who travel tend to be high-end customers who use more mobile services. Thus, roamers from other networks are profitable sources of revenue worldwide.

Agreements among carriers are required for every region in which roaming is enabled. Roaming agreements spell out costs, billing, and payment terms. To illustrate the complexity of roaming arrangements, most carriers have agreements with 200 to 250 other carriers. Some carriers use brokers that already have agreements worldwide and share revenue with the broker. Thus, calls made and received while roaming are more expensive than those in the subscriber's home territory; with the additional costs covering the fees imposed by the other network.

Once the agreement has been signed and the service tested, roaming is activated. Carriers lease high-speed links to other providers such as AT&T, France Telecom, and Belgacom (in Belgium), all of which have an international presence. These links carry the actual voice and data traffic. Signaling links are also established to perform functions such as the *handshake* between the handset and the user's home carrier. The handshake verifies that users are legitimate customers of the originating network and have roaming privileges. Because parts of the world use incompatible types of Signaling System 7 or Session Initiation Protocol (SIP), gateways are used to translate between signaling types.

CDMA Service

CDMA divides the spectrum by associating a unique code with each call. This is known as a *spread spectrum* technology. Each conversation transmitted is spread over a 1.25MHz frequency channel as it is sent. Use of this technology gives CDMA more capacity than GSM. The United States–based technology company, Qualcomm, pioneered CDMA in the commercial sector.

CDMA supports more phone calls and data sessions per cell than any other 2G air interface. The decision to use this superior multiplexing method cost many carriers in the United States a high price in lost compatibility to GSM. However, CDMA enabled them to offer voice and data services at a lower cost and to more easily upgrade their networks to 3G networks.

In the United States, Verizon Wireless and Sprint Nextel use CDMA technology. Carriers in other countries including China, Japan, and South Korea adopted it as their 2G service. Once Europe settled on a uniform air interface, most of the rest of the world followed suit and adopted GSM for compatibility while roaming.

Compatibility throughout Europe; a Mix of Standards in the United States

When analog cellular was developed in the United States, one organization, AT&T, set de facto standards for all telecommunications services. However, in 1984, AT&T was required to divest itself of the local telephone companies. When these local carriers in the United States upgraded to digital services during the 1990s, they were no longer part of AT&T and were free to select different standards. Also, new cellular companies that purchased spectrum at a government auction chose various air interfaces. Initially, all but the former AT&T local carriers chose CDMA because of its superior capacity.

Qualcomm, the developer of CDMA, was late in delivering CDMA software due to its complexity. Because of this, Southwestern Bell Mobility (now AT&T) initially commercialized Time-Division Multiple Access (TDMA). As the former Southwestern Bell Mobility purchased other telephone companies, it converted them to TDMA, as well. Starting in 2003, AT&T Mobility converted its entire TDMA network to GSM to align with carriers worldwide. AT&T Mobility upgraded its 2G network to 3G Wideband Code-Division Multiple Access (WCDMA) and began upgrading to pre-4G Long-Term Evolution (LTE) service in 2011.

Meanwhile, European standards bodies adopted GSM as a uniform technology for all of Europe. GSM was first used for commercial service in 1992. Prior to standardizing on GSM, Europe had a mix of incompatible analog technologies. The presence of a uniform air interface made using the same mobile handset across the continent convenient. Other countries around the globe adopted GSM because of roaming compatibility.

Connections to Customers and Mobile Networks via the Cell Site

A cell is the physical area in which a set of frequencies is used. Each cell site has a Base Transceiver Station (BTS) and antenna. (The BTS has different names in later-generation services.) With the increase in pedestrian use of mobile telephones, more cell sites are located in shopping malls and downtown areas. Carriers often share space at cell sites to save costs. For example, a large operator might lease space on a tall water tower for its antenna and on the ground for ancillary equipment.

Companies such as Crown Castle and American Tower in the United States, specialize in building towers and leasing space for cell sites. Instead of a single mobile carrier owning a tower or the land around the tower, a third-party company builds the tower and leases space on it as well as space for the rest of the equipment at base stations. This spares carriers from investing capital in towers and real estate. In Europe, carriers often share towers. In these arrangements, one of the carriers leases space at the tower to other carriers.

Mobile handsets and data devices are connected to cellular networks by the BTS. The BTS is connected to the antennas by coaxial cabling. It transmits and receives mobile calls from the cell site's antenna and amplifies (strengthens) signals. It also performs the conversion of signals between over-the-air radio frequency formats such as GSM and CDMA to those compatible with landline networks, and vise versa.

The Base Station Controller (BSC) is the traffic cop of the mobile network. It performs the precall setup, which means that it assigns calls to radio channels in the BTS, sends ringing to the correct channel, and measures signal strength. In digital 2G and 3G cellular service, one controller can manage many BTSs.

Third-Generation Digital Mobile Air Interfaces

The main drivers behind third-generation (3G) mobile networks were a need for more capacity and the capability for operators to offer revenue-producing services that require advanced 3G networks.

The International Telecommunications Union (ITU) started an effort called IMT-2000 (international mobile telephone) to define one advanced digital standard for next-generation voice and high-speed data on cellular networks. Unfortunately, the ITU subcommittees endorsed several 3G techniques due to political pressure from operators and manufacturers who wanted standards to more closely match the equipment they produced and used in their networks.

3G standards have various evolutions, referred to as releases or revisions, which improve upon and increase speeds, capacity, and suitability for converged networks capable of carrying voice, video, and data. Voice is transmitted by using circuit switching, which is less efficient than Voice over Internet Protocol (VoIP). The peak and attainable data rates associated with these services vary because of a number of factors, including distance from antennas, congestion within the cell, and weather conditions.

The Most Common 3G Technologies

As previously indicated, 3G standards are collectively known as IMT-2000. The most widely implemented 3G standards are WCDMA and CDMA2000. Although the first CDMA2000 3G networks were installed in 2000 and the first WCDMA network was installed in 2001, many carriers worldwide are still in the process of adding 3G protocols to their networks.

The following is a list of 3G technologies.

- **Wideband CDMA (WCDMA)** This is the 3G standard that most GSM cellular providers use. WCDMA is also known as the Universal Mobile Telecommunications System (UMTS).
- **Time Division-Synchronous CDMA (TD-SCDMA)** This is a standard supported by the Chinese government, which underwrote research and development by Chinese manufacturers. Thus, manufacturers do not have to pay royalties to license these 3G technologies. The government has left it up to operators to choose their own 3G technology. It has made spectrum available for the three main 3G standards. China Mobile has implemented TD-SCDMA, but China Unicom settled on WCDMA and China Telecom on CDMA2000.
- **CDMA2000** This is the standard used by most CDMA providers and some providers in newly developing countries. Verizon Wireless and Sprint Nextel use CDMA2000. CDMA2000 was the first IMT-2000 standard deployed commercially. SK Telecom implemented it in South Korea in October 2000.

The Transition to WCDMA

Most GSM operators implemented General Packet Radio Service (GPRS) before WCDMA. WCDMA supports higher data rates and has more capacity for voice. Installing both GPRS and Enhanced Data Rates for Global Evolution (EDGE) delayed the large expenses of upgrading to WCDMA. Unlike 3G, GPRS and EDGE operate on the same frequencies as GSM, and thus upgrades are less costly.

GPRS has a 64Kbps peak data rate with an achievable rate of about 30Kbps. This is about equivalent to dial-up data modems on landline networks. A disadvantage of GPRS is that packet data takes capacity from voice in GSM networks and dedicates it to data.

The Benefits of EDGE over GPRS

EDGE, as implemented, is a 2.5G interim technology in the evolution to 3G networks. Although there is a 3G standard for it, it has never been implemented.

EDGE supports more capacity for data than GPRS. The average data throughput is between 60Kbps and 120Kbps, depending on network conditions. It also uses network capacity more efficiently than GPRS because it dynamically assigns voice and data to channels as they become available instead of dedicating part of the network to voice and part to data. And finally, EDGE can handle more voice than GPRS.

Divergent Paths to 3G

The two main standards organizations, 3rd Generation Partnership Project (3GPP) and 3rd Generation Partnership Project 2 (3GPP2), specified interoperable protocols and architectures (the way devices are connected together and interoperate) for 3G core mobile networks. 3GPP is a collaboration agreement formed by European, Asian, and North American telecommunications standards bodies to jointly develop technical specifications for maintaining GSM, GPRS, and EDGE and for evolving WCDMA networks. 3GPP has expanded its scope to develop LTE and 4G LTE Advanced specifications.

3GPP2 is a parallel group that developed technical specifications for CDMA2000 networks. The goal of these groups and others like it is to ensure that networks are able to interconnect seamlessly and that subscribers can roam globally while maintaining feature transparency. For example, call waiting and caller ID should operate the same in a subscriber's local area as they do in other locations.

Migrating from 2G to Wideband CDMA 3G Service

WCDMA is the 3G service that most GSM operators install when they upgrade from 2G. The Japanese carrier NTT DoCoMo was the first carrier to implement WCDMA in October 2001. Other carriers in Japan as well as Europe followed. Carriers install WCDMA for its added voice capacity and capabilities to carry data services such as e-mail and web surfing.

As the amount of data transmitted on 3G networks increases, carriers upgrade to higher-speed 3G technologies such as High-Speed Downlink Packet Access (HSDPA) and High-Speed Uplink Packet Access (HSUPA). Whereas some carriers are upgrading to pre-4G protocols, around the world, many are still in the process of migrating to 3G networks.

The Costs and Logistics of Upgrading from GSM to WCDMA

European operators invested enormous amounts of money in spectrum and equipment for 3G services predicated on their desire for more capacity for voice and for higher achievable data rates. Japan, like other parts of Asia, did not hold auctions for spectrum for 3G services. Rather, many governments awarded spectrum based on *beauty contests* of the various carriers' qualifications. "Beauty contest" is a term commonly used for auctions that are focused more on the capabilities of providers than on the am ount of money bid. The lack of requirements to spend huge sums of capital on spectrum has left Asian companies with more resources to upgrade their networks. This afforded many Asian providers a head start in building advanced mobile networks.

The largest expense in moving from GSM to WCDMA is new base stations. The higher-frequency spectrum needed for 3G means that many more base stations are needed because antennas for high frequencies cover smaller areas than those used in 2G and 2.5G networks. In Europe, GSM operates at 900MHz and WCDMA at 2.1GHz. Because WCDMA is based on code-division access rather than time-division access, upgrades on GSM networks (based on time division) to full 3G services require new infrastructure equipment.

3.5 Technologies and the WCDMA Evolution

WCDMA Release 5 includes High-Speed Downlink Packet Access (HSDPA), which provides higher-speed data, increased capacity, and better Quality of Service (QoS) for data applications. It triples downlink throughput (the rate at which actual user data is carried) to the subscriber. In addition, Release 5 doubles capacity for voice traffic. HSDPA and its variations are 3.5-generation technologies.

Because of its high downlink capacities, HSDPA enables applications such as music downloads, web browsing, and e-mail with large attachments. Data is carried as Internet Protocol (IP) packets between the base transceiver stations and the radio network controller. Release 5 also enables multimedia messaging such as receiving voicemail and e-mail on laptops.

In conjunction with HSDPA, some carriers also implement High-Speed Uplink Packet Access (HSUPA), which increases the speed on the uplink transmission. The combination of HSDPA and HSUPA is also referred to as HSD/UPA (high-speed downlink/uplink packet access).

Doubling Voice Capacity with CDMA2000 1X

The first phase of 3G CDMA2000, CDMA2000 1X, provided "always-on" data rates anywhere from 60Kbps to 100Kbps plus doubled voice capacity. All that is required for upgrades to 1X are new cards in the Base Transceiver Station (BTS) and software in the mobile switching center. Routers, billing, authentication and authorization systems, and connections to IP networks are necessary for the data services.

Carriers in South Korea implemented the first release (IS-2000 Rel. 0) of CDMA2000 in October 2000. In the United States, Sprint Nextel, Verizon Wireless, and some smaller cellular operators upgraded to CDMA2000 1X in 2001–2004. Other international carriers such as China Telecom, VIVO (Brazil), and Telstra (Australia) also upgraded.

CDMA2000 1xEV-DO (Data Optimized or Data Only)

Network providers upgrade to higher data speeds by adding software and channel cards to their base stations for High Data Rate (HDR) service. HDR service is a data-only enhancement with higher downlink speeds. No capacity is gained for voice traffic. Download speeds (from the network to their wireless devices) of close to 1Mbps within a single 1.25MHz carrier (like CDMA2000 1X) are significant because they require less spectrum than protocols that require perhaps 5MHz per carrier.

The Evolution of CDMA2000: 1xEV-DO Service Revision A

The CDMA2000 1xEV-DO service Revision A is also referred to as Rev A. Its air interface supports packet-switched data in the over-the-air channel as well as the core. Because of its real-time capabilities, Rev A supports applications such as multiplayer games, push-to-talk, and videoconferencing in which latency must be minimal. Uplink speeds are increased to a peak of 1.8Mbps and downlink speeds to a peak of 3.1Mbps. Enhancements to CDMA2000 1xEV-DO include *multicasting*, which is the capability to transmit the same multimedia streams (for example, radio and video) to many users simultaneously.

Infrastructure in Second- and Third-Generation Mobile Networks

Third-generation (3G) networks use packet-switched technology for data. Voice is carried separately by using circuit-switched technology, which saves a path for the entire voice call. By contrast, fourth-generation (4G) protocols specify packet switching for voice as well as data. Figure 7-2 illustrates the 3rd Generation Partnership Project

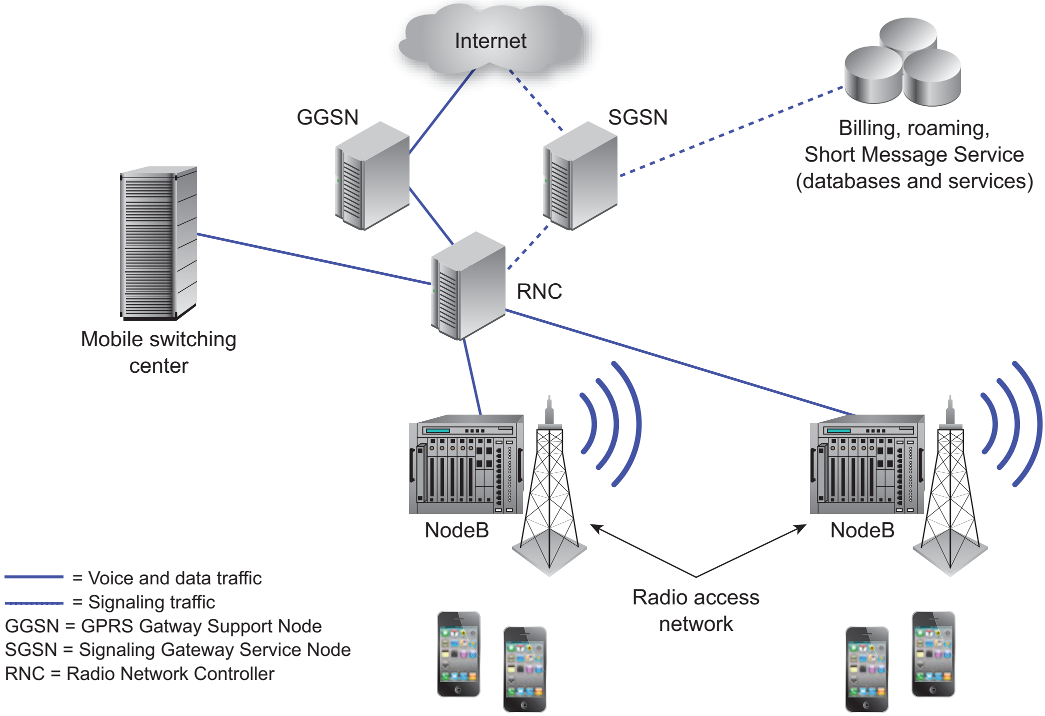

Figure 7-2 *The architecture in third-generation (3G) Wideband Code-Division Multiple Access (WCDMA) networks.*

(3GPP)–specified architecture for WCDMA mobile networks. Figure 7-3 depicts devices in a GSM network. Although the figures represent them as separate devices, in practice the controller functions for both second-generation (2G) and 3G networks are often located within the same piece of equipment.

3G networks are backward compatible with earlier GSM and 2.5G (EDGE and GPRS) networks. In addition, traffic from these earlier-generation air interfaces can be transported from cell sites to the core on the same (backhaul) facilities. (See the section “Connecting Cell Sites and Core Networks,” later in this chapter, for information about backhaul networks.)

The 3GPP2 and CDMA2000 specifications have similar architectures to those for WCDMA. 3GPP2 specifies backward compatibility to earlier CDMA technology so that carriers can mix older and newer cellular technologies using the same spectrum and existing base stations and mobile switching centers. Currently, when carriers upgrade to 3G services, they select WCDMA mostly because of its predominance worldwide. See Table 7-1 for infrastructure in 2G and 3G networks.

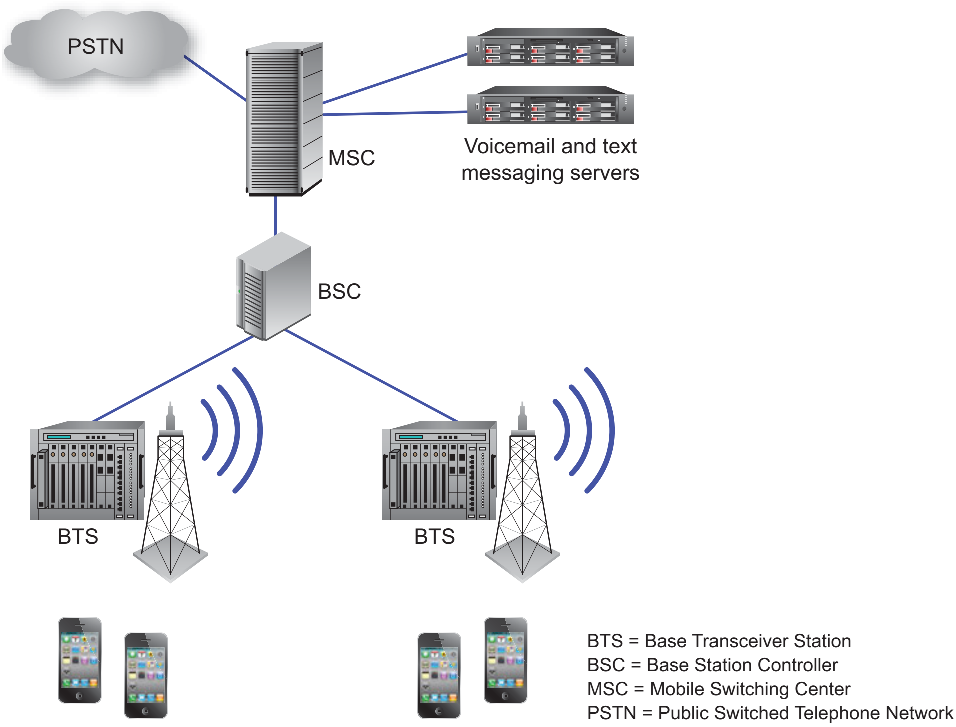

Figure 7-3 *The architecture in second-generation (2G) Global System for Mobile Communications (GSM) networks.*

Base stations are the most expensive portions of a mobile carrier's network. In rural areas, cell sites might cover up to 30 miles. In densely populated cities with high concentrations of traffic, a cell site might cover less than a mile. Therefore, network upgrades to services such as next-generation mobile service or acquisition of different spectrum that requires additional base stations or upgrades to existing cell sites are hugely expensive.

Mobile central office switches that route traffic within mobile networks and to landline networks are also part of all mobile networks. Newer mobile switches are built on *softswitch* technology, which supports Voice over Internet Protocol (VoIP) and multimedia applications. For information about softswitches, see Chapter 4, "Carrier Networks."

All of the aforementioned network types as well as 4G networks depend on *transport networks*. This is a generic term for protocols (T1, Gigabit Ethernet) and media (fiber optics, microwave) that are used on links between equipment such as base stations and equipment in the core network, including controllers, signaling devices, and switches in mobile networks. The transport network includes links to other networks.

Table 7-1 2G and 3G Infrastructure

Generation	Cell Site	Core	Core Functions
GSM 2G	Base Transceiver Station (BTS) contains antennas and radios, and performs similar functions to NodeBs in 3G networks of managing traffic between mobile devices and the mobile network.	Base station controller	Controls handover of calls to other cell sites and to the mobile switching center (mobile central office). Connects to other network controllers and radio base stations.
		Packet Control Unit (PCU)	Transmits data from base stations in 2.5G GPRS networks so that data traffic bypasses the mobile switch.
WCDMA 3G	NodeB translates between radio frequencies (signals carried over the air) and landline frequencies, and vice versa.	Radio network controller	Controls handover of calls to other cell sites. It is connected to other network controllers and to radio base stations.
		GPRS gateway support node (GGSN)	Converts Universal Mobile Telecommunications System (UMTS) data packets to those compatible with GPRS, the Internet, and other data networks, and vice versa.
		Signaling gateway service node (SGSN)	Transmits data between radio network controllers and network databases, applications, and billing systems. Also communicates with the GPRS gateway.
CDMA2000	BTS converts traffic between radio frequencies and landline signals.	Packet Data Service Node (PDSN)	Transmits data traffic between core and applications. Similar functions as GPRS gateway support node (GGSN).
		Internet Protocol Base Station Controller (IP-BSC)	Same functions as radio network controller.

FOURTH-GENERATION ADVANCED MOBILE SERVICES

There are two fourth-generation (4G) protocols: Worldwide Interoperability for Microwave Access 2 (WiMAX 2) and Long-Term Evolution Advanced (LTE-Advanced). Both of these protocols support all IP core networks, but access to the network—the air interfaces—is different. Currently, implementations of new WiMAX and LTE protocols do not support the full 4G speeds defined by standards bodies; nevertheless, they are often referred to as 4G services. Carriers that are currently installing LTE and WiMAX 2 are installing slower, pre-4G versions of the standards.

Criteria for 4G protocols were set by the International Telecommunications Union-Radiocommunication (ITU-R). 4G protocols are also referred to as *IMT-Advanced* (international mobile telecommunications). The ITU-R defines the capabilities required for protocols to be considered 4G, but other standards bodies do the actual development work of how these recommendations will be implemented. The ITU-R specified that 4G technologies must support 100Mbps downlink transmissions from the network to the user. Standards bodies developing LTE and WiMAX defined differing ways that 4G protocols reach that speed.

The two different standards bodies that developed 4G protocols areas follows.

- LTE Advanced: 3GPP.
- WiMAX 2: the Institute of Electrical and Electronics Engineers (IEEE). WiMAX 2 is also called WirelessMAN-Advanced.

According to the ITU-R definition, which was published in November 2010, all 4G technologies must meet certain capabilities. Although High-Speed Packet Access Plus (HSPA+)—a WCDMA-evolved third-generation (3G) protocol—does not meet all of these requirements, it does have more capabilities than other 3G services. You can find more information about HSPA+ in the next section. The key 4G criteria are as follows.

- Data rates of 100Mbps downlink speeds for mobile devices such as those in cars or trains, and 1Gbps downlink speeds for low-mobility devices. Low mobility refers to devices used in fixed locations or portable only within a building.
- Internetworking with services based on international mobile telecommunications (IMT), based on earlier 3G protocols, and with services transmitted on fixed, landline networks.
- An all-IP packet infrastructure.

- Internet Protocol version 6 (IPv6) addressing, which has more addresses than IPv4.
- The capability to support mobile TV.
- Efficient use of spectrum.
- Worldwide roaming compatibility between mobile 4G devices.

Internetworking refers to the fact that 4G devices can seamlessly be handed over between cell sites that use 3G and 4G protocols without transmission interruptions. Roaming with earlier generations of these protocols is also supported.

A large number of manufacturers compete with one another to supply 4G networks. These include Alcatel-Lucent, Ericsson, Fujitsu, Huawei, Motorola Solutions, Nokia Siemens, Samsung, and ZTE. There are also a number of Taiwanese manufacturers that are concentrating on developing WiMAX-compatible equipment.

Pre-4G Mobile Services: LTE, WiMAX, and HSPA+

The current versions of LTE, WiMAX, and HSPA+ are all pre-4G services. Mobile telephone companies are now implementing all of these services. The speeds on LTE and WiMAX can both reach ranges between 2Mbps and 25Mbps. These pre-4G services use Multiple-Input Multiple-Output (MIMO) antennas, a key factor in increased capacities. (For information on MIMO antennas, see the section "4G Multiple-Input Multiple-Output Antennas," later in this chapter.)

HSPA+, also referred to as evolved HSPA, is a 3rd Generation Partnership Project (3GPP) protocol that was defined in December 2010. Like LTE and WiMAX, HSPA+ uses a MIMO antenna, which is a major improvement over HSPA. The 3GPP specified MIMO antennas for HSPA+ after it specified them for LTE and WiMAX.

HSPA+ does not use Orthogonal Frequency-Division Multiplexing (OFDM) as an air interface. OFDM is capable of transmitting parallel streams simultaneously on narrow bits of spectrum. For more information on OFDM, see the section "The LTE and WiMAX Orthogonal Frequency-Division Multiplexing Air Interface," later in this chapter, as well as Figure 7-4. Although it does not use OFDM, HSPA+ does have a more efficient air interface than HSPA.

To attain high speeds, HSPA+ combines carriers (bits of spectrum) from different bands to achieve high bit rates. High bit rate is synonymous with high bit rates per second. HSPA+ can also be installed using spectrum from a single carrier. The advertised speed on this is 21Mbps. However, the average attainable download speeds are 2- to 6Mbps.

> NOTE Throughout this book, the term "carrier" has been used almost exclusively in relation to network service providers. However, as it applies to telecommunications, the term actually has two meanings. Thus, in addition to describing a network service provider, it can also refer to slices of spectrum (as is does for the topic at hand: HSPA+).

The next version, HSPA+2, uses spectrum from two different bands. It has peak speeds of 42Mbps. In 3G protocols, advertised speeds refer to peak speeds reached in a laboratory environment, under ideal conditions. In actual usage, attainable speeds are lower. 4G advertised speeds are those attainable under many network conditions.

For HSPA+ to reach even higher speeds in the future, spectrum from four carriers will need to be knit together. However, these techniques are complex. In addition, they decrease the top speeds and amount of spectrum available to other subscribers in the cell to accommodate more subscribers. Combining carriers results in less spectrum and fewer carriers available to other subscribers. Therefore, during peak hours, when there is more traffic, users might not reach these advertised speeds.

Carriers (network service providers, this time) choose HSPA+ when they don't have spectrum compatible with LTE or WiMAX. Not every country has made these spectrum bands available to carriers. They might also not choose HSPA+ if they have relatively new WCDMA infrastructure that is not fully depreciated.

Carriers that do upgrade can often upgrade to HSPA+ at a relatively low cost by adding new software. However, if they use HSPA+ in new spectrum bands, they are likely to need to add new antennas, as well.

Definitions of 4G

The ITU-R specifies that IMT Advanced, true 4G services must support data rates of 100Mbps and an all-IP infrastructure. Although HSPA+ and current implementations of LTE and WiMAX do not meet these criteria, carriers advertise them as 4G services in marketing campaigns. Equipment with true 4G capabilities is expected to be available by approximately 2014. But, current LTE, HSPA+, and WiMAX deployments are pre-4G services that deliver major improvements over earlier 3G technologies. A major goal of true 4G technology developers is the capability of mobile devices to keep up with the expected volume of mobile data, and for the capability of mobile networks to be used for broadband Internet access.

To add to the confusion about which technologies are 4G, the ITU-R issued a press release on December 6, 2010 explicitly stating that LTE-Advanced and WirelessMAN-Advanced (WiMAX 2) meet 4G criteria. The press release declared that current LTE, WiMAX, and other advanced technologies can be called 4G. The ITU-R further stated that more detailed specifications would be provided in 2012. This led to many writers' and carriers' statements that the ITU-R recognizes that LTE, current WiMAX, and HSPA+ are indeed 4G technologies. However, the acceptance of HSPA+ as a 4G protocol is still unclear. The important point is that mobile technologies now are capable of higher capacity and speed than ever before. The following is the ITU-R statement:

> *Following a detailed evaluation against stringent technical and operational criteria, ITU has determined that "LTE-Advanced" and "WirelessMAN-Advanced" should be accorded the official designation of IMT-Advanced. As the most advanced technologies currently defined for global wireless mobile broadband communications, IMT-Advanced is considered as "4G," although it is recognized that this term, while undefined, may also be applied to the forerunners of these technologies, LTE, and WiMAX, and to other evolved 3G technologies providing a substantial level of improvement in performance and capabilities with respect to the initial third generation systems now deployed. The detailed specifications of the IMT-Advanced technologies will be provided in a new ITU-R Recommendation expected in 2012.*

LTE Capacity and Roaming

LTE benefits include a higher capacity for data services, such as web surfing, future support for mobile broadband, and Quality of Service (QoS) for improved video transmissions. QoS saves a path in the network for each video transmission for the entire duration of the video. This provides the consistent service required for video.

As more networks adopt LTE, worldwide compatibility for roaming will be feasible. Roaming is dependent on the availability of LTE devices that operate on the same frequencies. An example is smartphones that operate on 700MHz and 2.1GHz networks. The roaming issue is especially significant for subscribers on CDMA2000 networks such as those of Verizon Wireless and China Telecom, both of which are deploying LTE. Current CDMA2000 customers have limited options for roaming because most of the rest of the world uses either GSM 2G services or WCDMA 3G technologies.

Mobile broadband is particularly significant in developing areas such as countries in Africa. These countries are currently experiencing the most growth of anywhere in the world with regard to the number of mobile phones, and for the most part, there are few landline broadband connections. It is expected that these areas will adopt mobile broadband for residential consumers rather than building out landline broadband infrastructure.

Current LTE implementations, based on Release 8 of the LTE standard, support between 2Mbps and 30Mbps downlink from the provider to the subscriber. True IMT-Advanced, 4G LTE, is based on Release 10 and will support 100Mbps.

The Benefits of LTE for Carriers

LTE provides benefits to carriers as well as subscribers. The most important among them are a simplified infrastructure and cell sites with fewer pieces of equipment to manage. Moreover, LTE software and hardware can be installed on standard computer platforms so that carriers can choose from a wide range of equipment manufacturers. LTE cell sites also support more users per cell site than 3G technologies because the air interface is more flexible and uses spectrum more efficiently. LTE is flexible on the amount of spectrum allocated to calls. The options are 1.4-, 3-, 5-, or 20MHz-wide bands. In high-traffic areas, carriers can allocate 1.4MHz bands to calls. During light traffic periods, 20MHz bands can be utilized.

When carriers upgrade to LTE, they are able to keep most of their 2G and 3G equipment in place because LTE is backward compatible. Re-use of infrastructure for LTE depends on the age of the rest of the equipment in the cell site and the spectrum deployed. Technical details about LTE infrastructure are included in the next section.

Carriers, particularly those using CDMA2000 technologies, will benefit from using a technology adopted by most carriers worldwide. One advantage is the potential to earn additional roaming revenue from carriers with compatible networks. Carriers make agreements with one another in which they receive payments when other subscribers use their network when they are out of range of their own carrier's network.

In addition, many LTE handsets include HSPA chips so that subscribers will be able to take their phones with them when they travel to GSM-based networks that use HSPA as well as on those with LTE. This is a particular advantage for business travelers who tend to generate more revenue than residential consumers. LTE is expected to be the predominant 4G protocol adopted by carriers worldwide. Manufacturers produce a wider choice of devices for networks which use the most prevalent air interfaces, because these networks represent a large pool of potential customers. Handset prices also tend to be lower because there are more choices and more competitive pressure.

Frequency- and Time-Division Implementations of LTE

The 3rd Generation Partnership Project (3GPP) standards group has defined two different air interfaces for LTE. One of the air interfaces is based on Frequency-Division Multiplexing (FD-LTE) and the other is based on Time-Division Multiplexing (TD-LTE). In common usage, LTE refers to FD-LTE because it is expected to be implemented more widely. FD-LTE is also referred to as Frequency-Division Duplex (FDD), and TD-LTE is also referred to as Time-Division Duplex (TDD).

Frequency-Division Multiplexing (FDM) requires paired frequencies, which means that one spectrum band is used for the downlink (from the carrier to the customer) and another band is used for the uplink (transmissions from the subscriber to the cell site). When carriers that use FD-LTE acquire new spectrum, they obtain one band specified by the government for uplink service and a different band specified for downlink service.

By contrast, TD-LTE uses the same frequencies for uplink and downlink transmissions. TD-LTE does not require paired spectrum, and unlike FD-LTE, it is asymmetric. A different amount of spectrum can be used in the downlink and in the uplink. For example, more spectrum can be allocated to the downlink than the uplink. China Mobile, the largest mobile carrier in the world, uses TD-LTE and some carriers in the rest of Asia are following suit and have announced plans to implement TD-LTE. The potential purchasing power of China Mobile makes it likely that manufacturers will supply a sufficient variety of TD-LTE-compatible handsets. Most of the rest of the world, including China Telecom, AT&T Mobility, and Verizon Wireless, are implementing or testing FD-LTE. Chinese companies manufacture and develop TD-LTE equipment.

Core networks are the same for both types of LTE. The network core consists of portions of the network where traffic from multiple base stations (cell sites) is aggregated and transmitted to either a mobile central office or the Internet. Chip designers are integrating both TD and FDD into their platforms so that carriers are able to support both types of LTE. Carriers able to support FDD and TD-LTE will be able to utilize spectrum suitable for either and support roaming for users with both types of handsets.

4G Multiple-Input Multiple-Output Antennas

LTE, HSPA+, and WiMAX use Multiple-Input Multiple-Output (MIMO) base stations. Equipment with MIMO antennas benefit by having more than one antenna and multiple input/output channels. Thus, they can carry the number of separate streams of voice or data as they have input/output channels. Each stream of traffic is carried on a separate frequency. A 2×2 antenna has two antennas and handsets communicating with it also have two antennas. This is analogous to multilane highways with two lanes in each direction.

The antennas currently on the market are the 2×2 models; 4×4 models are expected to be available next. An 8×8 antenna is specified for LTE-Advanced, which is Release 10, the 100Mbps, true-4G air interface. It's technically challenging to equip handsets with multiple antennas because space is required between them to avoid signal interference.

The LTE and WiMAX Orthogonal Frequency-Division Multiplexing Air Interface

Orthogonal Frequency-Division Multiplexing (OFDM) is the air interface used in LTE and WiMAX mobile broadband protocols. It is not used in HSPA+. OFDM increases spectral efficiency by sending several multiplexed streams of data over separate,

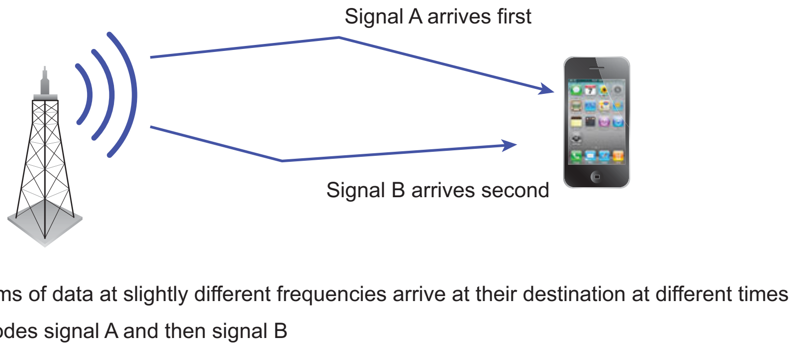

Figure 7-4 *Streams of bits sent by using the Orthogonal Frequency-Division Multiplexing (OFDM) protocol.*

narrow bands of spectrum simultaneously in orthogonal streams. Orthogonal streams are those that are transmitted at right angles to one another. Figure 7-4 illustrates an example of orthogonal streams in OFDM.

In addition, guard bands between each stream of data are not required, which is an important factor underpinning the spectral efficiency of OFDM. Guard bands are unused channels of spectrum that provide a buffer between streams to protect data from interference. Guard bands carry no data. For information on guard bands, see the section "Unlicensed Spectrum for 'Super' Wi-Fi," earlier in this chapter.

This narrowband, efficient use of spectrum is the main reason why LTE and WiMAX support many more users in each cell site than the 3G technologies WCDMA and CDMA2000. LTE supports 200 users per cell site, whereas CDMA2000 supports only 50.

The Increasing Number of LTE Deployments

Following the introduction of LTE in Sweden and Norway, Verizon and Metro PCS in the United States also implemented LTE. Vodafone in Germany and Chinese carrier CSL in Hong Kong are also early adopters. Interestingly, two different carriers in Uzbekistan also launched LTE. Carriers in other countries such as China and India are testing LTE or have announced their intention to use LTE. Factors promoting adoption include the need for more bandwidth and the need to replace outdated 2G equipment. These carriers can choose to skip 3G and implement LTE gear. Other carriers in some of these countries, such as China Mobile, are testing TD-LTE. The choices that a number of carriers are making between TD-LTE and FD-LTE depend on the spectrum that they are able to obtain. In certain instances, countries have made one or the other type of spectrum available, but not always both.

The Specifications for WiMAX Antennas and the Air Interface

WiMAX is a competing pre-4G protocol to LTE. Although the IEEE defined the air interface, the WiMAX Forum specified protocols and further development on the core network. The WiMAX Forum also has a certification program which verifies that equipment meets WiMAX standards. Like LTE, WiMAX uses MIMO antennas and OFDM as an air interface.

Prior to the availability of current mobile WiMAX (802.16e), WiMAX implementations were used for fixed Internet access. The fixed version of WiMAX, 802.16d, is used in some rural areas as a lower-cost way for providers to deploy broadband Internet access. It is also used for business customers in metropolitan areas as a backup to Internet access over wired broadband in the event of a cable cut. Fixed WiMAX networks are an improvement over traditional microwave in that they do not require line-of-sight. Thus, buildings or trees in the path of WiMAX signals do not block those signals.

Current pre-4G mobile WiMAX installations have been built using the 802.16e protocol for mobile devices. This release of WiMAX supports approximately the same speeds as the current release (Release 8) of LTE. Although the air interface is implemented differently, the core networks of each use standard IP-based devices. In January 2011, the Taiwanese state-run Industrial Technology Research Institute stated that it expects Taiwanese manufacturers to have 100Mbps 4G WiMAX equipment based on 802.16m ready for the marketplace by 2012. This is earlier-than-expected availability for LTE-Advanced gear.

WiMAX: Available Earlier Than LTE, Fewer Deployments

KT Corporation (formerly Korea Telecom) implemented the first mobile WiMAX network in 2006, three years before the first LTE networks were installed in Sweden and Norway at the end of 2009. To date, there are many more subscribers on LTE networks than on WiMAX-equipped networks, and that growth is expected to continue. This is due to the fact that the organizations supporting GSM standards—GSMA and 3GPP—decided on LTE as their 4G standard. Thus, most carriers already using GSM protocols are continuing to evolve along the path outlined by 3GPP for LTE.

In the United States, Clearwire offered mobile WiMAX services at the end of 2008. Prior to 2008, the Clearwire network supported only *fixed broadband*. Fixed broadband wireless services only support Internet access at a single location. With fixed wireless, customers can't use the service when they're away from their home or work. Sprint Nextel offers pre-4G mobile services on the Clearwire network. The mobile service is used from a fixed site for Internet access as well as anywhere else in the Clearwire network.

Clearwire had hoped to attract Verizon and AT&T customers by building its own high-speed mobile data network before other mobile carriers. However, the specter of competition from Clearwire spurred Verizon Wireless and AT&T Mobility to expedite their LTE network deployments. Clearwire has announced that, in the future, it too will implement TD-LTE service. Russian WiMAX operator Yota has also stated its intention to change from WiMAX to TD-LTE. Recognizing that a number of carriers with WiMAX networks have announced they will convert to LTE when they upgrade, WiMAX manufacturers are now including LTE capability in their WiMAX base stations.

WiMAX Technology

Although both WiMAX and LTE are based on OFDM and use MIMO antennas, data within packets is arranged differently in LTE and WiMAX. For this reason, LTE and WiMAX devices can't roam on each other's 4G generation networks. They can roam on networks using 2G or 3G protocols such as GPRS or CDMA2000 if the WiMAX carrier provides its subscribers with devices with these air interfaces, as well. However, subscribers won't be able to achieve 4G speeds when roaming on 2G or 3G networks.

In addition to the United States and Taiwan, carriers in Russia, China, India, Malaysia, Mexico, Spain, and other Asian countries have adopted mobile WiMAX. Some of these carriers have announced that they are switching to and testing LTE infrastructure so that their networks will be compatible with more networks for roaming. There will also be more choices available for infrastructure and customer devices.

Because WiMAX uses a time-division duplex version of OFDM, it is highly likely that carriers that change to LTE will adopt TD-OFDM rather than FD-OFDM. This is because WiMAX and TD-LTE use the same spectrum bands, making the change less costly because new antennas are not required.

Packetized Voice on LTE and WiMAX Networks

LTE and WiMAX support only packetized voice and data; they do not support the circuit-switched voice and Short Message Service (SMS) carried on 2G and 3G networks. Although LTE and WiMAX do support Voice over Internet Protocol (VoIP), there is no agreed-upon point protocol on how to carry the voice packets at this time. Therefore, mobile devices on current LTE and WiMAX networks handle voice by using 2G or 3G protocols in mobile handsets and networks.

The disadvantage of using circuit-switched voice in combination with LTE and WiMAX is that these devices do not support simultaneous voice and data transmissions. For example, when a user receives a voice call, her data connection is dropped.

The same device can be used for voice and Internet access, just not simultaneously. Handsets with 4G capability also have second- or third-generation air interfaces for voice.

The 3GPP organization is working toward agreement with manufacturers and carriers on a VoIP variation called Voice over LTE (VoLTE). Agreement on how to transmit VoIP is critical for roaming capabilities. The VoLTE protocol will be tightly specified so that roaming and interoperability with earlier-generation networks will be possible. VoLTE will be implemented over Internet Protocol Multimedia Subsystems (IMSs). IMS enables applications for voice, video, and online games to be stored, billed for, and accessed on a common IP platform that is available from mobile as well as wired networks.

When VoLTE is adopted, users will be able to use their mobile devices simultaneously for voice and for surfing the Internet. Carriers, including Verizon Wireless, started trialing VoLTE in 2011 and it is anticipated that it will be implemented widely in 2013. Because it will take many years for LTE and WiMAX to become ubiquitous, there are various schemes for roaming between networks with VoLTE and 2G and 3G networks.

THE STREAMLINED INFRASTRUCTURE OF LONG-TERM EVOLUTION ARCHITECTURE ....

Long-Term Evolution (LTE) uses fewer protocols and requires less equipment in its core network than second-generation (2G) and third-generation (3G) architectures. It also distributes some functions found in 3G core networks to equipment in the cell site.

LTE Cell Sites Offer Additional Functionality

An LTE cell site consists of antennas, amplifiers to adjust power levels, and a single piece of equipment, the evolved NodeB (eNodeB). The eNodeB allocates radio frequency (wireless spectrum) to users' devices and passes calls off to other cell sites and to the mobile carrier's core IP network. Importantly, the eNodeB manages Multiple-Input Multiple-Output (MIMO) antenna functions and Orthogonal Frequency-Division Multiplexing (OFDM) signaling.

Coaxial cabling connects the eNodeB to the cell site's antenna. The eNodeB contains a blade with a software-defined radio containing the air interfaces tuned to the available spectrum. A blade is a densely packed, horizontally placed circuit board with many ports. The modem in the software-defined radio translates radiofrequency signals into those compatible with landline networks, and vice versa for outgoing traffic.

The eNodeB is also referred to as the base station. Together with the antennas, amplifiers, and spectrum, it is used to access the mobile network. In combination, this equipment and spectrum make up the Radio Access Network (RAN). The eNodeB manages the RAN.

LTE architecture is streamlined in terms of the amount of equipment and protocols required compared to earlier generations of mobile networks. Refer back to Figures 7-2 and 7-3 for an illustration of the differences between cell sites in second-generation (2G) and 3G wireless networks. The Radio Network Controller (RNC) in the core of a 3G network has been merged into the eNodeB. Figure 7-5 presents a diagram of LTE architecture. This streamlining and distribution of functions results in data streams transmissions that use fewer protocols and equipment hops. This decreases latency (delays).

Moreover, in 3G networks, the centralized controllers in the core are often overloaded with the increased data traffic from smartphones. Refer to Table 7-1 for an overview of 2G and 3G infrastructure. Centralized architectures are more prone to failures from a single source.

In addition to the architecture, the names of devices in LTE core and radio access networks are different from those in 2G and 3G networks. For example, 3G base stations have NodeBs rather than eNodeBs (evolved NodeBs).

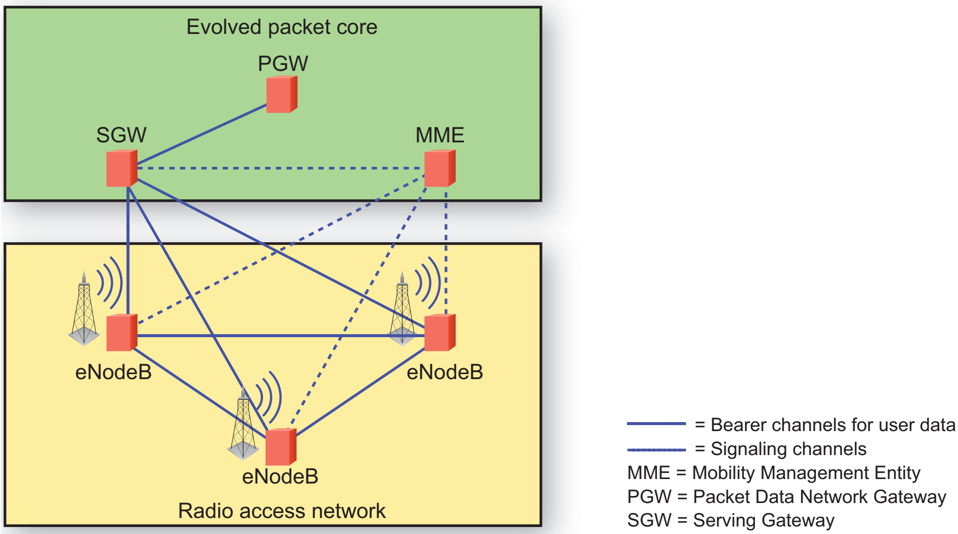

Figure 7-5 Fourth-generation (4G) Long-Term Evolution (LTE) architecture in the Radio Access Network (RAN) and the evolved packet core.

The Three Elemental Functions of the LTE IP Core

Traffic from hundreds of cell sites passes through a mobile carrier's core network. Signaling gateways for 2G and 3G networks are located in the core along with fourth-generation (4G) equipment. The LTE core network, also referred to as the *evolved packet core*, routes this traffic to data networks, the Internet, other mobile carriers, and other cell sites within the carrier's mobile network. Equipment and software located in the core also perform signaling and tracking calls for billing purposes.

In addition, signaling links are carried separately from user data and IP voice. Signaling is used to keep track of usage, perform security functions (to keep the network free from hackers and malware), and enforce policies. Policies include rules on the number of bits included in various data plans. Signaling enables carriers to monitor this volume so that a message can be sent to the user's device notifying him that he has used up his planned quota and will be charged extra for additional transmissions.

Functions within the LTE evolved core network are divided into three functional elements. Two functions, the serving gateway and packet data network gateway, are generally located in the same router. The functional elements making up the LTE's IP core are as follows:

- **Mobility Management Entity (MME)** This performs the signaling functions in the IP core. It sends and receives signaling information needed to set up, bill, and address calls to the eNodeB and to the Serving Gateway. In addition, the MME contains the security protocols for authentication and authorization.
- **Serving Gateway (SGW)** The SGW forwards the actual data packets on bearer paths between the eNodeB and the Packet Data Network Gateway. Bearer paths carry the actual user IP data. The SGW handles the protocol conversions between LTE devices and 2G and 3G systems and relays this traffic to and from the Packet Data Network Gateway and earlier-generation gateways.
- **Packet Data Network Gateway (PGW)** This interfaces with the public data network (the Internet and carrier private data networks). It additionally allocates IP addresses to user devices and is responsible for policy enforcement. It can classify packets as requiring Quality of Service (QoS). It also generates usage records that it sends to the carrier's billing system, indicating levels of customer voice and data usage. The PGW has links to the roaming database for functions related to roaming and billing roaming traffic.

The PGW and SGW transmit 2G and 3G traffic as well as LTE traffic to the Internet and other data networks. 2G and 3G traffic is handed off to these LTE gateways by earlier-generation controllers and signaling gateways.

Databases in the LTE Core

Gateways in core networks connect to a variety of databases that support roaming, billing functions, voice messaging, and text messaging services. These types of databases also support 2G and 3G mobile networks. The following is a listing of key databases in core 4G networks.

- The *Home Location Register* (HLR) contains information services and billing information on subscribers in 2G and 3G networks. The HLR also keeps track of the status and location of subscribers within its area. Visitor information is located in the Visitor Location Register (VLR) and keeps temporary records of roaming subscribers.
- IP databases in 4G networks are *Home Subscriber Services* (HSSs). These databases keep location information on roamers.
- Databases that store telephone identities and authentication codes for digital phones are located in the LTE core.
- *Messaging center* databases and processors handle Short Message Service (SMS) messages, which are short text messages. More advanced systems store multimedia messages including voicemail, facsimile, and e-mail. They also support the ability to access voicemail messages within e-mail inboxes.
- Billing databases called *Policy and Charging Rule Function* (PCRF) databases keep specific information on contract terms for each subscriber. The Packet Data Network (PDN) transmits usage records to the PCRF, which is connected to billing software.

Connecting Cell Sites and Core Networks

In addition to managing vast amounts of cellular traffic, carriers operate large landline networks between their cell sites and their IP core. The links between cell sites and equipment in their core are referred to as *backhaul*. Backhaul is also referred to as the *transport network*. Traffic from many sites is backhauled to a central location—the operator's core network. This network transports signals between base stations and core networks. Transport networks consist of links to mobile switches and other networks. From the core, traffic is sent to the operator's mobile central office switch, the

Internet, or another public data network. Depending on the amount of traffic, backhaul networks use the following:

- T1/E1 (1.54Mbps/2.05Mbps) on copper cabling
- Microwave (a Wireless Transmission Service at T1/E1) or T3/E3 (44Mbps/34.4Mbps) or Carrier Ethernet at speeds up to 1Gbps
- Gigabit Ethernet and Multi-Protocol Label Switching (MPLS) (multiple 10Gbps streams with MPLS-enabled QoS capabilities) on fiber-optic cabling

A backhaul network comprises the following:

- The access that connects cell sites in the same area together, before base station traffic is aggregated and transmitted to the core
- Aggregation networks that merge traffic from many cell sites and transmit it to the core network, as shown in Figure 7-6

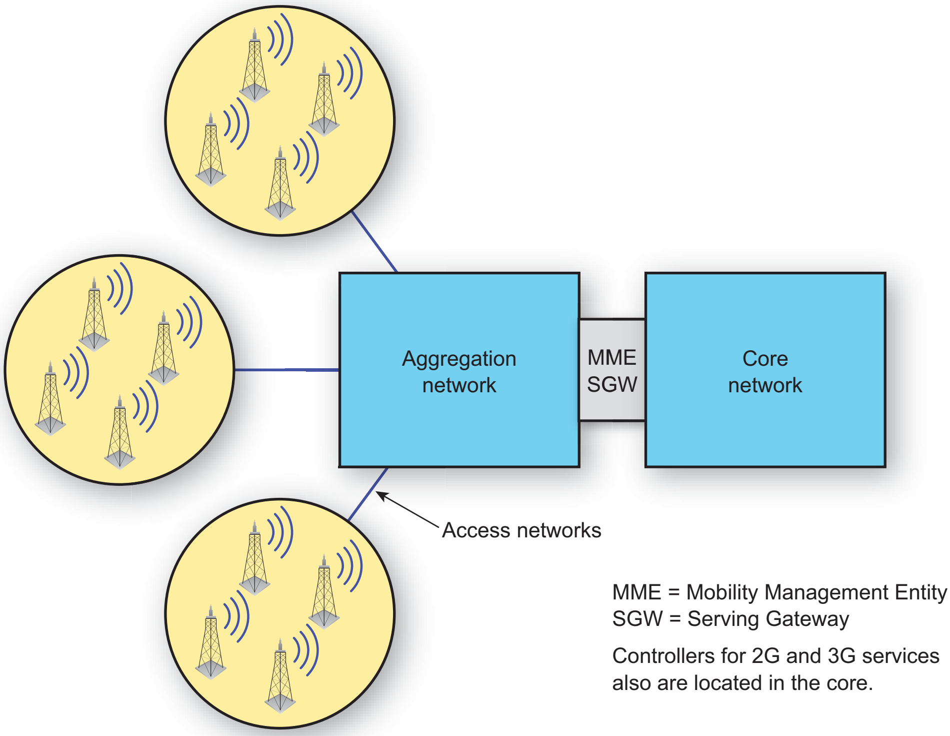

Figure 7-6 *The aggregation network consolidates traffic from multiple cells before sending it to the core.*

Traditionally, backhaul networks have consisted of between two and four T1 circuits carried over wireless microwave links. T1 technology is suitable for the predominantly voice traffic carried on 2G cellular networks. However, T1 service has inadequate capacity and is inefficient for transmitting the large amounts of data traffic generated by smartphones and tablet computers on 3G and 4G networks.

Worldwide, microwave is still the primary technology used in backhaul networks. New microwave services are available that transmit signals in IP packets using Carrier Ethernet. For more information on Carrier Ethernet, see Chapter 5, "Broadband and Wide Area Network Services." In addition, microwave has increased capacity and can now reach 1Gbps. Carriers, particularly those in high-traffic metropolitan areas, are upgrading to these new microwave technologies or to fiber-optic networks.

In the United States, AT&T and Verizon Wireless have upgraded much of their backhaul network to fiber. In Europe and in developing countries, most backhaul networks operate on microwave services. This is particularly true in the access portion of mobile networks because there is less fiber already in the ground in these areas.

Some of these networks use microwave in the access portion and fiber-optic cable in aggregation links. The higher costs for fiber are viable because more traffic is carried on these links. Fiber is likely to be more readily available in aggregation networks where carriers have previously laid fiber that often has spare capacity.

In many instances, the landline divisions of mobile carriers build these networks. When Verizon Wireless upgraded its backhaul network to fiber, it used the wholesale division of Verizon Communications to build it out. Verizon's wholesale division offers backhaul services on a wholesale basis to other providers in addition to Verizon Wireless. Cable Multiple System Operators (MSOs), AT&T, and other long-haul network carriers also provide backhaul links to mobile carriers. The traffic is transported on the same fiber that transmits traffic from landline carriers.

Cell Site Power Requirements

Regardless of the generation, every cell site needs local power for equipment at the site. Maintaining service during electrical outages is a critical issue and loss of power at cell sites is one of the reasons that mobile phones might not operate during disasters. However, not all carriers have adequate backup. Some have battery backup for momentary power glitches and short outages lasting only a few hours. Deployment of generators that operate for a few days is uneven.

The Functions of Radios and Modems in Mobile Networks

Every wireless device contains a radio. Radios in mobile networks extract radiofrequency signals from the air and convert them into small bits of frequency compatible with the devices. The radios then hand off slices of bits of data to modems within devices. At the transmitting end, radios convert signals to the frequencies used in the cellular network, and then transmit these wireless signals over the air.

At the receiving end, modems remove noise caused by interference and decode the radiofrequency data signals into those compatible with the landline network. If the amount of noise is so great that the signal can't be decoded, the modem requests that the base station retransmit the signals. Removing the noise from signals is the most complex function in modems. At the transmitting end, modems encode (modulate) the signals to make them compatible with the radiofrequency wireless network. Modems also add encryption at the transmission end for protection from eavesdroppers.

Software-Defined Radios

Software-Defined Radios (SDRs) have air interfaces based on software rather than hardware. The term "software-defined radio" was coined by the military and used in Europe and the United States throughout the 1990s. As it is used in mobile networks, the term is actually misleading because the radios are in fact based on hardware; only the modems are software-based. The military underwrote the cost to develop software-based radios and was willing to pay high prices for radio as well as modem functions in software. However, radios based in software are prohibitively expensive for commercial use.

SDRs, which are generally located within base stations in cell sites, enable carriers to support multiple air interfaces in a single radio. In addition to defraying infrastructure costs, carriers now can share cell sites because of the added flexibility of supporting multiple spectrum bands and air interfaces in a single base station. SDRs dramatically lower the cost of supporting numerous types of air interfaces and of adding new protocols. Without SDRs, each type of air interface requires hardware controllers in cell sites and a technician to manually install the hardware.

Air interface flexibility is an important factor that allows customers to use their mobile handsets when they travel. The speed at which the radio software completes operations is a factor in supporting handsets in automobiles and trains. Reliable cell phone operation when customers are moving at high speeds depends on a network's capability to support handovers between cell sites without dropping voice or data sessions. It also depends on networks that support many different air interfaces including 2G, 3G, and advanced 3G protocols such as High-Speed Packet Access plus (HSPA+) and High-Speed Downlink Packet Access (HSDPA). The advent of LTE, HSPA+, and Worldwide Interoperability for Microwave Access (WiMAX) increases the number of air interfaces that base stations, tablet computers, and handsets need to support. SDRs commonly support three air interfaces and five spectrum bands. There can be fewer air interfaces because the same air interface can be used on more than one spectrum band.

In addition to more easily being compatible with numerous mobile protocols, SDRs enable carriers to add new air interfaces without changing hardware. With radios that were manufactured in 2007 or later, these changes or additions can be made remotely without dispatching a technician. Eliminating the need to dispatch a technician saves money. If new spectrum is added, the antenna will also need to be changed.

Additional benefits of SDRs include lower manufacturing and power costs and improvements on interoperability between networks. When developers introduce new air interfaces, new chips are not required. Rather, new software is written and downloaded to carriers. Even utility costs are lower because SDRs require less power. This results in lower overall ongoing costs.

SDRs for Handsets, USB Modems, and Tablet Computers

Adding new air interfaces and supporting multiple air interfaces in handsets, USB modems (also referred to as *data sticks*), and tablet computers is a challenge for carriers. Each mobile device that a carrier supports must have radios compatible with the carrier's spectrum and air interface. It is more difficult to design cost-effective SDRs for handsets, USB modems, and laptops than for base stations. Consumer devices are smaller and require lower power consumption and lower prices.

Traditionally, radios and air interfaces in handsets and laptops have consisted of chips for each interface. This is changing as mobile devices are now available with air interfaces on software rather than hardware. Icera, Inc., located in Bristol, England, developed the first SDR for data-only modems. It designed a lower-power-consuming, low-cost Software-Defined Modem (SDM) by using generic, multipurpose reconfigurable processors rather than the larger, more power-hungry Application-Specific Integrated Circuit (ASIC) chips. ASICs are specialized chips built with the capability of many chips integrated within them.

Benefits for SDRs in handsets are similar to the benefits of SDRs at cell sites. Carriers that upgrade to more advanced protocols have the option to add the air interfaces as software transmitted over the air to the device. This flexibility can eliminate the requirement for carriers to purchase new handsets every time they add a new air interface. For carriers that subsidize customer devices, this is a major cost saving.

The capability to support fewer handsets also simplifies customer support for complex smartphones and tablet computers. The smaller size of SDMs also saves money by supporting multiple air interfaces without increasing the size of the device. Moreover, SDMs perform the complex functions needed to decode signals better than hardware-based modems, which are not as complex or flexible.

Innovation in SDRs for Devices

In January 2003, entrepreneurs who had experience designing chips for the telecommunications industry established a new chip company called Icera, Inc. They were able to raise the money they needed from venture capitalists who had profitted from the cofounders' earlier successes with startups. Simon Knowles, vice president of Strategy and DXP Technology and one of Icera's founders, stated that their thinking at the time was, "if we start now, we'll be ready the next time the industry is ready to buy."

The economic downturn of the early 2000s had dried up money sources for would-be competitors who had tried and failed to develop Software-Defined Radios. Thus, Icera, which was purchased by NVIDIA Corporation in 2011, was able to develop its chips and software before there was competition. Using multipurpose processors rather than more costly chips allowed it to keep the price of each chip at less than $5.

NVIDIA has a twofold strategy of marketing to mobile carriers as well as selling directly to device manufacturers who install the SDRs in their data sticks (USB modems) and other devices. Although mobile carriers don't buy directly from chip developers, before they purchase new equipment, they test it on their network. For this reason, manufacturers don't buy components for equipment until the carriers qualify them as compatible with their networks.

NVIDIA is negotiating contracts to have its chips installed in some of the 120 different types of tablet computers that it has determined are being developed or are available worldwide. It now has chips that support voice and expects those to be qualified by carriers for various handsets.

THE MICROCELL TECHNOLOGY OF PICOCELLS AND FEMTOCELLS

Picocells and femtocells are mini cell sites that are installed in residences, enterprises, arenas, and outdoor areas. Picocells cover larger areas, can handle more traffic, and were available earlier than femtocells. Femtocells are used in smaller sites such as homes. Both technologies provide relatively low-cost ways to add coverage inside buildings and at venues used for short-term services including athletic events and large conferences. Building owners rely on carriers to provide picocells and femtocells because only carriers have rights to spectrum used for mobile services. Picocells can cover about 5,000 square feet and femtocells about 2,000 square feet. Like traditional base stations, new picocells support multiple standards including third-generation (3G) and Long-Term Evolution (LTE) networks as well as multiple frequencies.

Picocells

Picocells are cell sites that cover larger areas and support a greater number of users (about 100) than femtocells (five or six). Depending on the size of the installation, the user or the carrier sets up and installs each picocell. For small installations, the carrier might mail picocells to the customer. Picocells are also referred to as *super femtocells*. Some picocells are automatically configured by the gateway at the carrier's data center.

Coverage within buildings has long been a challenge for mobile carriers. Large buildings, airports, concrete parking lots, and tunnels are particularly hard places for which to provide coverage. It's extremely difficult to penetrate walls without turning up power on antennas too high. The height of buildings also creates problems. Locating antennas higher up in the top floors of tall buildings provides coverage there, but the signal will be too weak to reach the street level. Picocells are one way to resolve these issues.

Hospitals and hotels, which need coverage for visitors, are prime examples of organizations that need additional cellular coverage within their facilities. A network of picocells or a distributed antenna system can solve the problem. Distributed antenna systems for in-building coverage are described in the next section.

Picocells within office buildings, hotels, or healthcare facilities consist of many base stations with antennas (picocells) located 300 to 900 feet apart. Picocells can be the size of a sheet of letter paper or as small as a Rubik's Cube. The picocells are connected to the location's wired broadband connection via its Local Area Network (LAN) for traffic back to the mobile providers. Traffic carried back to the carrier consists of Internet traffic and calls to people on the Public Switched Telephone Network (PSTN) or on other providers' mobile networks.

Picocells used for outdoor coverage can be attached to light poles and even low-rise buildings in densely populated areas with high concentrations of mobile traffic.

This solution is an inexpensive way to gain capacity by reusing a carrier's spectrum within a smaller area than that covered by larger *macrocells*. A macrocell site is a cell site with a larger antenna and a controller that covers a larger area and can handle more traffic. Picocells require local electricity and connections back to the mobile carrier's equipment.

Picocell Technology with Centralized Management Capability and Multisite Distribution

New systems for in-building coverage are suitable for enterprises that want uniform coverage for multiple sites. These systems have centralized controllers that track all mobile devices and manage the handover between antennas when employees move about the building. The local antennas and central controller are connected together by the LAN and by the enterprise IP network to smaller sites.

Using Distributed Antenna Systems for In-Building Coverage

Distributed Antenna Systems (DAS) are an alternative to picocells for coverage within buildings. DASs consist of *repeaters* connected to coaxial, twisted-pair, or fiber-optic cabling in buildings. A repeater amplifies cellular signals transmitted into buildings by equipment that the cellular carrier supplies. Repeaters are located throughout the building and transmit Radio Frequency (RF) signals to the macrocell. Unlike super femtocells, they don't actually offload traffic from the larger cellular network because they are not capable of reusing spectrum. They also are connected to building broadband services to offload traffic from a carrier's backhaul network.

DASs are also located in subway systems and sports stadiums for which traditional cell sites don't generally reach or provide adequate coverage. Building and transportation owners hire contractors to install the cabling over which the repeaters are connected and the signals travel. The carrier installs its own antenna that provides the cellular signals. In some of these systems, particularly public spaces such as subways and airports, multiple carriers are connected to the DAS.

For enterprises, gaining their carrier's agreement to connect to either a DAS or a microcell solution is a major challenge. Even large enterprises have experienced long delays in receiving permission or making upgrades to these in-building coverage installations. The advent of lower-cost solutions, more efficient spectrum re-use, and increased revenue from usage fees might provide the impetus to increase the speed and number of these implementations. Importantly, enterprises with in-building wireless systems are more likely to be "sticky" clients. They are less likely to drop their carrier after their investments of time and money in a DAS.

Deploying Femtocells for Improved Coverage

Femtocells are essentially miniaturized base stations on a chip that are designed to improve cellular coverage in homes, small businesses, and outdoor areas. A femtocell is a small device that plugs into the location's router so that the mobile traffic is transmitted over the customer's wired broadband connection. The main benefit of femtocells is improved indoor coverage where it is not uncommon for thick walls or electromechanical interference to disrupt cellular signals. Femtocells can also be used as a low-cost way for mobile carriers to fill in outdoor coverage gaps where they can be installed on telephone poles.

Femtocell gear within a customer's building consists of Access Points (APs) with integrated antennas. Technicians are not required to set up and install femtocells; they can be set up by the customer. The customer plugs the femtocell into a router, and then logs on to the Internet to identify the mobile phone numbers that are allowed to use the femtocell network. Setup at the carrier is highly automated. The access controller (gateway) located in the carrier's data center automatically configures the femtocell and sends the necessary billing information to the carrier's billing and maintenance system.

This automated setup is referred to as *zero touch provisioning*. It is a key ingredient in lowering the cost of adding coverage. In addition, the equipment itself is less costly than traditional, macrocell sites.

Femtocells in Carrier Networks

Femtocell traffic is routed within secure, encrypted software tunnels over a customer's broadband connections to a carrier's data centers. At the data center, femtocell traffic is routed by a gateway. The gateway removes the surrounding bits in the tunnel and sends the femtocell traffic to the carrier's core network. The gateway transmits traffic from thousands of femtocells either to the Internet or, for voice calls, to the mobile switching center. Femtocell traffic bypasses base stations as well as the backhaul facilities that carry traffic to the core network.

For mobile networks located in high-traffic metropolitan areas, the capability to bypass base stations and the backhaul network is a major advantage, because many of these backhaul networks are becoming congested with high-volume data traffic. The importance of femtocells is reflected by the fact that the 3rd Generation Partnership Project (3GPP) fourth-generation (4G) Long-Term Evolution (LTE) standard includes usage of femtocells for additional coverage. This standard specifies the way gateways and femtocell access points interface with one another as well as security and provisioning.

A key enabling technology that makes femtocells feasible is the improved software algorithms that detect signals from macrocells. Because of the small area covered—about 5,000 square feet—most of the traffic is located at the edge of the cell. Traffic at the edge of the cell has the potential to interfere with frequencies in macrocells because signals can "bleed" into surrounding areas. Improved software algorithms in femtocells have the capability to sense both the frequencies and the power levels in the microcell, and adjust them as required so that the femtocell signals don't interfere with the macrocell traffic. According to Dr. Andy Tiller, senior vice president of Product Management and Marketing for Cambridge, England–based femtocell and picocell maker ip.access:

> *ip.access's femtocells and picocells can sense the radio conditions in adjacent cell sites before they start transmitting. This so-called "Network Listen" scan enables the femtocell to, for example, raise its power if the signal from the surrounding macrocell is strong, or conversely, reduce its power if the signal from the macrocell site is weak. This decreases interference and improves voice quality and data speeds for mobile users in the vicinity—both those served by the femtocells as well as those in the surrounding macro network.*

HANDHELD DEVICES AND TABLET COMPUTERS.....

Handsets and tablet computers are a major expense when upgrading cellular networks, but they are an important marketing tool for attracting status-conscious customers. All networks require handsets with chips compatible with their air interfaces. The majority of carriers in the United States subsidize handsets that they sell to subscribers as an incentive to use their service. A carrier might pay $350 for a handset that it offers to customers for $250. The rationale is that ongoing usage revenue will offset the initial handset costs and that customers will gravitate to operators offering newer, more desirable handsets. Radios in handsets must also match the frequencies used in networks.

Multiband Handsets versus Multi-mode Handsets

Handsets that operate in more than one frequency band have *multiband* capability. Those that operate on 800MHz and 1.9GHz frequencies are dual band. Devices that operate on multiple air interfaces—Code-Division Multiple Access (CDMA), Global System for Mobile Communications (GSM), as well as various third-generation (3G) and 4G standards—have *multi-mode* as well as multiband capabilities. Multi-mode devices are also referred to as *multistandard*. Because carriers often have networks made up of two or more frequencies and air interfaces, it is important that handsets and data devices operate in more than one set of frequencies and air interfaces. Customers need handheld devices that match both the air interface and the frequency for compatibility throughout the carrier's network. Also, when networks are upgraded to next-generation, 3G, or 4G services, they might be deployed in pockets of the network and need to fall back to the lower-generation services for continuity. In addition, people who roam to other networks might need multiband and possibly multi-mode handsets.

Multiband Devices

Each handset needs to be designed to operate over specific frequencies. As mobile telephony grew in popularity, countries expanded the amount of spectrum available for the service. In doing so, they opened new frequencies for voice and data service. The European Union decreed that all countries in the Union use the same frequencies. Thus, European countries provisioned GSM in the same portions of the airways and manufacturers developed multiband devices compatible with the frequencies that were allocated. Most GSM phones are either dual- or triple-band and are capable of operating on various GSM frequencies, including 900MHz, 1.8GHz, and 1.9GHz, as well as 2.1GHz and 2.6GHz 3G and 4G protocols.

In the United States, carriers such as AT&T Mobility and Verizon Wireless offer multiband handsets for lower 700MHz and 800MHz frequencies and higher 1.9GHz frequencies.

Multi-mode Devices

Most digital mobile handsets are tri-mode or quadruple mode. Tri-mode phones operate with three air interfaces; for instance, GSM, Wideband Code-Division Multiple Access (WCDMA), and High-Speed Packet Access (HSPA). Quadruple phones operate with four different air interfaces, such as GSM, WCDMA, HSPA, and LTE. When callers are in GSM areas, they lose speedier Internet access and other advanced features associated with 3G and 4G cellular service.

Managing Security and Billing for Mobile Devices in Enterprises

Many enterprises pay for the mobile devices that employees use to check their e-mail and access enterprise applications remotely. These are seen as legitimate business expenses that enable employees to be productive in more locations, for extended periods of time. In the past, enterprises have specified the types of mobile devices that they would subsidize. Often these were BlackBerry devices. This was because Research in Motion (RIM), the manufacturer of the BlackBerry smartphone, offers an e-mail server that has strong encryption and integrates with Microsoft Exchange for e-mail and the ActiveSync protocol. It is also compatible with Cisco Systems's IPsec VPN for secure access to enterprise files and applications. IPsec is a security protocol that creates an additional layer of security during remote access to corporate files. In addition to secure access to corporate e-mail, it also enabled the device to automatically synchronize e-mail and applications such as calendars with corporate servers.

The BlackBerry is still a widely used smartphone for corporate applications. But, employees now often bring their own personal tablets and mobile handsets to work. In addition to accessing e-mail, they also often require access to corporate files stored on intranets. This creates security risks because not all of these devices support encrypted access or IPsec VPNs. For more information about VPNs, IPsec, and intranets, see Chapter 6, "The Internet."

Another issue in supporting mobile devices in corporations is managing the billing and support for mobile services. Support involves negotiating contracts with providers, correcting billing errors, ensuring that employees who leave the company turn in their handsets, and replacing damaged or out-of-date devices. It also involves the ability to remotely kill (disable) or lock lost or stolen mobile equipment and wipe sensitive data from their memory. All of this entails enormous amounts of staff hours, help-desk time, and expertise.

To ensure security and streamline these operations, companies are outsourcing the management of the billing and procurement process. They are additionally acquiring servers that support encryption and integration with Microsoft's e-mail and synchronization for many types of operating systems and devices, including Google's Android, Apple's iOS4 and iOS5, Microsoft's Windows, and RIM's BlackBerry operating systems. They additionally can be used to manage the distribution and security of apps made especially for enterprises.

Servers that support multiple operating systems are referred to as *multi-platform mobility solutions* or *enterprise mobility platforms*. Organizations have the option to obtain these platforms from a single vendor such as Good Technology or from two developers. One might offer a server to manage security and integration with Microsoft Office software.

The other vendor would manage provisioning, contract negotiations with mobile carriers, help-desk support for assistance with malfunctioning devices, and mobile carrier billing issues. Provisioning refers to the process of ordering a mobile handset from the mobile carrier, delivering it to the employee, and, depending on organizational policy, providing choices of handsets. In either case, the multi-platform mobility system can be integrated into an organization's Local Area Network (LAN) or located at a service provider in the cloud.

In addition to all of this, antivirus software is now available for mobile devices and tablet computers as well as laptops and desktop computers. Often, small organizations that don't manage and subsidize mobile devices for employees require that their employees install antivirus software and encryption on any mobile devices they use for work functions.

Killing Lost or Stolen Portable Computers by Using the Global Positioning System

A major source of security lapses occurs when corporate laptops and smartphones such as a BlackBerry are lost or stolen. Confidential corporate information and private e-mail messages are often stored on these devices. Currently, mobile carriers have the ability to remotely disable mobile handsets, laptops with cellular cards, and tablets when corporations report them lost.

Global Positioning System (GPS) chips within these devices enable organizations to locate them so that data can be deleted or the device can be locked. For the carrier to locate a device, it must be turned on and within the carrier's coverage area. Many mobility management platforms have this capability, as well.

Killing and locating lost devices is enabled in 3G networks. These networks depend on GPS to synchronize the timing in their networks so that signals arrive at their destination only once, and for other functions that require precise timing. GPS-equipped mobile networks can be used to provide location information, as well. Location-based applications that use GPS include applications that give parents the ability to track their children's locations and to find friends who are in the area. 4G networks also have GPS capabilities.

The Driving Force of Smartphones

A smartphone is a handheld mobile device that can be used for voice as well as data applications such as e-mail. It is essentially a mobile handheld computer capable of being used for voice calls. The first widely used smartphone was RIM's BlackBerry. In 1999, the BlackBerry was the only smartphone used by business people. The BlackBerry appeals to businesses because of the BlackBerry server's security features, including its capability to strongly encrypt transmissions.

In 2007, Apple introduced the iPhone. It was the first smartphone that was adopted by both consumers and business people alike. It created a seismic shift in handset designs, and fueled the demand for touchscreens and sleek, easy-to-use user interfaces. The icon-driven main screen made using the phone highly intuitive. The iPhone, which was initially available exclusively from AT&T Mobility, created a sensation and the device became a status symbol. It also created enormous traffic jams on AT&T's network as people used their iPhones for e-mail and functions such as the continuous updates of stock market ticker tape. AT&T Mobility stated that traffic on its network increased 5,000 percent in the first three years that the iPhone was available.

Following the success of the BlackBerry and iPhone, other manufacturers have introduced their own smartphones. Some of these new devices use Google's Android operating system. Unlike the iPhone, which is manufactured under the strict direction of Apple, Android-based phones are made by a variety of manufacturers such as Samsung and Motorola Mobility. Some are positioned for consumers who want a less costly handset than the iPhone; others are targeted at consumers who want higher-end handsets. In addition, they are not sold under exclusive contracts to a limited number of carriers. For these reasons, plus publicity about incomplete calls due to congestion on AT&T's network and lower prices for Android-based phones, the sales of phones running Google's Android operating system have surpassed iPhone sales.

The advent of smartphones offers revenue opportunities from data applications as well as network challenges to carriers. Smartphone users now expect the same level of service for video and e-mail on mobile devices as they experience on desktop and laptop computers. They bring attention to the potential of mobile networks and to the need to upgrade them to keep up with the pace of data usage.

Touch-screen Technology

A Swedish company, Neonode Inc., introduced the first touch-screen mobile phone in March 2002. This innovative device had a 2-inch screen and used a different technology than that employed by Apple. Neonode's patented technology projects infrared beams in an invisible grid over the screen. Finger locations are detected as the beams are crossed. These screens respond to touch, finger motion, and stylus inputs.

Neonode's phones were not widely adopted. In response, the company changed its business model from selling phones to licensing its screen technology to other companies. Neonode's technology can be used outdoors without glare. And it is for this reason that Sony selected it for its e-readers. It is also used in ATMs. For now, the technology is too costly for mobile phones, but Neonode is working on ways to lower its cost to make the technology viable for small, portable devices.

Apple uses what is called *capacitive technology* for its touch screens. This technology is used for BlackBerry devices, HTC Android phones, and Motorola Mobility's touch screens, as well. Capacitive touch screens use the inherent electrical properties of human fingers to determine where on the screen a user is touching. This is why nonelectric inputs such as a stylus or a hand in a glove cannot be used for input on these devices.

A third touch-screen technology is called *resistive*. It consists of two sheets of coated material separated by microdots, each with horizontal and vertical lines. When the sheets are pressed together, the exact location of the touch is determined by the lines of the two sheets coming in contact with one another. Because this technology is non-electric, it can be used with a stylus as well as a hand touch. This is less costly than capacitive technology. Resistive technology is not as satisfactory for hand input, because users need to press down on the display with greater force to elicit a response.

Battery Life

Because mobile devices are multifunctional, portable, and easier to use, people are more dependent on them for their voice and text communications as well as social networking, music, and increasingly, video, as well. They also use these devices on Wi-Fi networks and for video conferences.

Data applications require more power from the device. Bandwidth-heavy applications such as Internet access, video, and e-mail drain batteries more quickly than voice calls. This is because voice requires fewer bits to transmit than does data. In addition, large color displays drain batteries more quickly than the less-sophisticated screens on earlier devices. Thus, as people become increasingly dependent on mobile devices for more functions, it is important to find ways to extend battery life.

Currently, mobile devices, including smartphones and tablet computers, use lithium-ion batteries. Although there is ongoing research into improving battery life, there are no breakthroughs expected in the near future. But, this does not mean that manufacturers are not looking at other ways to provide longer battery use.

A current focus is on ways to design mobile handsets that use power more efficiently. One such technology, developed by QuickLogic, extinguishes screen backlighting when it is not required. The QuickLogic technology senses ambient lighting to determine when backlighting is needed. It maintains color by creating brighter color pixels so that mobile devices don't draw current from backlights in daylight.

Another way that manufacturers design handsets to improve power management is by including automatic sensing circuitry that shuts down memory, processors, and peripherals when a handset is not transmitting. For example, if the user is not in a Wi-Fi zone, the Wi-Fi circuitry is disabled so that it does not draw power when it can't even be used. Most smartphones and tablet computers include this form of power management. Other manufacturers are developing new screen technologies that consume less power.

In addition to research on display screens, batteries, and power management, companies such as Qualcomm are developing more convenient ways to charge phones. It is in the process of developing a magnetic tray on which people can place multiple wireless devices for automatic charging without plugging the device or the magnetic tray into an electrical outlet. So, instead of tossing a phone in a kitchen drawer or on a dresser in the evening before going to bed, users would be able to simply place it on a tray and have a fully charged device waiting for them in the morning.

Charging mobile devices gradually wears down the battery and shortens its life. Over time, batteries hold charges for shorter amounts of time. This is because every charge deposits chemicals on the device's contacts. These chemicals corrode the contacts creating resistance to the charge. A lithium-ion (Li-ion) battery experiences corrosion in a different manner, but it, too, becomes resistant to charges. Thus, less voltage reaches the circuitry that carries the current to the battery. Voltage refers to the "pressure" of the electricity flowing through the handset's circuits. Low "pressure" or voltage means that less electricity is reaching the battery.

Tablet Computers and the Increasing Amount of Traffic They Generate

Tablet computers are another source of increased data traffic on mobile and Wi-Fi networks. Despite its relatively high price, Apple's iPad tablet computer was an immediate hit when it was introduced in 2010. The iPad's success spurred other manufacturers to offer their own tablet computers, such as Samsung with its Galaxy tablet. Tablets can be purchased directly from carriers as well as through retail outlets.

Tablet computers have the potential to add considerable traffic to networks, create significant changes in computing, and have the potential to replace laptop computers as the second computer in many homes. Their small size also makes them easy for mobile employees to take with them when they travel. As a result of their design, tablet computers have smaller storage capacity compared to most laptops. This restriction in conjunction with their greater portability means it is more likely that people will depend more on cloud-based storage and applications such as those from Google and Microsoft for word processing, spreadsheet creation, and graphics for presentations. Storing documents in a provider's network enables users to access and edit files that were perhaps created on desktop computers from any network-connected device.

This provides access to more files on a mobile basis than can be stored in a single tablet computer. Moreover, edits and documents can be accessed from desktop, laptop, and tablet computers, regardless of which device was used to create or edit them. Thus, computing tasks previously accessed on a single desktop or laptop computer can now be accessed over internal, wide area, mobile, and landline networks.

At the enterprise level, centralized applications and documents will be located in either the organization's own centralized data center or at a provider's data center. In both cases, employees will access the applications and files over landline or mobile networks.

Tablet computers are additionally important because they make video conferencing, streaming movies and TV, and viewing photo slideshows from mobile devices more compelling. The improved resolution and larger screens—particularly when compared to smartphones—make tablet computers true multimedia devices. Improvements in home and enterprise wireless LANs as well as higher capacities on mobile networks facilitate the use of tablet computers as multimedia devices.

APPLICATIONS AND SERVICES

Applications on mobile devices attract customers, generate revenue, and are a tool for retaining customers.

Applications on Smartphones and Tablet Computers

Applications for mobile devices, or *apps* as they are commonly known, are small software programs developed to be used outside of browsers. Users start an app by tapping its icon with their finger. Apps are developed to accomplish specific, narrowly defined functions. Popular categories include games, comparison shopping, video and music (Pandora radio), and useful applications such as weather information and cooking.

There are also a growing number of applications for enterprise productivity. Productivity apps for vertical markets target industries such as insurance, delivery, equipment sales, and healthcare. Applications include those for managing mobile employees, providing salespeople with data, references that enable doctors with smartphones to look up drug interactions, and others that enable doctors to access patient lab results.

Most apps operate only on particular models of phones and operating systems. Verizon and Apple have App Stores that offer apps specific to the devices they support. Verizon's is for its Android and RIM handsets. Apple and Verizon screen all of the apps for their devices and select those that fit their criteria. Their model is considered a "closed garden" because of their restrictions to only applications they approve. Apple operates its App Store independently of AT&T. It does not currently share revenue from mobile apps with AT&T. Both Apple and Verizon share revenue from applications with app developers: 30 percent for Apple and Verizon, and 70 percent for developers. Verizon bills customers directly for apps that they download.

In addition to apps for particular operating systems and hardware, there are also cross-platform mobile apps. These can operate on multiple operating systems and hardware devices. Large, multinational mobile operators such as Telecom Italia Mobile and Telefónica offer cross-platform app stores for mobile apps that operate on the hundreds of different devices in the various countries in which they offer service. They do this by providing a software interface called an Application Programming Interface (API) that translates data between the mobile application and the particular operating systems and mobile devices.

Apps as a Strategy to Retain Customers

Mobile apps help carriers cement relationships with customers even as they provide revenue. The rationale is that customers will be reluctant to move to other carriers if it means that they lose their mobile apps. For example, Telefónica is in the process of having social networking software developed that will enable its customers to access mobile apps from within social networking sites. It is hoped that the close association between the mobile apps and the carrier will enhance the customer's relationship with Telefónica.

Worldwide Mobile Apps Compatibility

Currently, computer owners can move their documents and most of their applications when they upgrade their computers. Applications that are not compatible with a new computer can generally be upgraded with minimal effort. Downloading music and PDF files from the Internet works seamlessly on most computers. This is not the case with tablets and smartphones for which apps are not portable and most often are designed to work only on particular operating systems. Therefore, such files can't be moved to new phones that use different operating systems. They are not necessarily portable between operators either.

The *Wholesale Applications Community* (WAC) organization hopes to change this by establishing a uniform core set of standards for interfaces between applications and operating systems. It hopes that adherence to these standards will result in applications that can be used on a large variety of platforms and globally in many operators' territories. The organization was established as a nonprofit in February 2010. In addition to its first version of a technical standard, WAC 1.0, availability of a second version, WAC 2.0, was announced. To date, eight carriers including China Mobile, Telefónica, and Verizon are connected to the WAC platform. One of the APIs is a standard way for developers and carriers to bill for apps.

The membership of WAC is made up of the largest carriers in China, Spain, Germany, France, Japan, Italy, England, the United States, Canada, and Latin America. According to WAC, carriers will have the advantage of streamlined support. They will be able to support one App Store for all of their devices and operations, worldwide. This will simplify the number of different applications for which they will need to screen, price, and provide customer service. Equipment manufacturers and application developers have also joined the WAC community. Developers will have the advantage of being able to develop applications that can be used worldwide, rather than having to support each different operating system and device. The same compatibility applies to manufacturers' equipment.

Mobile Banking Transactions and Payments

In addition to running apps, mobile handsets can be utilized for mobile banking and financial transactions. These mobile applications include the following:

- **Payments for mass transit** User can pass their smartphone near a reader to pay for subway, bus, and train transportation instead of using tokens or purchasing monthly passes. Apps on mobile phones can take advantage of a short-range wireless technology called Near Field Communications (NFC) to interact with the reader. The user simply needs to pass her phone within 1.56 inches (4 cm) of the payment reader.
- **Check deposits** Smartphone apps use the device's camera to take a picture of the check and then transmit the image to the user's bank for deposit.
- **Money transfers directly to a mobile phone in a developing country** When a relative or friend sends money to a person in a developing country via Western Union, the electronic cash is sent directly to the receiver's handset. MoreMagic, a Massachusetts software developer, created this application.
- **Mobile wallets** Customers to whom money has been transferred via MoreMagic's app can use the electronic cash on their handsets to prepay for cellular airtime, send cash to others, or convert the electronic currency to cash through an authorized agent.
- **Online payments** People surfing the Internet on their smartphone can make online purchases through PayPal rather than having to type in their credit card number along with their name, postal address, and e-mail address.

All of these apps require some type of software platform that sits between credit card processing companies or banks and the mobile network. The platform must have integrated security protocols and the ability to communicate with the financial institutions that process payments. They also need to communicate with servers at merchants' sites and devices that act as "readers" of the mobile device making the transaction.

Each mobile handset and reader requires chips with NFC capability. The cost of these readers is often a stumbling block for retailers because they need to place one at every cash register. Alternatively, readers can be embedded in portable devices that sales associates use to process credit card sales. Another challenge for retailers is that there is no agreed-upon standard software platform. Thus, different chips are required for each platform because different carriers and mobile operating systems might adopt different software.

Using a mobile handset as a substitute for a credit card for bill payments and other transactions is particularly meaningful in developing countries where, for the most part, the population does not have bank accounts for access to checks or credit cards to pay bills. Rather than using traditional payment methods of this type, these consumers are able to use their mobile handset.

Machine-to-Machine Communications—between Devices with Embedded Radios

Machine-to-machine (M2M) mobile services refer to services that automatically monitor the status of other systems or send software updates to devices. An example of an M2M service is a central system that monitors vending machines remotely to determine inventory levels and diagnose possible problems. Another example of M2M traffic is automatic monitoring of residential electric meters.

Both of these applications require software platforms and radios at customer data centers as well as software and radios in the device to be updated or managed. Software is required in the vending machines and meters that are able to connect to a mobile network. However, these upgrades might require large investments. This is true when new software is added to a utility's meters. There is a potential to save on operational costs by eliminating the need for technicians to manually read the meters. It also has the potential to enable utilities to use energy more efficiently by monitoring the grid and adjusting power distribution accordingly.

These transmissions are carried over a mobile carrier's second-generation (2G) or third-generation (3G) networks. Currently, most are transmitted on 2G networks, which are ubiquitous. Moreover, many of the current applications do not transmit enormous amounts of data. Newer M2M applications such as video streaming, video security, in car systems, and other complex applications will require capacity provided by 3G and fourth-generation (4G) cellular protocols.

M2M applications represent a revenue opportunity for mobile carriers. One reason why is that there are many more machines than there are end users, and many machines now include software that can be upgraded for over-the-air diagnosis and updates. Automobiles are examples of systems that contain more and more software, including in-car entertainment systems that require automatic over-the-air updates. Many high-end and even moderately priced cars include options for touch screens on dashboards to activate various networked functions and entertainment systems. These include in-car Wi-Fi hotspots for passengers, outside sensors and rear view cameras to assist in parking, and embedded GPSs. As these in-car systems become accepted and increasingly sophisticated, prices will drop and they will become even more widely available.

Another advantage to carriers of M2M service is ease of support. Currently, carriers operate large customer service centers for responding to questions about billing and technical issues. Customer service for M2M service is lower than that for handsets because inquiries and customer service requests will only be required for the centralized staff members who manage these applications for customers.

The Wholesale Model for Downloads and Software Updates

Certain M2M applications for consumer devices involve a wholesale model by which companies that supply services to consumers contract for service with a carrier. A prime example is downloading e-books to e-readers. When consumers purchase a Kindle from Amazon or a Nook reader from Barnes & Noble, their e-book purchases are transmitted over a mobile operator's network. In these instances, book retailers contract with a carrier such as Sprint Nextel for electronic book downloads. There is no contract between the consumer and a carrier for the electronic book downloads. These types of applications are known as business-to-business-to-consumer (B2B2C). The actual transactions are between two businesses, but the service is provided to consumers.

Another application that uses a wholesale transaction involves car manufacturers paying carriers for subscriptions that automatically send over-the-air software updates to cars. An over-the-air update is one that can be sent to a car and implemented automatically without requiring a manual update at the dealer. As automobiles include more computer-driven functions—particularly electric vehicles—software updates and software maintenance will become more critical and sophisticated.

All M2M transactions require software applications that synchronize the transaction with the device, schedule the transaction, and perform authentication and security functions.

Using Prepaid Mobile Services

Prepaid wireless services are those for which customers pay in advance for mobile voice and/or data services. Prepaid service is most widely offered to customers who do not have credit and who pay cash for service. They "top off" their service, making additional payments when they need more minutes. This contrasts with the postpaid cellular model by which customers are billed for and pay for services *after* the end of the monthly billing period. In the United States, MetroPCS offers only prepaid service. Customers give MetroPCS a credit card number that MetroPCS bills every month. It offers no postpaid services. Other mobile providers in the United States rely on postpaid customers for the bulk of their revenue, but many offer prepaid as a way to round out their offerings.

Worldwide, prepaid users outnumber those with postpaid plans. With postpaid plans, customers receive monthly bills and often sign one- or two-year contracts for their service. According to UK-based research firm Ovum, prepaid connections made up 75 percent of the total worldwide user base in 2010. This statistic was published by *Rethink–Wireless* in a January 12, 2011 article by Caroline Gabriel titled "Shift to Prepaid Will Need New Back Office Systems."

The consumption of prepaid service is particularly high in developing countries. For instance, at MTN Nigeria, more than 90 percent of its subscriber base uses mobile prepaid for their service. Similar patterns apply to India, Bangladesh, and many African countries. Average monthly payments in rural areas of India and Bangladesh are $2–$3.

Prepaid services are not limited to low-priced devices and low monthly minutes of usage. Carriers are also starting to introduce prepaid as an adjunct to postpaid services. For example, a subscriber might have an unlimited plan for voice and text messaging but pay-as-you-go plans for data. Some subscribers who have Wi-Fi-enabled tablet computers might only need to purchase data service during months when they travel or plan to be in locations without free Wi-Fi. In addition, parents might want to purchase prepaid voice or data services for teenagers or even themselves as a way to control monthly mobile expenses.

The advantages for carriers are mainly the elimination of the costs associated with issuing bills and collecting overdue payments. For some carriers, it's a way to attract lower-income or immigrant customers who don't have credit. In countries where mobile penetration is high and most people already have existing postpaid service, prepaid is another way to add customers.

Prepaid services are offered both on a retail and wholesale basis. Sprint Nextel has four different prepaid product lines that it offers in addition to its postpaid offerings. Other prepaid companies such as America Móvil's Straight Talk sign interconnect agreements with carriers such as AT&T who it pays to carry prepaid traffic in the United States. America Móvil is headquartered in Mexico and offers service throughout Latin America. Straight Talk is its mobile virtual network operator. It resells prepaid on other carriers' networks outside of its own coverage area.

Whether purchasing prepaid directly through a carrier or through a reseller, customers are connected to a prepaid platform, which authenticates their device and tracks usage to determine either whether to charge a credit card or if the subscriber's amount of time or usage has been used up. The prepaid platform is connected to the carrier's core mobile network. Wal-Mart sells prepaid services using Straight Talk's prepaid platform.

WI-FI STANDARDS, ARCHITECTURE, AND USE IN CELLULAR NETWORKS

Wi-Fi networks first became prevalent in homes, where the savings that result from the elimination of running unshielded twisted-pair (UTP) cabling appealed to residential consumers. Companies, too, rely on these networks due to the proliferation of laptops, tablet computers, and mobile employees, as well as improvements in security and capacities. In addition, some mobile carriers are now using Wi-Fi technology to supplement their cellular capacity.

The 802.11 Standard, WLAN, and Wi-Fi

The designation 802.11 refers to the family of Institute of Electrical and Electronics Engineers (IEEE) standards around which most Wireless Local Area Networks (WLANs) are built. Recall that Wi-Fi is short for wireless fidelity. "WLAN" is a generic term applicable to any wireless LAN technology. Because 802.11 is the dominant WLAN technology, people use the terms "802.11," "Wi-Fi," and "WLAN" interchangeably. Table 7-2 lists the commonly installed 802.11 network protocols.

Table 7-2 *802.11 Wireless Local Area Network (WLAN) Standards*

Standard	Top Speed	Achievable Speed	Number of Channels*	Frequency Band
802.11a	54Mbps	25Mbps	24	5GHz
802.11b	11Mbps	5Mbps	3	2.4GHz
802.11g	54Mbps	12- to 25Mbps	3	2.4GHz

**The number of channels varies internationally.*

The 802.11 Standards

The standards presented in Table 7-2 refer to the frequencies, speeds, and number of channels in each Wi-Fi standard. Other 802.11 standards that specify capabilities such as security, Quality of Service (QoS), and internetworking with cellular networks are listed in Table 7-5 in the "Appendix" section at the end of this chapter. Wi-Fi networks in enterprises commonly support all three of the standards. Lower-priced equipment with only 802.11b and 802.11g is also sold to enterprises. Because they are less robust, are less expensive, and support fewer devices, home Wi-Fi networks generally only support 802.11b and 802.11g.

The frequency of a signal impacts its range (how far it is able to travel). Signals in lower-frequency bands travel farther than those in higher bands because these waves are longer (refer to Figure 7-1). The 802.11b and 802.11g standards cover a range of about 100 to 150 feet; 802.11a covers only about 75 feet. Because they cover smaller areas, networks that utilize 802.11a antennas require more antennas. Equipment that supports both standards is referred to as dual-band equipment. As its name implies, dual-band equipment supports two frequency bands.

The higher speeds achieved by 802.11a and 802.11g are possible because both are based on Orthogonal Frequency-Division Multiplexing (OFDM). This is because OFDM sends multiple streams of bits simultaneously. See the section "The LTE and WiMAX Orthogonal Frequency-Division Multiplexing Air Interface," earlier in this chapter, to read more about OFDM in LTE and WiMAX networks.

The following factors impact achievable speeds.

- Network congestion.
- The distance from antennas.
- Overhead, which is the number of bits required in packet headers for information such as addressing and error correction.
- Interference from thick walls or other material. These factors can also decrease range.

Worldwide, the number of channels available in each standard varies. When governments set requirements for the number of channels that can be used for each standard, they do not always do it uniformly. The standards themselves often define flexible requirements.

802.11a: Higher Speeds, Smaller Coverage Area, and More Channels

For the most part, 802.11a equipment is sold to enterprises that want greater capacity because it supports more simultaneous users per access point (antenna plus transceiver). This is the result of 802.11a having 24 channels rather than only three. Another advantage beyond capacity is that the 5GHz frequency is less crowded with devices that also operate on 2.4GHz, such as microwave ovens and mobile devices equipped with Bluetooth. These devices can cause interference with Wi-Fi equipment on the same 2.4GHz band. Enterprises that use 802.11a need to equip employee laptops with 802.11a network interface cards or chips to take advantage of the extra capacity. The 802.11a standard is available in access points sold to residential consumers, but often at higher prices than those with only 802.11b and 802.11g.

The Longer Range and Higher Capacity of 802.11n

The 802.11n standard is a Wi-Fi standard that is backward compatible with 802.11a, b, and g networks. It enables WLANs to cover longer distances by overcoming a certain amount of interference. It also increases achievable speeds, increases throughput (user data minus packet headers), and supports more users per access point. Improvements in spectral efficiency—the number of users supported in a given amount of airspace—are critical as the number of users and applications on WLANs increases. This is particularly true in networks in which more employees use tablet computers and in homes that stream video from the Internet for viewing on High-Definition Televisions (HDTVs). Wi-Fi equipment for consumers and enterprises generally includes 802.11n.

The Spectral Efficiency in 802.11n Antennas

Improvement in antennas is the reason 802.11n uses spectrum more efficiently and overcomes many “dead spots.” A dead spot is an area that access points don’t cover because of interference from building materials or the distance from an antenna. The 802.11n access points use Multiple-Input Multiple-Output (MIMO) technology. Like MIMO antennas used in advanced cellular services, MIMO antennas in Wi-Fi networks simultaneously transmit multiple streams at different frequencies within a single channel.

The four types of MIMO antennas are classified by the number of transmit and receive antennas installed within access points and user devices.

- 2×2 antennas have two transmit and two receiver antennas.
- 2×3 antennas have two transmit and three receiver antennas.
- 3×3 antennas have three transmit and three receiver antennas.
- 4×4 antennas have four transmit and four receiver antennas.

Routers with more antennas support higher capacity and speeds. To achieve the highest speeds and capacity, user devices as well as access points must have an equal number of antennas.

The increasing capabilities of Wi-Fi networks have resulted in greater dependence on wireless networks. This is particularly true in mobile environments such as hospitals, factories, and educational institutions. In addition, staff members in organizations now assume that they can take advantage of wireless access for tablets and smartphones during meetings, at lunch, and wherever they are within their building or within their organization’s campus.

WLAN Architecture in Enterprises

All WLANs have base stations (access points) and user radios (which are also referred to as the user interface). The air interfaces used in the base station must be compatible with that in the user device. In addition, networks with multiple base stations often have controllers that direct traffic to particular access points. Central monitoring software can be used to remotely change access point configurations and monitor traffic on the wireless network.

User Devices

Wi-Fi chips are embedded within a growing number of computers, handsets, and remote monitoring devices, such as the following:

- Laptops
- Cellular USB modems
- Cellular smartphones, and other handsets
- Tablet computers
- Set-top boxes connected to HDTVs for streaming TV and movies from the Internet; for example, Roku and Apple TV
- Printers
- Low-power medical devices used to monitor conditions remotely; for example, blood pressure and glucose monitors

Remote monitoring devices connect wirelessly to the broadband service within a home or building. Within enterprises, remote monitoring devices connect to the LAN backbone. The broadband circuit transmits information to a central location.

Access Points

An access point has an antenna and chips with 802.11a, 802.11b, 802.11g, and 802.11n radios. Access points also translate between radio frequencies and Ethernet signals on cabled networks. An access point has similar functions to base stations in cellular networks. Access points for the residential market also include routers and switches with ports to which Ethernet cables can be connected. The router functionality aggregates traffic and sends it to the Internet via dial-up, Digital Subscriber Line (DSL), and cable modems.

Access points for corporations are more expensive and feature-rich than those sold to residential customers. Some contain security capabilities, such as intrusion detection, the ability to detect hacker attacks, and Quality of Service (QoS) needed for voice and video. There are also robust access points for outdoor locations that are made to withstand harsh environmental conditions.

Cabling and Electrical Requirements

In a similar manner to cellular networks, Wi-Fi networks require wired connections to switches, controllers and data centers, and electricity for access points. Access points in organizations are connected to the LAN via a data jack and, from there, an unshielded twisted-pair (UTP) copper wire connection to the local wiring closet. Electrical and cabling requirements represent an often overlooked cost in implementing WLANs. The power each access point requires can be located remotely in wiring closets on each floor or locally by nearby electrical outlets. For local power, new outlets might be needed.

WLAN Controllers

For the most part, WLANs in small and midsize organizations have controllers that manage access points and monitor the network. Until recently, all Wi-Fi traffic was routed through these centralized controllers. The controllers were part of core switches or separate devices. If they are part of separate devices, they sit between the wireless and wired parts of networks. They act as gateways to the network, allowing access to only certain users. They often allow access to particular applications on a per-user basis. In addition, centralized controllers authenticate users and access points.

Newer Wi-Fi networks support a more distributed architecture that is similar to the distributed architecture in Long-Term Evolution (LTE) networks, for which the controller function has been moved to each cell site. In Wi-Fi distributed networks, there are still some functions in controllers. They are used to define the type of access different users are allowed. They can also pinpoint areas of congestion and gather statistics into reports on the overall functioning of the WLAN. Figure 7-7 depicts an example of a centralized console for reports on statistics and congestion monitoring.

The main difference between a centralized and distributed architecture is that all traffic does not have to go through the controller. Rather, traffic is directed from wireless devices directly to other access points within the organization or to the broadband connection for Internet access. This eliminates congestion at a central point while at the same time avoids a single point of failure. Moreover, the distributed architecture of some WLANs can route traffic around any access point that is out of service.

Sending traffic directly to other access points is possible because the access points contain more functionality. In particular, they can filter out traffic from untrusted sources such as *rogue access points*. A rogue access point is an unauthorized access point installed by an employee. Figure 7-8 presents an overview of a WLAN.

Cloud Service and Virtualization for WLAN Management

In addition to distributed architectures, new controllers can now be installed as virtual entities on servers. This lowers the cost of Wi-Fi networks by eliminating a separate server and additional utility fees for air conditioning and electricity. This is often possible because more of the functions are distributed to access points rather than contained in central controllers.

Some Wi-Fi manufacturers provide an option called Software as a Service. This is a cloud offering in which the Wi-Fi manufacturer manages the controller and reporting functions at its own data center. For more information on cloud computing and virtualization, see Chapter 1, “Computing and Enabling Technologies.”

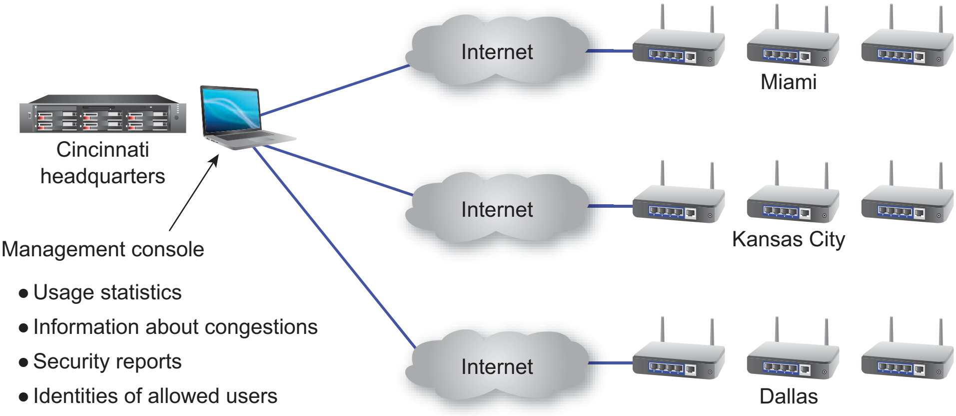

Figure 7-7 *A wireless network management console can be situated at the provider's location, in the cloud, or at the enterprise site.*

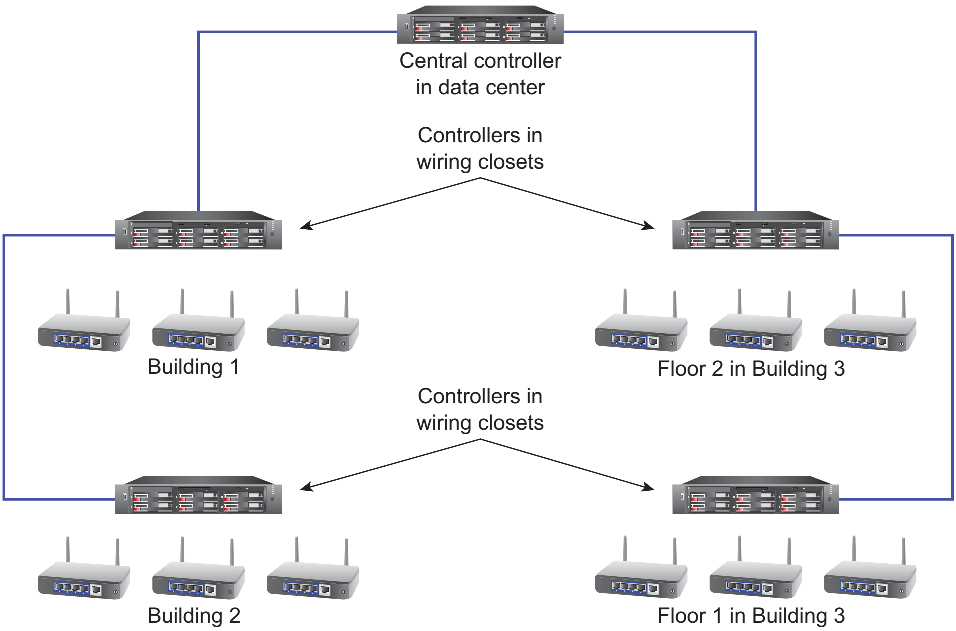

Figure 7-8 *An example of Wi-Fi architecture with controllers at each building, and a central controller for overall management of the Wireless Local Area Network (WLAN).*

Decreasing Errors and Improving Productivity in Hospitals by Using Wireless Service

A 400-bed acute care rehabilitation hospital, one with facilities to diagnose and treat patients on an inpatient basis, is planning to implement additional wireless applications on its existing Wi-Fi network. The overarching goals of this project are to increase productivity by getting information to mobile workers more efficiently and to reduce medication dosing errors. These applications will use the existing Wi-Fi network that will be expanded as required to support use for visitors, existing applications, and new applications.

Most of the rehabilitation facility's employees are mobile and not assigned to a fixed desk with a telephone and computer. Doctors and nurses are more productive when they have access to patient information remotely, at patient bedsides or near patient rooms. This enables them to input data such as current status on vital signs directly into a computer. Previously, doctors and nurses wrote this data on paper and then had someone else input the data at a centralized station.

The new wireless applications will save time and provide important tools to doctors because they will be able to write prescriptions at the patient's bedside. The applications will additionally provide realtime information on drug interactions with drugs patients are already taking. Staff members will also be able to research unusual disorders directly when they are with patients. By providing tools for medical personnel that they can use on a mobile basis, the hospital will improve staff productivity and decrease the chance of transcription errors.

The IT staff is planning to implement a broad program that utilizes iPad tablet computers and new workstations to enable nurses and doctors to be closer to patients and save time on accessing and inputting patient information. The following are key initiatives.

- Provide iPads to doctors for use during their rounds. The doctors will have access to patient information such as laboratory results and the ability to update information on patient conditions as needed during rounds.
- The hospital is considering providing smartphones to nurses and doctors so that they can communicate directly with one another.
- Changes in the floor layouts will bring access to computers nearer to medical staffs on patient floors so that they remain closer to patients. Rather than the current hub-and-spoke design in which the nurses' station and computers are centralized, one computer workstation will be located between every two patient rooms. The workstation will be for short-term tasks such as entering patient data including blood pressure and heart rate. It will be located in a recessed nook where nurses will stand to input patient information. In addition, there will be cubby-like

Continued

spaces at which nurses can sit down at computers for tasks that take longer to accomplish, such as writing intake and discharge reports.

- The hospital is instituting the use of barcode scanners to minimize errors in dispensing medication. Every time a nurse administers medication for infusion or oral intake, she scans the bar code on her own identification badge, the patient's wrist bracelet, and the medication container. A green LED on the scanner indicates that the medication is correct; red indicates an error. The scanners will be connected to computers that are hardwired to a mobile cart.

As a supplement to other therapies, speech and occupational therapists already use iPads and Wii game consoles with special programs that are used to enhance cognitive and keyboard therapies.

The most difficult challenge in deploying new applications is user acceptance. There are 400 nurses in the facility and most of them did not grow up with this degree of technology. They resist using applications that they perceive as adding to their workload. Therapists, doctors, and nurses all want easy-to-use applications that require little or no training. To overcome possible resistance, the hospital brought in three mobile carts, each configured differently, and let the nurses try them all out and recommend the one they liked best.

To ensure acceptance and success of the bar code scanning initiative, the hospital conducted a survey to ensure that the wireless network was adequate. Dead spots or difficulties accessing the central drug-dispensing database can lead to resistance in adopting the scanners. The hospital hired consultants to conduct the wireless audit to determine if there were dead spots in wireless Wi-Fi coverage. The consultants wheeled medical carts with bar code scanners throughout the facility to ensure that there was satisfactory coverage everywhere. The IT department is adding access points where needed for uniform Wi-Fi coverage.

In addition to user acceptance, infection control is a major concern when any hospital deploys new technologies. All keyboards, mice, scanners, and tablet computers need to be protected by rubberized covers to eliminate any nooks and crannies in which bacteria can form. This also permits these devices to be wiped down with antibacterial cleaning fluid without damaging the equipment.

Hospitals are also heavily regulated in terms of security and privacy requirements. These regulations require that all wireless devices are capable of using the centralized system that encrypts wireless transmissions. Access to patient information must be password protected. As a further protection, all web sites that hospital visitors and staff members access via the hospital's wireless and wireline networks are probed for malware so that viruses do not contaminate the hospital network or compromise patient privacy. The security software blocks access to web sites found to have malware.

Managing Security on WLANs

The broadcast nature of 802.11 networks makes them vulnerable to hackers. Access points continually broadcast their network's Service Set Identifier (SSID) and Wi-Fi-enabled devices respond to these broadcasts. These broadcast messages are vulnerable to eavesdroppers and can result in attempted logons by unauthorized users. Unlike wired networks, there are no natural boundaries. Thus, in apartment buildings and businesses, signals often easily leak into adjacent units and outside areas.

New security standards have been ratified that provide stronger encryption and authentication. The newer standards are known as Wi-Fi Protected Access 2 (WPA2), which is a subset of the IEEE-specified 802.11i standard. Both the subset and the full standard go by the same name of WPA2. However, administering it is time-consuming and complex, and security products and outsourced services are costly. Simpler, less-complex versions are available for homes and small businesses.

Four layers of security are required for enterprise WLAN service.

- User devices that are equipped with the following:
  - Virtual Private Network (VPN) software that enables the network to treat wireless devices differently.
  - Personal firewalls to prevent hackers from accessing data on laptops, notebooks, and personal digital assistants.
  - WPA2, which is strong 128-bit encryption to prevent eavesdropping (128-bit encryption refers to encryption with a choice 128 combinations of zeros and ones for every bit that is encrypted). This is also referred to as Advanced Encryption Standard (AES).
- Access points.
- The LAN.
- Applications.

The complexity is due to the fact that software on the user device, the access point, controllers, and security servers must all match. In addition, enterprises have the following tasks:

- Distribute client software to each user's device.
- Check for rogue access points.
- Enter names in databases.

- Use a strong authentication method such as a Remote Authentication Dial-In User Service (RADIUS) server with Authentication, Authorization, and Accounting (AAA) capability.
- Monitor usage.
- Ensure that portable devices don't spread viruses to the corporate network that they might have picked up from e-mail attachments or the Internet.

When corporations use WPA2, employees' laptops won't be compatible with corporate networks unless their home 802.11 networks also use WPA2.

Using Wi-Fi to Offload Traffic from Congested Mobile Networks

To ease congestion caused by increased tablet and smart phone traffic, carriers often supplement mobile services in densely populated areas with Wi-Fi in airports, train stations, and cafés where mobility is not required. In addition, Wi-Fi hotspots relieve backhaul congestion by transmitting traffic over broadband links rather than on the mobile network.

Wi-Fi equipment is less costly than base stations in mobile networks and spectrum is free. While cellular service excels at covering large areas, Wi-Fi service does extremely well at providing coverage inside buildings where it is relatively inexpensive to add access points.

This trend has been made possible by the advent of handsets with chips that support both Wi-Fi and mobile air interfaces. These interfaces are now tightly integrated and have the capability to automatically hand traffic off between cell sites and Wi-Fi networks. They additionally support both voice and data. However, using voice on Wi-Fi networks drains batteries more quickly than on mobile networks.

The downside of operating large numbers of small cell sites and hotspots is maintenance. Large carriers can have 50,000 of these sites to manage. Many mobile operators outsource management of their picocell sites, small cellular base stations, and hotspots to other firms. Picocells are another option for coverage inside buildings. For more information about picocells, see the section "The Microcell Technology of Picocells and Femtocells," earlier in this chapter.

Using Wi-Fi Hot Zones to Cover Outdoor Areas

Another way that carriers are starting to use Wi-Fi is for offloading data traffic from cellular networks in outside areas as well as within buildings. They do this by deploying multiple access points in congested areas such as Times Square in New York City. These Wi-Fi areas are referred to as *Wi-Fi hot zones*. The hot zone in Times Square was built by AT&T, which is building hot zones in other areas, as well. Carriers such as PCCW Ltd in Hong Kong, and China Telecom are also constructing Wi-Fi hot zones. A hot zone consists of multiple access points that have the capability to hand traffic off to other access points and to cellular networks as people move out of the Wi-Fi coverage area.

The downside of this strategy is that older phones do not automatically switch between Wi-Fi and cellular networks. In addition, Wi-Fi service drains handset batteries more quickly than cellular service. Wi-Fi hot zone strategies are attractive to carriers whose amount of spectrum cannot keep up with heavy data demands in metropolitan areas. They are additionally attractive for carriers that have not upgraded to LTE, and carriers such as AT&T, which has expertise in managing and implementing hot zones. Another strategy for hot zone maintenance is to use the vendor organization that built the hot zones to manage them.

Wireless Internet Service Providers

A Wireless Local-Area Network (WLAN) hotspot is a public area where people with Wi-Fi–equipped laptops, tablet computers, and handsets can access the Internet. The Wi-Fi hotspot business is multilayered and includes aggregators, cellular providers, and companies that supply "back office" services such as billing, roaming, and secure access to corporate networks from hotspots. Hotspot operators are also referred to as Wireless Internet Service Providers (WISPs).

The largest hotspot operator in the United States is AT&T Wi-Fi Services (formerly Wayport before AT&T purchased it in 2008). AT&T Wi-Fi Services is an aggregator. Aggregators install hardware and Internet access for hotspot services and resell it to other providers who provide billing, marketing, and customer service to end users. AT&T offers free Wi-Fi access directly to its own subscribers as well as on a wholesale basis to other providers. These providers in turn offer it to their own customers. T-Mobile USA also owns an extensive number of hot spots. It offers the service at no charge to its subscribers.

SATELLITES ....

Geosynchronous satellites orbit 22,300 miles above the Earth's surface. Because of this distance, each satellite can beam signals to a very large area; therefore, less equipment is required for coverage. This makes satellite service attractive for rural and difficult-to-cable areas.

Satellite Networks

Satellite networks are composed of a hub, the satellites themselves, and receiving dish antennas. Receiving antennas also are called *ground stations*. Receivers on antennas convert Radio Frequency (RF) signals to electrical signals. The transmitter on the antenna converts electrical signals to RF signals. The point from which broadcasts originate is the hub. The hub has a large dish, routing equipment, and fiber links to the enterprise's headquarters for commercial customers. All communications broadcast from the hub travel up to the satellite and then down to the ground stations (the satellite dishes).

Satellites are used to broadcast television and radio signals and to transmit positioning information to aircraft and air traffic controllers. Satellites are particularly suited to broadcast signals to large areas for applications such as weather monitoring, mapping, and military surveillance.

Satellite Telephones

The phones associated with these services are larger, heavier, and more expensive than cellular phones, and per-minute rates are high. However, during catastrophic disasters, they are sometimes the only operational service because of damaged or destroyed cell towers and lack of electricity at cell sites. They are often used in war zones where commercial facilities have been destroyed. They are also used on tankers, fishing vessels, and geology expeditions, and in remote mountainous regions where cellular service is not available.

Because geosynchronous satellites are located so high in orbit, there is an inherent delay of a half second or so in voice and data transmissions. This delay is the result of the time it takes the signal to travel to the satellite, be processed by the satellite, and then travel to the receiving station. Thanks to improvements in technology, today this delay is barely perceptible. In the 1970s and 1980s, users who placed calls to international locations often experienced delays of several seconds, which could make it quite difficult to carry on a conversation. If both parties in a telephone call spoke at the same time, parts of words were "clipped."

New, High-Frequency Satellite Service for Airplanes and Internet Access

Satellite service is now used to transmit TV, movie, and data signals to Wi-Fi access points on airplanes. These newer satellites operate on the higher-frequency K_a band. This enables them to support the high bandwidths required for on-demand services. For a fee, passengers can view on-demand TV and movies on their Wi-Fi-equipped laptops and tablet computers. Wi-Fi antennas distribute the signals to passenger devices within the aircraft's cabin. Satellite providers with these higher-frequency satellites also market their services to rural areas for Internet access.

Higher speeds result in lower delays when compared to older satellites. The delays are a half second or so compared to a few seconds on lower frequencies. However, these delays are still longer than those on most landline broadband services. The stronger beams in satellites that operate on higher frequencies result in smaller dishes and are more susceptible to interference from snow, fog, and rain.

SUMMARY

A number of factors have increased the complexity of managing and upgrading mobile infrastructure. These include the rapid increases in technological innovation, huge growth in data traffic, high costs of new spectrum to support additional traffic, and the trend of implementing smaller cell sites based on fourth-generation (4G), femtocell, picocell, and Wi-Fi technology.

The use of smaller cell sites is one method carriers employ to support dense concentrations of data traffic. However, adding smaller cell sites entails adding more support. This is one factor that has added to the increasing complexity of managing networks. Other strategies implemented to handle traffic growth are leasing new, costly spectrum and upgrading networks to use existing spectrum more efficiently. Carriers often utilize all of these strategies.

A further factor fueling complexity is that technological innovation has been spurred by the emergence of new equipment suppliers from China and Taiwan. This increased competition between manufacturers has led them to develop new products with upgraded functionality in order to stay competitive. Thus, carriers have a growing number of choices of products and suppliers when new generations of services are developed to handle additional video and data.

In addition, carriers are faced with the challenges of managing many different generations of technologies including second-generation (2G), third-generation (3G), advanced 3G, and pre-4G services. Although Software-Defined Radios (SDRs) have made it less complex to upgrade cell sites, managing multiple bands of spectrum along with multigeneration services requires complex diagnostics and staff members with the ability to support older 2G gear as well as newer, more advanced, pre-4G equipment and software in both the core and cell sites.

In addition to managing complex networks on a day-to-day basis, carriers need to create strategies for upgrades and maintenance that are affordable and enable them to keep prices competitive. For these reasons, carriers are signing contracts to outsource maintenance of all or part of their infrastructure to manufacturers. Part of the rationale for outsourcing is the desire to save money on maintenance staffs and to concentrate corporate resources on competitive strategic initiatives, such as marketing campaigns or development of competitive offerings. For all of these reasons, carriers are also starting to share network infrastructure with other carriers.

One strategy for both attracting customers and earning revenue is to host applications that subscribers can download to mobile devices. Developers use specialized software to create these applications, which on mobile device are typically called *apps*. In return for making apps available to subscribers, developers share the revenue they earn with carriers. The general rule of thumb is that carriers receive 30 percent of the fees that subscribers pay and the rest goes to the developers. The downside for subscribers is that many apps are not portable. Thus, subscribers who change carriers might lose all of their apps.

APPENDIX..

Table 7-3 Mobile Services Worldwide

Technology	Frequencies	Features	Comments
First-Generation Cellular Service			
Advanced Mobile Phone Service (AMPS)	UL: 824MHz to 849MHz DL: 869MHz to 894MHz	Analog, early cellular technology. Provided basic calling and voicemail. Implemented in the late 1980s. More capacity than previous noncellular services.	Two providers, the local telephone company and a competitor, originally in each metropolitan area. All telephones were compatible with all networks in the United States.
Nordic Mobile Telephone (NMT)	From 410MHz to 490MHz (varies by country) Band A (most used): *UL: 425.5MHz to 457.475MHz *DL: 462.5MHz to 467.475MHz	Analog technology and service offered in Europe. Provides basic calling and voicemail.	Code-Division Multiple Access 450 (CDMA450) is being licensed and deployed within the NMT frequency bands.

Table 7-3 (Continued)

Technology	Frequencies	Features	Comments
Second-Generation (2G) Cellular Service			
Digital cellular service (CDMA, Time-Division Multiple Access [TDMA], Global System for Mobile Communications [GSM] and Integrated Digital Enhanced Network [iDEN])	UL: 824MHz to 849MHz DL: 869MHz to 894MHz	Digital service with more capacity than analog service. Provides advanced features such as caller ID and Short Message Service (SMS).	CDMA, TDMA, GSM, and iDEN are digital cellular air interfaces.
Personal Communication Service (PCS)	UL: 1.85GHz to 1.91GHz DL: 1.93GHz to 1.99GHz	PCS added more digital spectrum, competitors, and innovative services, driving prices down.	PCS refers to higher-frequency 1.9GHz services. Second- and fourth-generation services operate on PCS frequencies.
GSM	UL: 890MHz to 915MHz DL: 935MHz to 960MHz	A cellular digital technology. The same handsets can be used in all countries that use GSM multiplexing.	Standard used in Europe, the Far East, Israel, New Zealand, and Australia. Also used by T-Mobile and AT&T Mobility in the United States.
Digital Cellular System (DCS)	UL: 1.71GHz to 1.785GHz DL: 1.805GHz to 1.880GHz	DCS service added more digital spectrum for most existing carriers and a few new entrants.	DCS refers to higher-frequency 1.8GHz services in Europe. GSM is considered a DCS air interface.

Technology	Frequencies	Features	Comments
Enhanced Specialized Mobile Radio (ESMR)	UL: 806MHz to 821MHZ DL: 851MHz to 866MHz	Nextel (now part of Sprint Nextel) services operate on these frequencies.	Nextel and other SMR operators use iDEN technology developed by Motorola to support voice, paging, push-to-talk, and messaging on the same telephone. Also suitable for 4G service.
***2.5-generation services (2.5G)**		Many GSM mobile operators deployed these packet data services in the interim to 3G. They use the same spectrum as GSM. This is a lower-cost solution than 3G but with less efficient spectrum utilization.	
GPRS	Same as GSM, DCS, and PCS	General Packet Radio Service	Appropriates voice channels for data; 40- to 60Kbps.
EDGE		Enhanced Data Rates for GSM Evolution	Data speeds of about 110Kbps. Requires fewer voice channels for data than GPRS.
***Third-generation services (3G)**		3G packs more services into a given amount of spectrum than 2.5G technology.	

Table 7-3 *(Continued)*

Technology	Frequencies	Features	Comments
WCDMA, also called UMTS CDMA2000 1X CDMA2000 1xEV-DO UMTS TDD TD-SCDMA	IMT-2000 bands: **UMTS:** Uplink: 1.885GHz to 2.025GHz (in the United States: 1.71GHz to 1.755GHz) Downlink: 2.11GHz to 2.17GHz (in the United States: 2.11GHz to 2.155GHz) **CDMA2000:** 450MHz (NMT), 800MHz, 1.7GHz (Korea), 1.9GHz (PCS), and 2.1GHz (UMTS) **UMTS TDD:** 1.885GHz to 1.92GHz or 2.01GHz to 2.025GHz (primary), plus 2.3GHz to 2.4GHz (secondary) **TD-SCDMA:** TBD (China)	More capacity for voice, higher-speed data, acceptable video, low-latency applications, and so on. Standards bodies have specified all of these frequency bands for 3G services.	Carriers launched value-added 3G services to generate higher revenues. CDMA2000 1xEV-DO (data optimized) is always combined with CDMA2000 1X (voice and data) on a single chip. WCDMA is normally combined with GSM on a single chip for voice services. UMTS TDD uses one frequency band for uplink and downlink data transmissions. The Chinese government commercialized TD-SCDMA, a homegrown version of UMTS TDD.

Table 7-4, on the next page, lists the major 3G standards. The releases and revisions are upgrades.

Table 7-4 Releases and Revisions to 3G Cellular Services

Name of Service and Release	Downlink Data Rates: From the Network to the Subscriber	Uplink Data Rates: From the Subscriber to the Network
CDMA2000 Releases (1.25MHz Channel Bandwidth)		
CDMA2000 1X (Release 0) Doubles voice capacity	Peak data rate: 153.6Kbps Average data rate: 64Kbps	Peak data rate: 153.6Kbps Average data rate: 64Kbps
CDMA2000 1xEV-DO (Release 0) Data optimized. High data rate (HDR).	Peak data rate: 2.4Mbps Average data rate: 500Kbps to 1Mbps	Peak data rate: 384Kbps Average data rate: 144Kbps
CDMA450 Same features as other CDMA standards but operates in lower frequencies so that fewer base stations are needed.	Same as 1X and 1xEV-DO	Same as 1X and 1xEV-DO. Deployed mainly in rural areas because of its capability to cover large areas.
CDMA2000 1xEV-DO (Revision A) or CDMA2000 DO Rev. A Supports low-latency (delay) data in a single 1.25MHz channel.	Peak data rate: 3.1Mbps Average data rate: 1.8Mbps	Peak data rate: 1.8Mbps Average data rate: 630Kbps per sector (standard) Average data rate: 1.325Mbps per sector
WCDMA Releases (5MHz Channel Bandwidth)		
WCDMA (Release 99)	Peak data rate: 2Mbps Average data rate: 220Kbps	Peak data rate: 384Kbps Average data rate: 64Kbps
WCDMA (Release 4) Enables operators to prioritize data services per customer subscription choices.	Peak data rate: 2Mbps Average data rate: 384Kbps	Same as WCDMA (Release 99)
WCDMA (Releases 5 and 6) HSPD/UPA (high-speed downlink/uplink packet access) Doubles the uplink speed	Peak data rate: 14Mbps Average data rate: 2Mbps	Uplink: 1.4 Mbps

Table 7-5 *802.11 (Wi-Fi) Standards*

802.11 Standard	Description
802.11ac	A proposed Wi-Fi standard designed to provide gigabit speeds on Wi-Fi networks. Will be used mainly with the 802.11a protocol.
802.11af Super Wi-Fi	A proposed Wi-Fi standard designed to operate in the white space 700MHz spectrum freed up by TV broadcasters. It is envisioned as providing Internet access in rural areas because it can cover large areas.
802.11d	A standard that supports the capability for Wi-Fi devices to operate in different countries that require different power levels and frequencies. Enables equipment to be adjusted according to the rules of each country.
802.11e	A Quality of Service (QoS) standard, the Wi-Fi Multimedia (WMM) section of 802.11e that defines prioritizing voice and video. Was approved October 2004.
802.11f	A standard that supports the capability for access points from different manufacturers to interoperate in the same Wireless Local Area Network (WLAN).
802.11h	A proposal that defines ways for 802.11a networks to dynamically assign packets to other channels if there is interference with other access points and services such as radar, medical devices, and satellite transmissions. In some countries, radar and satellite use the same frequencies as 802.11a.
802.11i	A standard for improved security. It's also referred to as Wireless Protected Access 2 (WPA2).
802.11k	A standard to make information for radio measurements, such as roaming requests by access points, statistics on device usage, and traffic levels in channels, available to WLAN management systems so that they can balance traffic between access points.
802.11n	A standard to increase throughput—actual user data transmitted and the range covered by each access point. Improvements achieved through enhancements in antennas that decrease effects of interference.

802.11 Standard	Description
802.11p WAVE (Wireless Access for Vehicular Environments)	A standard for applications such as toll collection, vehicle safety services, and commerce transactions via automobile. It enables communications between vehicles and roadside access points or other vehicles
802.11r	The standard that defines methods for switches to quickly hand off sessions between access points so that users don't have to be authenticated again. This is important to avoid delays for voice on WLANs.
802.11s	A proposed IEEE mesh networking standard. It will define how access points forward packets between each other. Envisioned for community-wide Wi-Fi networks.
802.11u	An IEEE standard that enables automatic interworking between cellular and Wi-Fi networks. A user's mobile device with embedded Wi-Fi with 802.11u can automatically switch to Wi-Fi when it's in a Wi-Fi hotspot that has an agreement with the user's carrier. This is part of the Wi-Fi Alliance initiative known as Hot Spot 2.0 to simplify cellular devices' Wi-Fi access.
802.11v	Improves the ability to manage Wi-Fi networks by enabling statistics gathering and power management that will improve battery life. A must in client device and access point.
802.11w	A standard used for security that protects Wi-Fi devices from attackers with spoofed (fake) addresses.
802.11x	A proposed security standard for authentication and security to prevent unauthorized packets from entering wired LANs from Wi-Fi networks. It's an alternative to creating virtual private networks.
Control and Provisioning of Wireless Access Points (CAPWAP)	A proposal for WLAN switches to control access points by centralizing intelligence in one device, a controller. Will be used to standardize roaming between cellular and Wi-Fi networks.
Unlicensed Mobile Access (WMA)	A way to route cell phone traffic over Wi-Fi networks. The cellular network maintains control of calls so that it can bill for traffic.

Table 7-5 *(Continued)*

802.11 Standard	Description
Wi-Bro (formerly HPi)	A Korean version of 802.11e.
Wi-Fi Direct	A Wi-Fi Alliance standard that enables any device with Wi-Fi Direct software to communicate directly with another device. This allows a laptop to act as an access point so that nearby computers can also access the Internet. Includes WAP2 security. Can be used for printing, as well.

8 Mobile Carriers Worldwide

In this chapter:

INTRODUCTION

During the past decade, large swaths of the population in Africa, Asia, and Latin America acquired mobile services for the first time. Mobile devices are often the first telephones that these populations have had because landline phone services were not widely available. Low rates and wide availability of mobile services have helped these populations stay in touch with family members who have moved to distant cities and other countries to increase their economic opportunities.

As more people acquire mobile services for voice, carriers are exploring ways to increase revenue by offering new services such as mobile payment services. In Kenya, small-business owners use mobile handsets to make and collect payments as well as receive wages. Subscribers can additionally receive remittances from distant relatives on their handsets. These remittances are often the capital used to start these small businesses.

There are challenges as well as opportunities for carriers that operate in high-growth countries such as India and Kenya that have low per-minute rates for cellular service and populations with low wages and high poverty rates. The combination of low prices and low Minutes of Use (MoU) makes it difficult to operate profitably. Carriers recognize the need to lower their operating costs, increase the volume of customers to make up for the low Average Revenue Per User (ARPU), and offer affordable handsets to customers.

Another obstacle for carriers that operate in developing countries is the competition of other mobile providers in many of these areas. In contrast to Europe, where generally there are only four carriers in each country, India and Indonesia both have nine or more mobile providers. This is another factor along with poverty that drives down mobile prices. Governments often encourage large numbers of providers to offer services in anticipation of revenue from annual license fees and spectrum auctions.

Carriers in many of these regions face additional problems in attempting to upgrade and expand their networks. Fraud and corruption by government officials is common in many countries and results in less money available for governments to invest in infrastructure improvements at all levels, from basic road construction and maintenance (to facilitate rudimentary transportation) to the installation of advanced fiber-optic cabling (to connect mobile networks to one another and to the Internet). In addition, companies that are headquartered in countries that prohibit bribing businesses or government officials often find that a pervasive culture of bribery in certain foreign markets makes it difficult for them to operate. If a potential customer or official expects gifts or entertainment as a condition of making a sale or granting a permit, companies that are not allowed to abide by those tactics will be at a disadvantage.

Even with these obstacles, large multinational telephone companies have been attracted to countries with emerging economies where they hope that the vast numbers of potential mobile customers will offer growth opportunities that will offset low ARPU. Multinationals often have the capital to build new networks that they are able to operate for years before the networks are profitable. This can sometimes freeze out smaller competitors who need to earn revenue faster and do not have the resources to bid on an adequate amount of spectrum or develop networks for nationwide service.

Unlike most of Africa and India, rates for mobile services in Latin America, particularly Brazil, are high because of the dominance of two major carriers, América Móvil and Telefónica. There is not enough competition in these countries to drive down mobile rates. Moreover, countries such as Brazil and Costa Rica have growing middle classes that are able to afford premium mobile services.

Large multinationals also often have the resources to invest heavily in upgrades to infrastructure required to support data. In Europe, where overall revenues are declining due to less use of cellular phones for voice, carriers are hoping that revenue from data services will offset declines in revenue from voice services. To that end, European carriers have increased capacity to support applications such as video streaming and additional Internet access. As of yet, data revenues in Europe have not made up for declining voice revenue.

One way to gain capacity is to add spectrum for next-generation services. Another way is to "*re-farm*" spectrum used for older Global System for Mobile Communications (GSM) service and use it for next-generation Long-Term Evolution (LTE) service, instead. The term "re-farm" refers to changing the type of mobile service deployed on certain spectrum. The European Union has developed rules to allow refarming spectrum originally used only for second-generation (2G) services to also support higher capacity fourth-generation (4G) technology. This is because 4G services were designed to support data and packetized voice, whereas 2G services were designed to support only voice.

Another way to affordably add capacity is by using a wholesale model by which multiple carriers share infrastructure built by a single carrier. This is being planned in Russia and Brazil where multiple providers will share capacity on the LTE networks. Each operator will pay fees to use the network. In this way, investments are concentrated on a single network, which is able to reach larger areas than a single carrier's network. This is particularly true in rural areas where there are fewer customers, which makes it more difficult to make a profit.

In Brazil, the government will subsidize the cost of building the LTE network. These types of investments impact the ability of businesses to reach the Internet for everyday functions, the resources needed to educate students with modern job skills, and the ability of the general population to access Internet-based resources necessary to participate in modern economies.

Government policies play a critical role in mobile services. In addition to direct investments in infrastructure, they have an impact on the amount of competition, availability of spectrum, and access of various competitors to one another's networks and reasonable roaming rates. Roaming rates are the fees carriers are allowed to charge competitors whose customers use their devices outside of the territories of the small providers. Roaming fees are most often those that large carriers charge smaller competitors. Prohibitively high roaming fees impact mobile rates and the ability of small carriers to operate profitably.

In countries such as China that have strong central governments, spectrum decisions and auctions are often handled at a faster pace. China was able to decide early which LTE technology each of its three carriers would develop and made spectrum available for them. The government also invested directly in fiber-optic backbone networks needed to support mobile networks.

Although carriers are discussing strategies for building 4G networks, for the most part they are still in the process of upgrading networks to third-generation (3G) technologies. In India, carriers are just planning to widen the availability of 3G networks. Russia and China are among the only countries in developing markets that have made spectrum available for LTE networks. Although technology is changing at a faster pace than ever before, the reality is that it still takes years for these changes to be made available on a global basis.

THE LARGEST MOBILE CARRIERS WORLDWIDE ......

Across the globe, intense, competitive pressures are keeping prices affordable in most markets. At the same time, operators are searching for new revenue sources and are upgrading their infrastructure to support additional applications, including multiplayer games, audio downloads, and mobile enterprise services. In addition, operators have expanded into developing and newly developed areas such as India, China, Africa, Latin America, and Eastern Europe where there are more opportunities for growth. Implementing expensive upgrades and expansions, the need for capital, and competitive pressures have fueled the strategy by carriers to grow by acquisition. The acquiring carriers are typically large conglomerates. The top 10 mobile carriers provide service for 42 percent of the world's mobile customers and the top 20 provide service to nearly 60 percent of subscribers, worldwide. Table 8-1 presents a list of the 20 largest mobile providers. In addition to mobile services, these carriers offer wireline Internet access and voice service to both business and residential customers.

Table 8-1 *The Largest Mobile Providers, Worldwide (Courtesy Wireless Intelligence, April 15, 2011)*

Global Share of Top 20 Operator-Group Connections, Q4 2010			
Ranking	**Operator-Group**	**Share**	**Cumulative**
1	China Mobile	11%	11%
2	Vodafone Group	7%	18%
3	Telefónica Móviles, SA	4%	22%
4	América Móvil Group	4%	26%
5	Bharti Airtel	4%	29%
6	China Unicom	3%	32%
7	Deutsche Telekom AG	3%	35%
8	Reliance Communications	2%	37%
9	France Telecom Group	2%	39%
10	MTN Group	2%	41%
11	Sistema	2%	43%
12	Verizon Wireless	2%	45%
13	Telenor Group	2%	47%
14	AT&T Mobility	2%	49%
15	Telkomsel (Telekomunikasi Selular)	2%	51%
16	Vimpelcom Group	2%	53%
17	WIND Telecom Group	2%	55%
18	China Telecom	2%	56%
19	Tata Teleservices	2%	58%
20	BSNL	2%	59%

ASIAN MARKET

Asia is a densely populated, diverse continent. It includes countries such as Bangladesh, where per-capita income is extremely low, as well as highly developed countries such as Japan and South Korea, which each boast high per-capita incomes. Government policies in these two countries are major factors in the early development of advanced mobile services and the highest percentage of populations with fiber to homes worldwide. In both of these countries, the governments made spectrum available at low or no cost and subsidized widespread construction of fiber-optic networks. Interestingly, Japanese carriers earn close to half of their mobile revenue from data services. In most other countries, revenues from data services are in single digits as a percentage of total revenue from mobile services. This is a result of Japan's higher income per capita and advanced mobile infrastructure.

A major part of revenue streams in countries such as India and the Philippines depend on companies in other countries that pay them for outsourced services. It is also a hub of lower-cost manufacturing for the rest of the world. As wages in China and the Philippines increase, more companies are moving their manufacturing to Vietnam where wages are still comparatively low. These industries are opening new employment opportunities for sections of populations that previously subsisted on lower wages in agriculture. They are also providing income for people so that more children are being educated. Consequently, more of the population is able to afford increasingly sophisticated mobile services.

Southeast Asia includes the south of China and portions north of Australia. Indonesia, which is located in Southeast Asia, is the fourth most populous country in the world. In addition to its sizable population, Indonesia boasts the largest economy in Southeast Asia, and its 12.4 percent poverty rate (as of the end of 2011) has been decreasing. There have been improvements in the unemployment rate, as well, which was at 7.4 percent in early 2011. However, inflation is still a problem. Moreover, corruption makes it difficult for foreign companies to do business there.

Like many other countries in Asia and Africa, Indonesia has a large number of mobile providers, nine of them by early 2011. Thus, competition is intense and prices are low.

China Mobile and Singapore Telecommunications, known as SingTel, has a major presence in Asia through its roaming services and subsidiaries in India and Australia. The government of Singapore owns 54 percent of SingTel. In 2004, SingTel formed a separate company, Bridge Alliance, which sells prepaid mobile cards for roaming in Asia and Australia. Bridge Alliance also has a partnership with FreeMove, which has service throughout Europe. These two organizations offer their customers the option of purchasing roaming services throughout Europe and Asia.

Bridge Alliance has grown to include mobile operators in 11 Asian countries. Many of Bridge Alliance's partners are operators in which SingTel is a part owner. This includes SingTel's subsidiary Optus in Australia, which supplies SingTel with two-thirds of its annual revenue. The alliance sells prepaid mobile phone cards that can be used in any of the 11 countries for unlimited cellular voice or data transmissions for periods of one to three days per prepaid card.

Other large mobile providers in Asia include the following:

- China Mobile
- China Unicom
- Vodafone, headquartered in the United Kingdom
- Telenor, headquartered in Norway
- Hutchison Whampoa, headquartered in Hong Kong
- Etisalat, headquartered in the United Arab Emirate
- VimpleCom, headquartered in Russia

Malaysia has one of the highest per-capita incomes in Asia and has a robust middle class. Its government is a constitutional monarchy. It also has many mobile competitors. Most residential customers currently access the Internet over High-Speed Data Packet Access (HSDPA), an advanced 3G (3.5-generation) mobile protocol. In addition, the Malaysian government has initiated a Broadband Plan to assist in the implementation of new broadband Internet technology.

Interestingly, voice mail is not widely available in most Asian countries. This contrasts with North America and Europe, where voice mail was used extensively before the widespread availability of text messaging. In most of Asia, consumers skipped directly to text messaging. In countries such as China, India, and Thailand, people rely on text messaging to leave messages when there is no response to a phone call. Text messaging is also used for distant communications if long-distance mobile fees are prohibitively expensive.

China

China is the fourth largest country worldwide in terms of geographic area, following only Russia, Canada, and the United States (see Figure 8-1). Despite this, it is the most populous in the world with 1.3 billion citizens. Equally impressive, it has 120 cities with populations that exceed 1 million people. To the Chinese, cities of 1 million are considered relatively small.

Figure 8-1 China and its neighbors.

China's government is controlled centrally by the Chinese Communist Party, which dictates many facets of industry and technology. After the death of Party Chairman Mao Zedong in 1978, Chinese leaders started focusing on building a quasi-market-based economy. They began rebuilding infrastructure and developing economic policies to improve living conditions and China's standing in worldwide commerce.

In the 1990s, the Chinese government recognized that it needed telecommunications infrastructure to become a leading technology country and undertook a major push to develop this infrastructure starting with the eastern coastal region.

According to Dixon Doll, the cofounder and managing general partner of early-stage venture capital firm Doll Capital Management:

> *The Chinese government recognized right from the beginning (and they were very, very savvy to do this) that for their economy to thrive and prosper, they needed a world class telecommunications infrastructure in place, and they did a great job of taking all the investment and planning steps necessary to achieve this goal.*

In the information economy we live in today, if you can't get connectivity to your business, you're in a very tough spot. There are a lot of studies about macroeconomics that talk about the critical success factors for an emerging market economy. You have to have ample supplies of energy and a good communications system. A good communications system facilitates speed, volume of business transactions, and more than anything else, facilitates the substantial amounts of productivity increases, which are central to a thriving economy.

Because of the cost of digging trenches and laying cabling to its large population, most of whom had no landline telephone service, China concentrated on building out its cellular infrastructure. For large businesses, it developed Ethernet-based IP networks rather than investing in older circuit-switched technology. In some areas, IP-based networks use the same fiber-optic lines and other infrastructure as the backhaul network connecting antennas and controllers in cellular base stations to mobile switching offices and the Internet.

China maintains tight controls on the media. To limit contact with the outside world, access to many web sites such as YouTube and Facebook is restricted. Also, citizens are often not allowed access to e-commerce sites that compete with Chinese companies. However, some sophisticated users, particularly college students, have found ways to circumvent these restrictions.

The three largest mobile providers in China, China Mobile, China Unicom, and China Telecom, are all owned by the Chinese government. (For more information about Chinese carriers, see Table 8-2.) These providers have other similarities. All of them offer subsidized handsets, enjoy spectacular growth in mobile subscriptions, operate both fixed-line and wireless networks, and currently have a low percentage of mobile subscribers on their 3G networks. However, the number of 3G subscribers is growing due in part to China's investment in 3G infrastructure. Providers are planning to increase the appeal of 3G by operating *app stores*, increasing the number of smartphones available to customers, and lowering 3G fees. As of December 2011, China Unicom, which was initially the only carrier to offer Apple's iPhone, had the largest percentage of users on its 3G network.

The Chinese government reorganized the structure of the mobile telecom sector by merging six mobile operators into the aforementioned three organizations in 2008. This was done so that each would have nationwide coverage and provide competition to China Mobile. To streamline operations at China Unicom, which at that time operated both Code-Division Multiple Access (CDMA) and Global System for Mobile Communications (GSM) networks, the government directed China Unicom to divest itself of the CDMA network and give it to China Telecom. China Telecom is now the only operator that uses CDMA technology in China.

Each of the three carriers has experienced enormous growth. By the end of October 2011, there were close to 952 million mobile subscribers in China. China Mobile, which had 203 million mobile subscribers in December 2004, had increased its subscriber numbers to 639 million by November 2011.

Cell coverage is excellent throughout both urban and rural areas of China with the exception of the sparsely populated mountainous western and north-western regions. There are no charges to receive calls and costs for local calls are extremely low. However, long-distance service is expensive. Thus, most people text rather than pay long-distance fees to reach people in other areas. When people travel within China they often purchase a Subscriber Identity Module (SIM) card associated with the distant city to avoid these fees.

NOTE SIM cards are clip-on or internal cards with microchips that store user identity and other information such as speed-dial lists and e-mail addresses.

China Telecom provides the most extensive services outside China. It operates international subsidiaries including China Telecom Europe Ltd., which is headquartered in London and offers system integration and information services to carriers and corporate customers as well as broadband connections into China for these customers. Its VelaTel subsidiary currently offers 4G wireless broadband to customers in Peru under the brand GO MOVIL. It has stated that its goal is to provide affordable wireless broadband in underserved markets with available, affordable spectrum. China Telecom has also announced plans to become a Mobile Virtual Network Operator (MVNO) in England and the United States with expansion into other countries at a later date. To learn more about MVNOs, see Chapter 3, “Competition, Industry Structures, and Regulations.”

China has the most Internet users in the world at 457 million as well as an active e-commerce sector. Unlike its policy of owning mobile providers, the government does not own Internet companies. It does, however, heavily monitor messages on social networks and limit searches primarily to e-commerce sites in China.

Instant messaging service QQ, which is similar to Skype, is used by a majority of young people for video chatting and Voice over Internet Protocol (VoIP) calling. Tencent Holdings Ltd., a public company based in Shenzhen, China, owns QQ. Some Chinese residents also use MSN, Twitter, and Skype. However, Sina Corporation’s Weibo is the most popular microblogging site in China and supports social networking functionality, as well. Its features include groups, audio messages, and direct video uploads to complement its microblogging service.

Search company Baidu maintains the lion’s share of search customers in China. Its main competitor, Google, has a market share of less than 20 percent. As in the United States, a large portion of Google’s revenue in China is derived from advertising on its site.

Table 8-2 Mobile Providers in China

Company Name	Services	Notes
China Mobile	GoTone: postpaid brand. M-zone and Easyown: prepaid, lower-cost services marketed to students and young people. Offers services to corporations as well as individuals.	The largest mobile provider worldwide. Owns 90% of Pakistani wireless provider Paktel. Currently is trial-testing Time-Division Long-Term Evolution (TD-LTE). 3G service is based on Chinese-developed Time-Division Synchronous CDMA (TD-SCDMA).
China Unicom	Second largest fixed-line and mobile provider. WO is its 3G brand. Ru Yi 133 is its prepaid GSM brand.	Telefónica owns 9.5% and has a strategic partnership with Unicom for roaming, equipment purchases, and research and development. Its 3G service is based on WCDMA.
China Telecom	Third largest mobile provider; largest fixed-line provider. Offers Internet access and television service.	Announced it will use LTE for its 4G service. The only CDMA provider in China.

China has four main social networks: Renren, Kaixin001, Qzone, and Pengyou. Renren is China's largest social network, and like Facebook, it started on college campuses. It also has many of the same features as Facebook. With the exception of Qzone, these networks require that subscribers use their real names. To date, social networks have not attracted as large a percentage of users as those in Western countries. This might change as social networking sites expand from mainly large cities to the smaller cities and as more people have access via smartphones, rather than mainly accessing social networks at Internet cafés. Tencent owns both Qzone and Pengyou.

China has been known to "borrow" technology from the West. Clones of the iPad are sold, alternatively called APad or iPed, and are based on the Android operating system. China's own version of the iPhone is also available. The Chinese government has explicitly stated its policy of enhancing technology developed in other countries. A quote from China's "National Medium- and Long-Term Plan for the Development of Science and Technology (2006–2020)" was printed in the *Wall Street Journal* on February 2, 2011 in an article by John Bussey, titled "US Firms, China Are Locked in Major War over Technology." The quote from the Long-Term Plan made clear the goal of

> *…enhancing original innovation through co-innovation and re-innovation based on the assimilation of imported technologies.*

China has affirmed that its goal in developing its own technology is to avoid paying high royalty fees to outside companies. All companies that use 2G Code-Division Multiple Access (CDMA) and 3G Wideband CDMA (WCDMA) and CDMA2000 pay royalties to Qualcomm, an American software company headquartered in California. This is one reason that China developed its own versions of the 3G and 4G cellular protocols, TD-SCDMA and TD-LTE.

India

India, at slightly more than one-third the geographic size of the United States, has a population of nearly 1.2 billion people. In comparison, the United States has only 311 million people. Worldwide, India is second in population only to China. According to its national regulator, Telecom Regulatory Authority of India (TRAI), there were 850 million cell phone subscribers as of August 2011. Overall, 60 percent of the population has a mobile subscription. However, in urban areas there is a *teledensity* of 127 percent because some people subscribe to two mobile services and have two telephone numbers; one phone is for incoming calls and the other for low-cost outgoing calls.

The largest potential for mobile growth is in rural areas where, according to TRAI, only 27 percent of the population has a mobile handset. Because more than 70 percent of the population lives in rural areas, small villages represent potential growth areas for voice and data services. The Indian government hopes to raise the educational level in part with high-capacity mobile networks based on 3G and 4G technologies. They have also announced plans to subsidize low-cost tablet computers for children (costing less than $35) and provide free tablet computers to schools. Because 65 percent of the population is younger than 35 years of age, lowering poverty levels by improving a child's technical skills can have a large impact.

The high density of cell phones in cities and towns is made possible in large part by low prices for mobile services. Prepaid, the leading form of service, has rates of 1¢ per minute, which is the lowest in the world. A major factor in the low per-minute rates is the intense competition among the many mobile providers. The low rates have made it difficult for carriers to earn profits. To alleviate this problem, the government is considering easing rules on mergers such that operators within a circle can merge, as long as there is a minimum of six operators in each circle.

The Department of Telecom (DoT) is expected to issue relaxed merger and acquisition rules by the end of 2011. The DoT has stated its intention to not let the number of providers drop below six. The DoT in October 2011 announced rules allowing operators to share and trade airwaves.

Prior to 1994, telephone service was provided only by two state-owned carriers: BSNL and MTNL. In 1994, telecommunications was deregulated and the National Telecommunications Policy was created to allow private companies and foreign entities to provide telecommunications services. Foreign entities are not allowed to own 100 percent of a carrier. To encourage competition, the Policy also lowered license fees required to operate telecommunications and mobile networks. Table 8-3 lists cellular mobile providers in descending order of number of subscribers, as of December 2010.

India is divided into 22 service areas called *circles*, with between nine and 14 operators in each circle. The government grants spectrum rights to particular circles in spectrum auctions. BSNL has rights to all of India, except Delhi and Mumbai, and MTNL has spectrum in Delhi and Mumbai. Rights can be granted to multiple circles per carrier. Because of its potential for growth, international carriers from Bahrain, Japan, Malaysia, Norway, Russia, Singapore, and the United Arab Emirates have expanded into India. A number of India's conglomerates, notably Bharti Enterprises, have also expanded into mobile services. Bharti is now India's largest carrier, with coverage through almost the entire country and Time-Division Multiplexing LTE (TD-LTE) service in the state of Kolcata. In addition to helping to lower mobile rates, competition has spurred improvements in customer service.

In addition to low per-minute rates, competition has sparked innovations. New mobile phones now can be equipped with two Subscriber Identity Module (SIM) cards simultaneously so that subscribers can use their handsets on multiple carrier networks. Phones that can be equipped with four SIM cards simultaneously have been announced.

Low Broadband Penetration

Most residents in India's urban areas have mobile phones and use them primarily for voice. As carriers continue to build out and upgrade their networks, this might change. To enable development of new value-added data, e-commerce, and Internet access services, and to add capacity, the government auctioned off spectrum for 3G and 4G services in 2010. Availability of mobile networks with greater capacity plus attractive low-priced smartphones will likely spur mobile broadband Internet access. However, operators are still in the process of building out 3G networks, so there are concerns that adequate capacity will not be available if subscribers purchase tablet computers or smartphones for Internet access and e-mail.

Table 8-3 Mobile Providers in India

Company Name	Brand Name	Ownership Percentages
Bharti Airtel	Airtel	Bharti Enterprises, 67%; Singapore Telecommunications, 33%.
Reliance Communications	RCom	India's Reliance, 67%; public ownership, 26%; expected to offer TD-LTE service on its LTE spectrum.
Vodafone	Vodafone	Vodafone subsidiary, 74%; Indian investors, 26%; Vodafone is buying out its former Indian partner Essar.
Bharat Sanchar Nigam, Ltd.	BSNL	State-owned; also operates fixed-line networks.
Tata Teleservices	Tata Indicom Tata DoCoMo Virgin Mobile	Japan's DoCoMo, 26%; Tata Group, 74%. Tata Indicom and DoCoMo serve different parts of India. Virgin Mobile resells service on both networks.
Idea Cellular, Ltd.	Idea Cellular	India's Aditya Birla, 80.8%; Malaysia's Axiata Group Berhad, 19.1%.
Aircel Cellular, Ltd.	Aircel	Malaysia's Maxis Communications, 74%; India's Apollo Hospital, 26%.
Unitech Wireless	Uninor	Jointly owned by Norway's Telenor and India's Unitech.
Videocon	Videocon	Wholly owned by India's Videocon Industries, Ltd.
Mahanagar Telephone Nigam, Ltd.	MTNL	State owned; also operates fixed-line networks.
Loop Telecom, Ltd.*	Loop Cellular	Indian conglomerate Essar, 8%; India's Santa Trading Pvt, Ltd., 86%.
MTS India	MBlaze	Russia's Sistema, 73.71%; India's Shyam Group, 23.79%.
Ping Mobile	Ping	HFCL Infotel Ltd. A fixed-line and mobile provider.
Etisalat DB Private, Ltd.	Cheers	Jointly owned by United Arab Emirates telephone company Etisalat, and India's Dynamix Balwas Group. Might exit India because its 2G license was revoked.

**Loop Telecom intends to return its telecom license spectrum to the Indian government so that it can be put up for auction.*

India has an educated population located mainly in urban areas, but very few wireline broadband connections. Residential broadband connections are based on Digital Subscriber Line (DSL). They are costly and not widely available. Thus, most people still use dial-up public switched network services for Internet access.

The growing middle class, many of whom work in information technology services and software development, represent potential subscribers for mobile broadband. To help serve the need for broadband and to earn additional revenue from spectrum auctions, the government has announced plans for another auction of spectrum for 4G networks, which will add capacity for value-added services such as mobile banking over the long term.

Currently, banking services are not available to most of the general public. It is hoped that availability of next-generation data networks will spur creation of platforms for mobile payment methods needed for e-commerce. Another impediment to the development and uptake of e-commerce is the lack of good roads in rural areas and in secondary cities over which to deliver equipment needed to build and maintain next-generation mobile networks. And because there are few doctors, applications that enable the analysis of X-rays and other diagnostic tests remotely over mobile broadband links could increase the availability of healthcare.

Although the standard of living is improving due to increased industrialization and growth in the service sector, there is still a high level of poverty. Bringing mobile services such as mobile banking to more of the population can help raise the standard of living in rural areas. This would enable more people to participate in e-commerce by developing small businesses. However, new services aimed at people below the poverty level will have to be priced extremely low to be affordable. An open question is whether the growing middle class and business customers will provide enough revenue growth to sustain costly infrastructure build-outs needed to support high-speed, mobile data networks.

LATIN AMERICA

In Latin America, mobile services have revolutionized the lives of ordinary people throughout the region. Prior to the widespread availability of mobile services, mountainous regions and small rural towns had no phone service at all and often no electricity. Mobile services brought the ability to conduct business and stay in touch with remote family members. Despite their relatively high prices, mobile phones have become a necessity and it’s not uncommon for every family to have one, even in small villages.

Throughout Latin America, branches of América Móvil, which is owned by Mexican conglomerate Telmex, and Spain’s Telefónica dominate the industry. This dominance by the two conglomerates has resulted in Latin America’s high prices relative to other emerging markets and some developed countries, as well. Brazil has the highest monthly fees for service. Worldwide, Latin America has the second highest number of cellular subscriptions, after the Asia-Pacific region, and Chile and Argentina have the most mobile devices in Latin America. Chile has the highest concentration of mobile subscribers in the region with many people owning more than one device. However, owing to its large geographic and population sizes, overall telecommunications revenue in Brazil is higher than in any Latin American country.

Brazil

Brazil lays claim to the largest land mass, population, and economy in Latin America. Geographically, it is the fifth largest country in the world, only a bit smaller than the United States. Its population, 201 million people as of the end of 2010, is the fifth largest worldwide, behind China, India, the United States, and Indonesia. Brazil's economy, as measured by gross domestic product (GDP), is the seventh largest in the world.

Brazil's population is a melting pot that includes its indigenous people who were there before Portuguese colonialists arrived in 1500. The populations of Brazil comprises people from Portugal and other European countries, Africans (brought there as slaves, prior to abolition in 1888), the Middle East, and Japan, many of whom immigrated to Brazil in the 1900s.

Brazil has a stable, democratic government that peacefully transitioned from military control in 1989. Lack of civil strife and a wealth of natural resources are major contributors to its growing economy. Brazil's economic upswing began after 1994 when fiscal policies were initiated to control inflation. However, because of its reliance on revenue from commodities such as oil, agricultural products, and minerals, it is dependent on commodity prices which can fluctuate over time.

In addition, competition from China has resulted in declining exports for its low-priced manufactured goods, such as textiles, machinery, and metal products. In an attempt to promote its own products and manufacturing industry, Brazil has raised tariffs on imports. This has resulted in higher prices for imports that include equipment for upgraded mobile networks and mobile handsets. However, there is a large middle class and more than 80 percent of the country lives in cities; both of these factors help to create concentrations of populations with buying power. Infrastructure for mobile services and Internet access is improving in Brazil's largest cities.

Although 52 percent of the Brazilian population is in the middle class, there is still a large income disparity between the very wealthy and everyone else. Although 89 percent of the population is literate, the large quality gaps between schools in wealthy and middle-class districts and those in slums and rural areas are holding back growth in the middle class. The educational quality gap is resulting in fewer children from poor and rural areas receiving university educations. This is important because the size of the middle class directly impacts the number of people who can afford high-speed Internet access via wireless broadband.

Internet access is also skewed toward wealthier areas in large cities. At the end of 2011, only 39 percent of Brazilian households had broadband Internet access. Most of those were costly at about $50 monthly. According to the United Nations Public Administration Network news report issued on May 17, 2011, excerpted from Xinhua News, close to half of the households with Internet access had speeds of only 256Kbps. Most fixed-line broadband services, particularly higher-speed services, are concentrated in large cities in the Southeast, chiefly São Paolo and Rio de Janeiro. These services are largely based on Digital Subscriber Line (DSL) technology, with some based on cable modems. Lower-income areas are starting to achieve access via cyber cafés.

To increase broadband adoption, the Brazilian government announced a National Broadband Plan in 2010 to improve the availability and lower the prices of wired and mobile broadband in underserved areas. To that end, the government is subsidizing construction of fiber-optic networks and last-mile connections in these areas. It is also adding broadband connections to schools in underserved areas to foster online learning. The government's goal is to increase GDP by enabling more people to make online purchases and to improve businesses' access to broadband in smaller cites. In addition, Brazil's major phone operators are constructing a national fiber-optic backbone to enable high-speed mobile connectivity in time for its hosting of the 2014 World Cup and the 2016 Summer Olympics. Officials are expecting a spike in usage during these events along with increased roaming revenues.

Telecommunications was privatized in 1998. Prior to that, the government owned the main wireline provider, Telebras. As part of the privatization, Brazil opened the country to competition and granted spectrum licenses in each region to mobile providers. Many of these providers subsequently merged and there are now four main mobile carriers that control 90 percent of the market. There are smaller providers, as well, in outlying regions. Table 8-4 lays out a list of the largest mobile carriers in Brazil.

In all but the most remote areas of the Amazon in the northern and northeastern regions, almost every family has cellular service, which is for the most part based on the Global System for Mobile Communications (GSM) service. While there are more subscriptions than there are people, the overall penetration of mobile services is much lower with concentrations in the largest cities in Brazil's southeast. Of Brazil's 217 million wireless subscribers, 21.3 million had third-generation (3G) handsets by the end of June 2011. This total is growing quickly and the government plans to auction off more spectrum for 3G service. Vivo, the largest mobile operator, upgraded its network to HSPA+, a 3.5G advanced cellular technology, throughout much of its territory.

Table 8-4 Mobile Providers in Brazil

Mobile Provider	Brand Name	Owner	Notes
Vivo Participacoes	Vivo	Telefónica SA of Spain	Telefónica merged its fixed-line company Telesp with Vivo to save money on overhead and sell an integrated offering of fixed-line, Internet access, cable TV, and mobile services.
América Móvil	Claro	Telmex of Mexico	Created by the merger of four Brazilian mobile operators. Claro mobile services are offered throughout Latin America. Telmex also owns Embratel, Brazil's largest fixed-line, Internet access, cable TV, and satellite operator.
TIM Brasil	TIM	Telecom Italia Mobile of Italy	Telecom Italia also owns Intelig Telecomunicações Ltda, which operates a 9,300-mile fiber-optic network in Brazil.
Telemar Norte Leste	Oi	Telemar Participacoes of Brazil; Portugal Telecom 25.28%	Also offers Internet access and cable TV to individual and corporate customers. Parent company Telemar Participacoes merged its fixed-line entities, Brasil Telecom and Tele Norte Leste Participacoes, into a single entity with Telemar Norte Leste. All use Oi brand.
Nextel Brasil	Nextel Brasil	NII Holdings	Formerly part of Nextel, before it was acquired by Sprint. Offers services to corporate and individual customers in Argentina, Mexico, and Brazil. Plans to cover most of Brazil with new spectrum for 3G service.

In addition, mobile operator Oi has announced its plan to trial Long-Term Evolution (LTE) technology. The expectation is that LTE service will be available in time for the 2014 World Cup in Rio de Janeiro. Growth and opportunities for mobile services and new applications are expected to come from growth of mobile broadband on third- and fourth-generation networks. It is hoped that a growing middle class, improvements in education, and government investments in infrastructure will fuel this growth. Investments by foreign entities will also be an important source of growth and new industry for Brazil's strong economy.

SUB-SAHARAN AFRICA

Africa has the second largest number of mobile connections worldwide after the Asia-Pacific region. Africa's growth in mobile services has been triggered by the availability of lower-cost devices and services, improvements in mobile coverage, and its growing middle class. Part of this growth is attributed to the high proportion of users with more than one Subscriber Identity Module (SIM) card. Each SIM card is considered a single mobile connection.

Africa has the most potential for mobile subscriber growth. This is true despite the fact that there are large pockets of poverty and widespread unemployment, even in the fastest-growing African countries and those with relatively modern infrastructure. South Africa, which accounts for half of the telecom revenue in sub-Saharan Africa, had a 24 percent unemployment rate in January 2012. Sub-Saharan Africa is that portion of the continent that is south of the Sahara Desert. Northern Africa, which includes Algeria, Egypt, Libya, Morocco, and Tunisia, is considered part of the Arab world (see Figure 8-2).

In addition to unemployment, there is widespread corruption, and business is often negotiated through bribes. This makes it difficult for companies from countries such as the United States to conduct business. Corruption in governments damages economies because less tax revenue is available to create and update transportation and other types of infrastructure. Unfortunately, money that could be spent on subsidizing upgrades to fiber-optic networks often goes directly into the pockets of officials and private individuals instead. In addition to corruption, much of African commerce is hurt by high crime rates and civil unrest. Poverty is a major contributing factor to both of these conditions.

Despite these problems, the mobile industry in Africa is thriving but not as profitable as in locations where there is less poverty and higher rates for mobile services. Much of the growth in mobile services is expected in rural areas where wages are lower than in cities. This translates into low revenue per user. Because of the intense competition among the many providers in each country, the Average Revenue Per User (ARPU) is low. Per-minute rates are so low that they are affordable to all but the lowest-income residents. More than 95 percent of subscriptions are based on the prepaid

Figure 8-2 *The African continent.*

model by which subscribers pay in advance for service. For the vast majority of the population, mobile service is their first means of electronic communications. In most African countries, wireline, fixed telephone services are not widely available to residential consumers.

Although foreign investors own many of the largest phone companies, the largest mobile provider in Africa, MTN Group, Ltd., is headquartered in South Africa. It provides service in 21 African and Middle Eastern countries including Nigeria, Botswana, and Uganda. The two other large mobile providers in Africa are Bharti of India and

Vodacom, which is owned by the UK's Vodafone. French carrier France Telecom also has a large presence in Africa through its mobile subsidiary Orange.

Despite Africa's problems, many countries in Africa have a slowly growing middle-class population. Moreover, the area is rich in agricultural products such as coffee and tea. It is also flush with minerals and natural resources including oil and gold. African countries are also helped by direct foreign investments, aid efforts by governments and Non-Governmental Organizations (NGOs), and remittances sent by Africans who have emigrated to countries such as the United States, Europe, and even other countries within Africa.

Commerce has been aided by installation of new undersea cables in East, West, and Southern Africa that have enabled lower-cost Internet access. These undersea cables extend fiber-optic connections to Points of Presence (PoPs) in adjacent countries, benefitting each of these regions as well as countries directly connected to the undersea cables. Previously, business and commercial organizations paid thousands of dollars monthly for broadband Internet access. This is because broadband links had to be connected all the way back to Egypt or South Africa to reach the Internet and remote offices in other continents. The high costs and lack of facilities hampered day-to-day operations for many organizations.

Kenya

Kenya is considered the financial and transportation hub of East Africa. Its banks provide services for other countries in the region. While its economy was growing before 2007, it stagnated after post-election violence in 2007 that erupted due to accusations of fraud related to manually counted votes. Tourism, a major source of income, declined and hotels closed down after the election violence. Although it picked up again and more tourists resumed undertaking safaris to Kenya's national parks, recent kidnappings and murders of foreigners by Somalian militants may dampen tourism again. In addition, to avoid problems, future election results will be tallied electronically, making it more difficult to tamper with results.

Even though about 50 percent of the population is below the poverty line and a large income disparity still exists between the very wealthy and the rest of the population, there is a growing middle class and many Kenyans hope to provide a college education for their children. These parents often start saving as soon as they're married so that their children will have the money to attend one of Kenya's public universities. Remittances from family members that emigrated to other countries also provide a safety net for the population living below poverty levels. The high rate of poverty results in most mobile subscriptions that use prepaid services, which are less costly for customers and less profitable for carriers.

Elementary education is free throughout Kenya, and most children are educated to that level. However, until recently all secondary schools had fees. In some areas, the government is starting to offer free high school. There are both public and private universities in Kenya, with a limited number of scholarships. Some people attend evening classes at smaller colleges that provide additional training and certificates. As these graduates enter the labor force, there will be both a growing number of people in the workforce able to purchase high-end mobile services, and a labor force with the technical skills to develop sophisticated networks and applications.

In 2010, Kenya approved a new constitution that distributes power more evenly between the president and the parliament. Prior to this, the president selected his government ministers from the parliament and set the parliament's agenda. Under the new constitution, members of the parliament are not allowed to be part of the president's cabinet and the parliament sets its own agenda. It is hoped that these changes will enable the parliament to have better oversight and the wherewithal to combat corruption.

Interestingly, business and financial organizations pushed Kenya to modernize technology so that banks and insurance companies have access to the reliable Internet connections needed to conduct business. Kenya has also received support from China in the form of loans and technical expertise to upgrade facilities. Organizations in Kenya use a mix of satellite services and landline broadband for Internet access. For the most part, residential customers use mobile handsets for Internet access. However, this is changing in wealthy areas. Telkom Kenya has announced that it will offer fiber to the home in two wealthy suburbs of Nairobi, Kenya's capital. Broadband provider Jamii Telecom has announced plans for fiber to the home in 11 districts in Nairobi as well as other cities. Table 8-5 presents a list of the largest mobile carriers in Kenya.

Kenya has a vibrant, hard-working population and there are signs that the middle class is slowly growing. Also, it is upgrading its main highways and the maintenance on them has improved, allowing e-commerce deliveries to more easily reach consumers. This goes hand in hand with the network upgrades that enable potential customers to access e-commerce sites.

Advances in mobile services have enabled improved access to information and commerce. Many people, particularly those younger than 40, use Facebook, Twitter, text messaging, and e-mail. In urban areas, many people access these services over third-generation (3G) networks. However, the four main cellular providers are engaged in an intense price war that has resulted in lower ARPU.

Moreover, like Russia, the government has announced a plan for a public, private partnership, wherein private companies and the government will share the cost to build a next-generation, wholesale LTE network. They have stated their intention to subsidize this network as a way to make advanced mobile services available to a wider population than would be possible if each provider had to pay for upgrades to LTE. This is a more efficient way to use spectrum than splitting it up among multiple networks. However, it's not certain that this plan will succeed due to disagreements among the largest carriers about the type of spectrum to use for the initial build-out. Most of this spectrum is currently used for television broadcasts.

Kenya was one of the first countries in Africa to use mobile phones to transfer money, pay bills, and receive salaries. Safaricom, the former state-owned carrier, offered the first mobile payment and transfer system, which it named M-Pesa. Subscribers that sign up for an M-Pesa account are able to receive remittances transferred to them from jobs, customers, and relatives in other countries. They can also use the money transferred to their phone to make purchases, or they can go to a local Safaricom agent to change the e-cash into hard cash. They are also able to use their phone to transfer money to relatives in small rural villages. Much of the commerce in villages and small businesses is based on mobile payments.

Table 8-5 *Mobile Providers in Kenya*

Carrier	Brand Name	Ownership	Notes
Safaricom, Ltd.	Safaricom	Formerly government owned; government now owns 35%, Vodafone 20%, and remaining offered on the African Stock Exchange.	Provides fixed-line, Internet, and mobile services. Has conducted tests of LTE and plans to introduce LTE in the future.
Bharti Airtel	Airtel Kenya	Indian conglomerate Bharti	Bharti is the fourth owner of Airtel in ten years. Markets heavily in rural as well as urban areas.
Telkom Kenya	Orange Kenya	France Telecom	Plans to offer triple-play service (mobile, TV, and Internet access) in areas with fiber to the home. Currently is developing a 3G network.
Essar Telecom Kenya, Ltd.	Yu	Indian conglomerate, Essar	Network based on GSM and 2.5G, but no 3G spectrum or plans.

Nigeria

Nigeria, with its estimated population of 155 million to 162 million people (as of July 2011), is the most populous country in Africa. It is located in West Africa and is a little more than twice the size of California. Nigeria has the second largest economy in sub-Saharan Africa, after South Africa. Nigeria has had a multiparty, democratically elected, parliamentary form of government since 2007, when there was a peaceful transition from military to civilian rule. Prior to 2007, Nigeria had a history of civil wars among tribes. There is still intense rivalry between the poor, primarily Muslim, people in the north and the more industrial, primarily Christian population in the south. In addition, there was election violence and accusations of vote tampering following the 2011 nationwide elections.

Although Nigeria has a low rate of unemployment—less than 5 percent in 2010—inflation for that year was 13.9 percent. Furthermore, 50 percent of the population lives in rural areas where earnings, primarily from agriculture, are low and inflation eats away at buying power. Nigeria has other challenges, as well; there is extensive corruption and graft throughout the government. Electricity tends to be only sporadically operational, resulting in network and equipment outages, and its infrastructure—particularly roads—needs upgrades. These improvements would make it possible to attract and sustain industries that support and use high-capacity Internet access and mobile services.

There is close to universal primary education, and state-supported secondary schools are available. However, there are only 30 public universities supported by the 36 states and six federal universities. Both of these types of universities have far fewer available seats than there are people qualified to attend them. There are also private universities, and some students attend foreign universities. There are plans to build public polytechnic institutes where students will receive technical degrees. As Nigerian mobile operators upgrade their networks, mobile applications and Internet offerings will require a population with adequate income levels to use these services. Training and education as well as infrastructure upgrades are important steps in making this possible.

In 2010, the government announced plans to privatize the production and distribution of electricity in an attempt to improve infrastructure. In addition, to improve Internet access from mobile devices, mobile provider Etisalat Nigeria is using a loan from a consortium of eight Nigerian banks to extend its mobile network nationally. In 2011, another mobile provider, MTN Nigeria, announced a plan to invest $1 billion USD on improvements in fiber-optic capacity and acquisition of base stations to improve coverage of its mobile service.

While Nigeria has a robust mobile industry, it is still growing. According to the Nigerian Communications Commission, there were more than 129 million cell phone subscriptions as of the end of February 2012. Table 8-6 lists the largest mobile providers by market share. Despite competition, rates for mobile services are high compared to those in countries such as Kenya, Singapore, South Korea, and Malaysia. In addition, there were only 2.3 million lines of fixed-wired and wireless Internet access subscribers in the entire country as of February 2012. Of these services, 91.9 percent were based on GSM, 6.9 percent on CDMA, and only 1.19 percent on WiMAX, satellite, or fixed-wireline Internet access.

Table 8-6 Mobile Providers in Nigeria

Carrier	Brand Name	Ownership	Notes
MTN Nigeria Communications	MTN	MTN Group, 76%; private investors, 24%	Largest mobile company in Nigeria. Provides coverage to 86% of the population. The largest subsidiary of South Africa's MTN Group.
Globacom	Glo Mobile	Private company Mike Adenuga Group	Owned by a local Nigerian company, which is expanding into nearby countries.
Bharti Airtel	Airtel Nigeria	Indian conglomerate Bharti	In 2010, Bharti purchased all of Zain's mobile operators.
EMTS Limited	Etisalat	Etisalat of United Arab Emirates; private Nigerian investors	Plans to expand 2G and 3G for nationwide coverage.
M-Tel, Ltd.	Yu	Mobile arm of publicly owned fixed-line carrier NITEL	Due to failure to pay its debts, M-Tel might be liquidated.
Multilinks	Multilinks	Helios Investment Partners, a Nigerian company that owns Helios Towers Nigeria	Operates on CDMA technology. Has requested financial assistance from the government.
Starcomms, Ltd.	Starcomms	Nigerian publicly traded company	Starcomms uses 2G and 3G CDMA and lost subscribers in 2010.

Publicly owned Nigerian Telecommunications, Ltd. (NITEL) is one of two providers with wired infrastructure throughout Nigeria. The Nigerian government has attempted to privatize NITEL by putting it up for sale. However, to date, successful bidders have failed to make the required down payments and privatization has stalled. Because of the difficulty of earning profits in rural areas with low population densities that do not generate revenue required for investment in new facilities, many people believe that a public-private partnership will be required to subsidize offerings and upgrades in these areas. NITEL's mobile arm, M-Tel, has mounting debts and the lowest percentage of mobile customers in Nigeria.

The other provider of wired service in Nigeria is Global Communications, which offers service under the Glo-1 brand. Global Communications is an African-owned company that installed an undersea cable between the United Kingdom and Nigeria in 2010. The cable has additional landing points along western Africa in Ghana, Senegal, Mauritania, and Morocco from which it offers landline Internet access. This offering has increased bandwidth options for businesses in Nigeria as well as western Africa. See Chapter 4, "Carrier Networks," for information about undersea cables.

Commercial customers also access the Internet via Very Small Aperture Terminal (VSAT) satellite services, offered mainly by European providers. VSAT technology is a low-cost satellite service. Customers attach small dishes to their buildings that beam signals to and from satellites. The dishes are wired to customers' data center equipment.

Consumers for the most part access the Internet from third-generation (3G) mobile devices and fixed WiMAX. See Chapter 7, "Mobile and Wi-Fi Networks," for information on WiMAX and 3G services. Cyber cafés are a popular option as well for Internet access because they provide higher speeds than 3G mobile services.

EUROPE

Europe has a mature mobile market and excellent cell phone coverage. Its networks are based on GSM, and consumers take the ability to use their cell phone throughout the continent for granted. The mature market combined with declining voice usage has resulted in a lower Average Revenue Per User (ARPU) and fewer opportunities for growth. To date, revenue from data usage has not made up for the decline in revenue from voice calling. At the same time that average revenues are declining, carriers are faced with the need to invest in spectrum and equipment for higher-generation data services that add capacity to networks. Despite lower revenues per user, most operators have robust operating margins because of recurring monthly subscription fees.

Other than the Scandinavian countries and individual carriers in Austria, Denmark, Estonia, Germany, Poland, and Uzbekistan, Europe is behind Asia-Pacific and the United States in upgrading their networks to pre-fourth-generation (pre-4G) Long-Term Evolution (LTE). Rather, they are stretching their data networks' capacities by investing in High-Speed Packet Access (HSPA), High-Speed Packet Access Plus

(HSPA+), and Wi-Fi offloading. Wi-Fi offloading refers to using hotspots to carry a portion of a network's mobile data. HSPA is an advanced third-generation (3G) technology, and HSPA+ is variously described as 3.5G or pre-4G service. For more information about HSPA and HSPA+, see Chapter 7.

The major factor holding back implementations of LTE by additional carriers is the shortage of suitable spectrum. There are countries that have committed to holding auctions. France and Germany held 3G and 4G auctions in 2011. Some countries have committed to making these auctions technology-neutral by allowing carriers a choice of the type of mobile service to offer on the spectrum they win at auction.

The following is a partial list of carriers that currently offer LTE in Europe:

- TeliaSonera in Estonia, Norway, Sweden, Finland, and Denmark
- Telenor in Sweden
- Tele2 in Sweden
- MTS in Uzbekistan
- UCell in Uzbekistan
- T-Mobile in Austria and Germany
- Mobyland in collaboration with CenterNet in Poland

In addition to the aforementioned implementations of LTE, trials such as Telefónica's O_2 German subsidiary and Turkcell's in Turkey are being conducted. Besides spectrum shortages in some networks, 3G equipment is not fully depreciated. Thus, if these carriers implement a new technology, they will still have the expense of updating older equipment, which will lower their net profits.

Interestingly, in the Scandinavian countries, which have the highest concentration of LTE service, the number of fixed-broadband connections has shown no growth or a small decrease. Some subscribers, particularly young people who don't own homes, are substituting LTE service for fixed-broadband service. In the future, as capacities in 4G networks increase, this trend might result in more people substituting mobile service for fixed broadband.

The Role of the European Union

The European Union (EU), an economic and political union of 27 European countries, was formed to develop a common market through the standardization of monetary systems, external tariffs for countries outside of the Union, and the free movement of people and goods within the EU countries. Currently, people in EU countries can travel to other European countries without a passport. Not all member countries adhere to a single currency or a single external tariff. In addition to the common marketplace, the EU has developed and is in the process of working with member nations to establish regulations that conform to the 2009 Telecoms Reform on broadband, which was agreed to by the member nations.

The published goals of the Telecoms Reform are to increase the availability of broadband in rural areas, increase the speeds and availability of broadband, and establish a single European telecom market. While reforms that were initiated in the mid-1980s have resulted in a 30 percent reduction in broadband prices, there are still only a limited number of carriers with services throughout Europe. Moreover, although in many Western European countries more than 70 percent of households have Internet access, percentages in rural areas and Eastern Europe are much lower. The new reforms are geared toward establishing uniform rules so that carriers can more easily operate in multiple markets that have matching regulations. This is planned to encourage competition and innovation to increase service offerings throughout the EU. A quote from the introduction to the new rules published in December 2009 states the following:

> *Telecoms are more than ever central to our lives and work. Economic and social activities alike have come to rely on telecom services and infrastructure. …Moreover, the introduction (in the 1980s) of competition has raised standards of service all round, making former monopolies much more responsive to the needs of consumers.*

A key ingredient of the reforms is the functional separation rule that is designed to increase competition and consumer choice. This rule requires telecom operators to separate operation of their broadband networks from the sale of services. Different parts of the telephone companies will sell services to businesses and individuals and other parts will maintain the infrastructure and offer wholesale access to providers. This increases the number of ISPs that can operate without requiring each to invest in cabling to subscribers. To make sure there is adequate funding for infrastructure, telephone company investors and wholesale purchasers (ISPs) will be able to invest jointly in new fiber-optic cabling and electronics. Currently, much of the infrastructure is based on copper and microwave.

Other parts of the regulations include rules on network neutrality such that capabilities of the network are transparent and consumers have access to published minimum quality levels. Carriers will still have the ability to use network management techniques and set caps on the amounts of data that users can transmit. There are other regulations that cover privacy, the establishment of a new European Telecoms Authority, and more flexibility on spectrum use.

Expansion in Eastern Europe, Asia, and Africa

Due to the saturation of cell phones in Western Europe, large carriers have expanded by offering service in Eastern Europe, Asia, Africa, and Latin America. Eastern Europe offered opportunities after the fall of the Berlin Wall in 1989 and democratization in many of these countries. These events resulted in privatization of formerly government-owned incumbent telephone companies and openness to competition for telecommunications services. In addition, operators began modernizing their equipment. Improvements in economies resulted in populations eager for new mobile services. A similar phenomenon resulted in opportunities in many developing countries worldwide. Thus, the largest European operators offer services throughout Europe, Asia, Africa, North America, and Latin America. These operators offer fixed, landline services as well as mobile services.

The following cellular carriers headquartered in Europe are large conglomerates that offer services internationally and are among the ten largest carriers, worldwide.

Vodafone Group, PLC

UK-based Vodafone is the second largest wireless operator worldwide, after China Mobile. It offers services in more than 20 countries around the globe. Although it initially only offered mobile services, Vodafone now has fixed-line services in Germany, Italy, and Spain. It purchased these assets as a way to expand its offerings and increase revenues. Vodafone has aggressively offered new data services in Europe with which it hopes to offset decreases in voice revenue.

Vodafone has announced its intentions to move all of its DSL customers in Germany to LTE. It is doing this to avoid paying high interconnection fees to incumbent telephone company Deutsche Telekom for use of the last-mile copper lines between Vodafone's customers and its Digital Subscriber Line (DSL) equipment. Eliminating DSL will streamline Vodafone's German operations by enabling it to maintain a single network for all customers.

Although it has services in Asia, the Pacific, Africa, and the Middle East, two-thirds of its revenue originates in Europe. Its largest European subscriber bases are in the United Kingdom and Germany. In Europe, it has offerings in countries including the Netherlands, Germany, Greece, Italy, Romania, Spain, Switzerland, the Czech Republic, and the UK. Vodafone has noncontrolling stakes in Verizon Wireless in the United States and providers in Fiji and Kenya.

Vodafone has announced its intentions to concentrate on offerings in Europe, India, and sub-Saharan Africa. As a result, it has sold its minority stakes in certain Asian properties as well as a French mobile operator. It might also sell nonstrategic assets in other countries.

Telefónica Móviles, SA

Telefónica, the incumbent telephone company in Spain, is the largest mobile and fixed-line provider in Spain and the second largest mobile provider after América Móvil in Latin America. It has European operations under the brand name O_2 in the Czech Republic, Germany, Ireland, the Isle of Man, Slovakia, and the United Kingdom. Declining sales in Europe are being offset by growth in revenue in Latin America. By the end of 2011, 53 percent of Telefónica's sales were in Europe, and 47 percent were in Latin America. In Europe and Latin America, it operates under the brand name Moviestar. Telefónica's companies offer cable TV, fixed-line voice services, and Internet access.

Deutsche Telekom AG

As of the first quarter 2011, Deutsche Telekom was the seventh largest mobile operator in the world. It is the leading fixed-line operator in Germany and offers mobile services under the T-Mobile brand in Germany and in 15 other European countries. It also offers a "no-frills" brand for mobile, broadband, and Voice over Internet Protocol (VoIP) services called Congstar. It additionally owns a payment services provider, ClickandBuy, and a web hosting organization. In addition to selling services to individual residential customers, it also offers services to multinational organizations. The German government in conjunction with a state-owned bank owns 32 percent of Deutsche Telekom.

In 2011, Deutsche Telekom announced its agreement to sell its subsidiary in the United States, T-Mobile USA, to AT&T. T- Mobile USA had lost market share steadily throughout 2009 and 2010 and hasn't invested enough in spectrum or infrastructure to build out an LTE network which would enable it to compete more fully with AT&T and Verizon Wireless. In 2011, regulators in the United States turned down AT&T's merger request for Deutsche Telekom's largest subsidiary. Deutsche Telekom's losses in the United States contrast sharply with Telefónica's success in Latin America.

In an effort to lower costs, Deutsche Telekom formed a joint venture with France Telecom in 2010 to operate its mobile services under a new brand, Everything Everywhere in the United Kingdom. Everything Everywhere is the largest mobile provider in the United Kingdom. The consolidation has enabled the joint venture to operate far fewer base stations than the two organizations operated separately. France Telecom and Deutsche Telekom have also announced a joint venture to share 3G networks in rural areas in Austria. They are exploring additional ways to cooperate, such as partnering for the acquisition of 4G spectrum.

France Telecom SA

France Telecom's mobile brand is Orange SA. Orange sells mobile services in 12 European countries including the United Kingdom, Switzerland, and France. It is the third largest mobile provider in Europe. It has mobile customers in an additional 23 countries in Africa. It also offers fixed services to business and residential customers and owns undersea cable facilities. The French government owns about 27 percent of France Telecom. France Telecom sold its Swiss unit in 2012 and has put its minority stakes in Orange Austria and Sonaecom Portugal up for sale to focus its resources in the Middle East and Africa. In 2010 it purchased a stake in a mobile carrier in Morocco and in 2011 in one in Iraq.

Telenor Group

Norwegian phone company Telenor sells telecommunications equipment and voice and data services in addition to mobile services. Beyond its offerings in Norway and Sweden, it sells services in Denmark, Ukraine, Hungary, Thailand, Malaysia, Bangladesh, and Pakistan. It also has a minority ownership in Russian carrier Vimplecom.

The Russian Federation

The Russian Federation, more commonly referred to as simply Russia, is almost double (1.8 times as large) the geographic size of the United States and is the largest country in the world by landmass and the ninth largest in population. However, 90 percent of the population is concentrated in cities in the Western and Southwestern European regions. As shown in Figure 8-3, only 10 percent of Russia's land mass is in Europe and 90 percent is in Asia. However, Russia is often thought of as part of Europe because of the lopsided distribution of its population. Russia is actually a Eurasian country because it is in both Asia and Europe. The eastern region, Siberia, and the tundra are sparsely populated. Russia's large size and sparse population in the eastern region makes it costly to build nationwide networks.

Due to a variety of factors, Russia's population declined from the early 1990s to 2010. Despite this decline, Russia's economy is improving. This is due in part to

Figure 8-3 *The vast expanse of the Russian Federation.*

revenue from oil exports. Russia has large reserves of oil, and gas as well as minerals in sections of the Barents Sea in the Arctic region. However, weather conditions make production and mining efforts there quite costly. Much of Russia's economy depends on exports of oil and gas, and grain commodities. Thus, when global commodity prices drop, its economy fluctuates widely.

Close to 100 percent of Russian citizens have been educated and about 25 percent are in the middle class. However, wealth is disproportionately concentrated in the hands of a small portion of the population.

In terms of total mobile subscriptions, Russia has a mature mobile market. As of January 2011, there were 220 million mobile subscriptions spread over its 143 million people, but only 3 percent of these were on third-generation (3G) or newer networks. Thus, there is a limited potential for growth in the number of mobile subscribers. Revenue growth will come from the use of smartphones and computers for data services. However, the aforementioned disparity in wealth distribution has the potential to dampen consumer demand for enhanced mobile services.

The largest cell phone companies in Russia are Vimplecom, Mobile Telesystems (MTS), and MegaFon. Table 8-7 presents the largest mobile providers. But, there are many smaller providers located in the 83 regions into which Russia is divided. When spectrum is given out, it is allocated for use in particular regions. The Russian government has selected the mobile carrier Scartel, which operates under the brand name Yota, to build out a nationwide Long-Term Evolution (LTE) mobile network.

The government plan is for Vimplecom, MTS, and MegaFon as well as state-owned fixed-line operator Rostelcom to operate as Mobile Virtual Network Operators (MVNOs) on the Yota network. Providers that operate as MVNOs offer service on another carrier's network infrastructure. The MVNO bills customers, markets the service, and is able to add value-added services such as the ability to use mobile handsets to make payments and access apps. An advantage in this approach is that resources for building new infrastructure are needed for only one network. Four separate carriers will not be required to spend money building duplicate networks. Allowing the single 4G network to be shared ensures that there is competition among the operators to provide enhanced services, low prices, and good customer service.

As part of the MVNO agreement, Vimplecom, MTS, Rostelcom, and MegaFon will each have an option to purchase 20 percent of Yota in 2014. Yota has been building out a fourth-generation (4G) WiMAX network but has announced plans to convert it to LTE technology. It will bid on additional spectrum for LTE service. The government has announced that these auctions will be held in the second half of 2012. However, the military is now using this spectrum. Before Yota can take possession of the spectrum, the military services must be relocated to other spectrum. The government has tasked the four future MVNOs to negotiate an agreement with the military to cover the cost of the relocation.

Government support for building out a single advanced mobile network has the potential to result in lower prices for mobile broadband as carriers will not have to charge high prices to cover upgrade costs. The four carriers operating as MVNOs and Yota will essentially share these costs. High-capacity network services, if they're priced affordably, have the potential to benefit the economy by giving more people access to tools needed to conduct business electronically.

The Russian government is also using the carriers' agreement to build an LTE network as a way to stimulate its mobile equipment manufacturing industry. Some spectrum allocations have included provisions that Russian firms participate in the build-out of the LTE network. Russian Technologies State Corporation, which owns 25 percent of Yota, has stated plans to manufacture 4G phones. The Russian government is also negotiating agreements for joint ventures with foreign manufacturers such as Huawei and Samsung for the new network build-out. Nokia Siemens has signed a joint venture agreement with a Russian company to produce LTE equipment.

It's not clear if these combined agreements will be successful. These joint ventures might create delays in the build-out as manufacturers attempt to cooperate with one another. If the efforts to create a new network and make mobile Internet access as well as new services affordable are successful, the large Russian population and investors will both partake in wide-ranging benefits. It will also create opportunities for small carriers to offer services over infrastructure that they most likely do not have the resources to build on their own.

Table 8-7 Mobile Providers in the Russian Federation

Carrier	Brand Name	Ownership	Notes
MTS	MTS	Russian conglomerate Sistema, 54%	Has grown by purchasing mobile, fixed-line, broadband, and cable TV providers.
MegaFon	MegaFon	Russia's Telecom Holdings, 33.1%; Finnish/Swedish's TeleSonera, 43.8%; Russia's Alfa Group, 23.1%	Only carrier with spectrum licenses for all of Russia.
Vimpelcom	Beeline	Russian company Alfa Group; Norway's Telenor, 36.4%	Fifth largest carrier worldwide. Headquartered in Amsterdam.
Scartel	Yota	Telconet Capital Fund, 74.9%; Russian Technologies State Corporation, 25.1%	Russian Technologies is government controlled. It was established in 2007 to attract investments and develop military/industrial and technology products.
Rostelcom (Russian spelling Rostelkom)	Rostelcom	State telecom holding company Svyazinvest, 50.7%; the rest is publicly traded	Links between Russian carriers, undersea fiber cable, satellites, television broadcasting, Internet access, and cellular service. In 2010 merged with seven regional telecom firms.
Tele2	Rostov Cellular	Swedish mobile provider Tele2 AB, 100%	Rostov is known as the low-cost provider in areas in which it provides service.

The Vimplecom/WIND Telecom S.p.A. Merger

In a complex purchase arrangement, Vimplecom, the third largest mobile provider in Russia, purchased WIND Telecom in 2011. WIND Telecom is the third largest mobile provider in Italy. At the time of its purchase, it owned the largest mobile provider in

North Africa, Orascom. After the purchase was finalized, Vimplecom announced that it was divesting itself of the Orascom operations in Egypt and North Korea. It initially announced its intention to keep its Algerian unit, but is currently negotiating a price with the Algerian government that plans to nationalize it. To complicate matters, as of this writing, Vimplecom is in the midst of a tax dispute with the Algerian government and has been fined for foreign exchange violations.

As a result of its purchase of WIND Telecom, Vimplecom is now the fifth largest mobile provider in the world. It will have subscribers in 19 international markets, including Cambodia, Canada, Italy, Pakistan, Bangladesh, Ukraine, Vietnam, and Zimbabwe. Its offerings include fixed-line as well as mobile services.

SUMMARY

During the past decade, attracted by the potential for dramatic growth in mobile subscribers, large international carriers and local business people have invested heavily in mobile networks in Asia, Africa, Russia, and Latin America. There are many challenges in these endeavors. High rates of poverty and low wages in many of these areas have resulted in low per-minute rates with few minutes of use per person. Intense competition is another factor that keeps prices low. Countries such as India and Indonesia have nine or more providers. Moreover, the prevalence of prepaid rather than postpaid contracts results in high churn rates where subscribers frequently change carriers in hopes of saving money by taking advantage of special offers for new subscribers.

Mobile carriers in these countries hope to earn high revenue from growth in subscriber numbers or large numbers of customers, despite low average revenue per user. Although, profit margins might be low, the volume of customers often results in high monthly cash flow.

Internet access via mobile devices is the main area for growth in much of the world. Currently, the most common method of accessing the Internet in many areas of Asia and Africa is at Internet cafés. To make Internet access more widely accessible, carriers are expanding the availability of third-generation networks and trialing fourth-generation networks. Cooperation from governments is essential because these upgrades require new spectrum, permission to use existing spectrum for next-generation mobile protocols, and major capital investments.

Governments have the power to make spectrum available and allow it to be repurposed from only second-generation networks to high-capacity networks. They can also partner with carriers to fund network upgrades. Many have stated their intention to take these steps. They additionally have the ability to improve roads and electric service to increase the stability and ease of maintaining mobile networks.

Some governments recognize that decreasing the number of competitors and licensing fewer carriers increases the likelihood that mobile providers will be able to attract additional customers. The potential to attract customers improves the likelihood that providers will earn adequate profits to fund upgrades. In certain countries, governments have relaxed or stated their intentions to relax rules against mergers and restrictions that prevent carriers from providing nationwide coverage.

Governments play a vital role in not only promoting competition but also ensuring that there are not so many providers that few of them have an incentive to upgrade their networks. Mobile networks have the potential to lift the economy by providing a vehicle for carrying innovative services that create new business opportunities for entrepreneurs. However, they are capital-intensive businesses that require large investments and a stable infrastructure.

Glossary

2G (second-generation cellular service)

Based on digital access to cellular networks. GSM and CDMA are 2G cellular technologies.

3G (third-generation cellular service)

3G mobile standards specify techniques that are capable of supporting more voice traffic and broadband mobile multimedia (speech, audio, text, graphics, and video) services. There are three main 3G services, including WCDMA, CDMA2000, and UMTS TDD. *See also* **3GPP** and **3GPP2**.

3GPP (3rd Generation Partnership Program)

A collaborative group that is developing an agreement to jointly create technical specifications for maintaining LTE, GSM, GPRS, and EDGE and for evolving WCDMA and LTE networks. European, Asian, and North American telecommunications standards bodies formed the 3GPP.

3GPP2 (3rd Generation Partnership Program 2)

An analogous group to 3GPP, but it is working on evolving technical specifications for CDMA2000 networks.

10base-T

An IEEE specification for unshielded, twisted-pair cabling used for Ethernet LANs that transmit at 10Mbps. The distance limitation for 10base-T networks is 100 meters.

100base-T

An IEEE standard compatible with 10base-T for transmitting at 100Mbps over unshielded twisted-pair cabling on LANs.

802.11

A set of IEEE standards for LANs. 802.11a, 802.11b, and 802.11g are the most common ones and are used in homes to share Internet access, in enterprises, and in hotspots.

802.15.4

The IEEE standards upon which the ZigBee Alliance tests and certifies equipment, and adds functions to sensor networks.

802.20
A set of IEEE standards for wireless technology based on OFDM. Flarion, which is part of Qualcomm, builds 802.20 equipment.

8YY toll-free numbers
An abbreviation describing the format of the North American Numbering Plan for toll-free numbers. The first three digits of toll-free telephone numbers must be the number 8 followed by 0 or 2 through 9 for the second and third digits. When central office switches see the 8YY format, they request a database check to determine where the toll-free number should be routed.

adaptive bit rate streaming
The ability of equipment (encoders) used to stream video and multimedia content from the Internet to computers and mobile devices to adjust the bit rate dynamically to the user's processing capabilities and bandwidth availability.

ASCII (American Standard Code for Information Interchange)
The main 7-bit code personal computers use to translate bits into meaningful language. Most computers now use extended ASCII, which supports 8-bit codes. Each group of 8 bits represents a character. Computers can "read" one another's binary bits when these bits are arranged in a standard, uniform "language." ASCII is the most commonly used computer code.

access fees
Carriers pay access fees to local telephone companies for transporting long-distance traffic to and from local customers. The FCC sets access fees for interstate traffic, and state utility commissions set access fees for intrastate traffic. They are intended to offset the costs that local phone companies incur in providing links to local customers, but they have been decreasing, and residential and business customers are paying some of these costs in the form of monthly charges called Subscriber Line Charges (SLCs). VoIP traffic is exempt from access fees.

ACD (Automatic Call Distribution)
Equipment and software that distribute calls to agents, based on parameters such as the agent who has been idle the longest. ACDs are part of telephone systems or adjuncts to telephone systems. ACDs are also referred to as contact centers. *See also* **contact centers**.

ANI (Automatic Number Identification)
The business or residential customer's billing number. Customers such as call centers pay for callers' ANIs to be sent to them simultaneously with incoming 800 and 888 and other toll-free calls.

APs (Access Points)
These contain antennas and chips with 802.11a, 802.11b, 802.11g, or 802.11n air interfaces for 802.11 wireless LANs. Access points translate between radio frequencies and Ethernet signals for cabled networks. An access point has similar functions to base stations for cordless home phones.

API (Application Programming Interface)
Software used to translate programming code between two different programs. An API can be used when an application at an enterprise accesses an application on the cloud.

architecture
Defines how computers are tied together. Some vendors refer to the architecture of their equipment in terms of the growth available and the hardware and software needed for their systems to grow.

ATM (Asynchronous Transfer Mode)
A high-speed switching technique that uses fixed-size cells to transmit voice, data, and video. A cell is analogous to envelopes that each carry the same number of bits. Used mainly in older networks.

band re-farming
The reuse of portions of spectrum for more advanced mobile protocols. Many countries are re-farming spectrum originally used only for older second-generation services to newer fourth-generation technologies.

backbone
A segment of a network used to connect smaller segments of networks together. Backbones carry high concentrations of traffic between on and off ramps to networks.

backhaul
A term used mostly to describe the links between antennas at base stations and mobile central offices, and services in the cellular networks core. Traffic and signaling information is backhauled from where it enters the network to the mobile core, and vice versa.

bandwidth
The measure of the capacity of a communications channel. Analog telephone lines measure capacity in hertz (Hz), the difference in the highest and lowest frequency of the channel. Digital channels measure bandwidth in bits per second (bps).

BGP (Border Gateway Protocol)
A routing protocol with more than 90,000 addresses. Used by carriers to route packets on the Internet. BGP enables routers to determine the best routes to various destinations.

bill and keep
A carrier-to-carrier billing method that eliminates the requirement for carriers to bill each other access fees. It is used by billing companies only to bill carriers that carry less traffic than carriers with whom they exchange traffic.

bit error rate
The percentage of bits received in error in a transmission.

blade
Circuit boards are often referred to as "blades" when they are dense, such as when they have many ports (connections) or software for a specialized application such as security.

Bluetooth
A set of standards for special software on low-cost, low-powered radio chips that enables devices to communicate with one another over a short-range wireless link. Bluetooth eliminates cable clutter between computers and peripherals in offices and supports wireless headsets for mobile handsets.

BOC (Bell Operating Company)
One of the 22 local Bell telephone companies owned by AT&T Corporation prior to 1984. Examples of Bell Operating Companies are Michigan Bell, Illinois Bell, and Pac Bell. Bell Operating Companies are now part of AT&T Inc., CenturyLink, and Verizon Communications.

border elements
Another name for media gateways. *See also* **media gateways**.

bps (bits per second)
The number of bits sent or received in one second.

BRI (Basic Rate Interface)
The ISDN interface made up of two B channels at 64 kilobits each and a signaling channel with a speed of 16 kilobits.

bridge
A device that connects local or remote networks together. Bridges are used to connect small numbers of networks. Bridges do not have routing intelligence. Organizations that want to connect more than four or five networks use routers.

broadband
A data transmission scheme in which multiple transmissions share a communications path. Cable television uses broadband transmission techniques.

broadband wireless access
Provides similar capabilities as DSL, cable modems, T1/T3/E1/E3, and other broadband technologies using wireless media rather than cabling. WiMAX and LTE can be used for broadband wireless access service.

broadcast
A message from one person or device forwarded to multiple destinations. Video and e-mail services have broadcast features whereby the same message can be sent to multiple recipients or locations.

BTA (Basic Trading Area)
A relatively small area in which the FCC allocates spectrum. There are 491 basic trading areas in the United States.

CAP (Competitive Access Provider)
Originally provided midsize and large organizations with connections to long-distance providers that bypassed local telephone companies. CAPs are now often referred to as Competitive Local Exchange Carriers (CLECs) or competitive providers.

CCIS (Common Channel Interoffice Signaling)
A signaling technique used in public networks. Signals such as those for dial tone and ringing are carried on a separate path from the actual telephone call. CCIS allows for telephone company database queries used in features such as caller ID, call forwarding, and network-based voicemail. CCIS channels are also used for billing and diagnosing public network services.

CDMA (Code-Division Multiple Access)
An air interface used to transmit digital cellular signals between handheld devices and cellular carriers' networks. CDMA assigns a unique code to every voice and data transmission by using a channel of a particular carrier's airwaves. CDMA is a spread-spectrum technology that is used by Verizon Wireless, Sprint, and South Korean carriers such as SKT.

CDMA2000 (Code-Division Multiple Access 2000)
A 3G technology for carrying high-speed data and multimedia traffic on cellular networks.

CDMA2000 1X (Code-Division Multiple Access 2000)
The earliest version of the CDMA2000 3G technology for carrying high-speed data and multimedia traffic on cellular networks.

CDMA2000 1xEV-DO (Code-Division Multiple Access 2000 Data Optimized or Data Only)
A later, higher-data-rate version of CDMA2000 1X 3G technology for carrying high-speed data and multimedia traffic on cellular networks.

central office
The site in the Public Switched Telephone Network with the local telephone company's equipment that routes calls to and from customers. It also has equipment that connects customers to Internet service providers and long-distance services.

channel
A path for analog or digital transmission signals. With services such as ISDN, T1, and T3, multiple channels share the same one or two pairs of wires or fiber.

CIC (Carrier Identification Code)
The four-digit code (previously three digits) assigned to each carrier for billing and call-routing purposes. AT&T's CIC is 0288. If someone at a pay telephone dials 1010288 and then the telephone number she is calling, the call is routed over the AT&T network.

CIR (Committed Information Rate)
A term used in frame relay MPLS networks to indicate the speed of the transmission guaranteed for a customer. *See also* **MPLS**.

circuit switching
The establishment—by dialing—of a temporary physical circuit (path) between points. The circuit is terminated when either end of the connection sends a disconnect signal by hanging up.

CLEC (Competitive Local Exchange Carrier)
A competitor to incumbent local telephone companies that has been granted permission by the state regulatory commission to offer local telephone service. CLECs compete with the incumbent telephone company. CLECs are also simply called local telephone companies.

CLID (Calling Line ID)
The number that identifies the telephone number from which a call was placed. For most residential customers, the calling line ID is the same as their billing number, their Automatic Number Identification (ANI).

CO (Central Office)
The location that houses the telephone company switch that routes telephone calls. End offices are central offices that connect end users to the Public Switched Telephone Network.

compression
The reduction in size of data, image, voice, or video files. This decreases the capacity needed to transmit files.

concatenation
The linking of channels in optical networks so that voice or video is transmitted as one stream. This is done to ensure that there are no breaks in the transmission.

connectionless service
The Internet protocol is connectionless. Each packet travels through the network separately. If there is congestion, packets are dropped. Packets are reassembled at their destination.

contact center
Another term for automatic call distribution. The term *contact center* implies that call centers have the capability to respond to e-mail and facsimile as well as voice calls.

convergence
The use of one network for voice, data, and video.

cordless
Cordless telephones provide portability, mainly within homes and apartments.

core networks
The portions of carrier and enterprise networks that carry the highest percentage of traffic, and where switches and routers connect to other switches and routers rather than to customers. High-speed core routers are located in core networks.

CPE (Customer Premises Equipment)
Telephone systems, modems, terminals, and other equipment installed at customer sites.

CSU/DSU (Channel Service Unit/Data Service Unit)
A digital interface device that connects customer computers, video equipment, multiplexers, and terminals to T1/E1 and T3/E3 lines.

CTI (Computer Telephony Integration)
CTI software translates signals between telephone systems and computers so that telephone systems and computers can coordinate sending call routing and account information to agents in contact centers.

CWDM (Coarse Wavelength-Division Multiplexing)
A multiplexing technology standard that enterprises and carriers deploy to connect corporate sites to public networks and to bring the capacity of fiber closer to residential neighborhoods. It carries up to eight channels of traffic on a single fiber pair.

dark fiber
Fiber-optic cables without any of the electronics (that is, multiplexers and amplifiers). Carriers can lay dark fiber and add SONET, Gigabit Ethernet, and wavelength-division multiplexers later.

DCE (Data Circuit-terminating Equipment)
A communications device that connects user equipment to telephone lines. Examples include modems for analog lines and CSUs for digital lines.

dedicated line
A telephone line between two or more sites of a private network. Dedicated lines are always available for the exclusive use of the private network at a fixed, monthly fee.

de-duplication
A method of compression that removes changes in files sent between two sites where each site has a copy of the file as it was originally sent. De-duplication sends only changes each time after the original transmission. The receiving end adds the changes and puts the file back together.

DID (Direct-Inward Dialing)
A feature of local telephone service whereby each person in an organization has his own ten-digit telephone number. Calls to DID telephone numbers do not have to be answered by onsite operators. They go directly to the person assigned to the ten-digit DID telephone number.

DiffServ (Differentiated Services)
Used in routers to tag frames. The tags request a particular level of service on the Internet and other IP-based networks.

DLC (Digital Loop Carrier)
Used to economically bring fiber closer to customers. Carriers run fiber cabling from central offices to DLCs and they lay twisted-pair copper cabling from DLCs to customers.

divestiture
In January 1984, Divestiture deregulated long-distance service in the United States. It separated the former AT&T from its 22 local Bell telephone companies. Agreement on Divestiture was reached by the Justice Department, which negotiated an antitrust settlement with the former AT&T, called the Modified Final Judgment.

DNIS (Dialed-Number Identification Service)
The service used to identify and route toll-free and 900 numbers to particular agents or devices within a customer site. For example, if a customer has multiple 800 numbers, the network provider routes each toll-free number to a different four-digit number at the customer's telephone system. The onsite telephone system then routes the call to a particular group of agents, voice response system, or department.

DNSSEC (Domain Name Service Security Extensions)
An Internet security standard for preventing users from using other organizations' domain names, which is also known as *spoofing*. Disguising domain names makes it more difficult to track the origin of traffic.

domain name
Everything after the @ sign in an e-mail address. It includes the host computer, the organization's name, and the type of organization (for example, *.com* for commercial and *.edu* for educational). Both .com and .edu are top-level domain names. The domain name can also designate the country, such as .bo for Bolivia. A domain name is part of the TCP/IP addressing convention.

DoS (Denial-of-Services) attack
An attack by which hackers bombard networks with thousands of packets intended to disrupt the capability of the attacked network to function.

Downlink (DL)
On broadband and mobile networks, the downlink portions are those that carry traffic from the carrier to the customer.

downloading
Receiving an entire file from another location. When music is downloaded, the entire music file must be downloaded to the computer's hard drive before it can be played.

DS-0 (Digital Signal level 0)
A transmission rate of 64Kbps. This refers to one channel of a T1, E1, E3, T3, fractional T1, or fractional T3 circuit.

DS-1 (Digital Signal level 1)
The T1 transmission rate of 1.54Mbps. There are 24 channels associated with DS-1 or T1.

DS-3 (Digital Signal level 3)
The T3 transmission rate of 44Mbps over 672 associated channels. (T3 is equivalent to 28 T1s.)

DSP (Digital Signal Processor)
Compresses (shrink the number of bits required for) voice and video, performs digital-to-analog and analog-to-digital voice conversions, and packetizes voice and video in real time for IP networks.

DTE (Data Terminal Equipment)
Devices that communicate over telephone lines. Examples include multiplexers, PBXs, key systems, and personal computers.

DVB (Digital Video Broadcasting)
A standard approved by the European Telecommunications Standards Institute (ETSI). It has lower resolution than HDTV.

DWDM (Dense Wavelength-Division Multiplexing)
A way of increasing the capacity of fiber-optic networks. DWDM carries multiple colors of light, or multiple wavelengths, on a single strand of fiber. Also known as Wavelength-Division Multiplexing (WDM).

E1
The European standard for T1. E1 has a speed of 2.048 megabits with 30 channels for voice, data, or video, plus one channel for signaling and one for diagnostics.

E3
The European standard for T3. E3 has a speed of 34.368Mbps with 480 channels. It is equivalent to 16 E1 circuits.

E-911 (Enhanced 911)
The capability for agents who answer 911 calls to receive the callers' phone numbers and locations.

EDGE (Enhanced Data Rates for Global Evolution)
EDGE mobile services offered by cellular carriers have higher data rates than second-generation cellular networks. EDGE is often used by carriers as they transition to higher-data-rate, third-generation mobile service.

end offices
The central offices connected to end users and to tandem central offices. Most end offices are based on circuit switching, but they are slowly being converted to *softswitch* technology to carry VoIP.

endpoint
Any device connected to LANs, such as computers, printers, and VoIP telephones.

Ethernet
Based on the 802.3 standard approved by the IEEE. It defines how data is transmitted on and retrieved from LANs. It is used by devices such as personal computers to access the LAN and to retrieve packets carried on the LAN.

Exabyte (EB)
A unit of measurement to indicate the number of bytes in storage networks. An Exabyte is equal to 1,000,000,000,000,000,000 bytes or 1 billion gigabytes. A byte is equal to 8 bits, or one character.

FDDI (Fiber-Distributed Data Interface)
An ANSI-defined protocol in which computers communicate at 100Mbps over fiber-optic cabling. FDDI can be used on backbones that connect LAN segments together. It is not widely used.

fiber-optic cable
A type of cable that is made from glass strands rather than copper wire. The key advantage of fiber-optic cabling is that it is nonelectric. Thus, it is immune from electrical interference and interference from other cables within the same conduit. Fiber-optic cabling can be used for higher-speed transmissions than twisted-pair copper cabling.

Fibre Channel protocol
Used in storage area networks and data centers for gigabit-speed, highly reliable, short-distance access to devices such as disks, graphics equipment, video input/output devices, and storage devices that hold massive amounts of data.

firewall
Software and hardware that prevents unauthorized access to an organization's network files. The intention is to protect files from computer viruses and electronic snooping.

fixed mobile convergence
The capability to use the same handset or portable computer for Wi-Fi as well as mobile voice and data sessions. For voice calls, it is the capability to continue the call when moving; for example, from a hotspot or home to a cellular network, and vice versa.

fixed wireless
Wireless service between fixed points. Generally, these are between an antenna on a tower and a dish on a business or residential customer's building. It is also used to connect two buildings together as a lower-cost option than running cabling. Used most often in rural or hard-to-cable areas.

fractional T1
A less expensive T1 access scheme in which the customer pays for use of just a fraction of the 24-channel capacity of T1 lines. The most common capacities are 2 channels = 128Kbps, 4 channels = 256Kbps, and 6 channels = 384Kbps.

fractional T3
A less expensive T3 access scheme in which the customer pays for a fraction of the 672-channel capacity of T3 lines. For example, it might have the capacity of six T1s or 144 channels. Fractional T3s are cheaper than a full T3 line.

frame relay network
An older public virtual data network commonly used for LAN-to-LAN communications and Internet access. Customers, usually small and midsize organizations, connect to frame relay services over T1 or DSL lines from each of their locations to the frame relay network. They are not suitable for voice or video and are slower than MPLS networks.

FTP (File Transfer Protocol)
A part of the TCP/IP suite of Internet protocols. It is software that lets users download files from a remote computer to their computer's hard drive.

gateway
Allows equipment with different protocols to communicate with one another. For example, gateways are used when incompatible video systems are used for a video conference.

GGSN (GPRS Gateway Support Node)

Converts 3G data packets to those compatible with GPRS, the Internet, and other data networks, and vice versa.

Gigabit Ethernet

A high-speed service used for site-to-site carriers' backbone networks, metropolitan area networks, Internet access, and in enterprise internal networks. These networks operate at 1- or 10Gbps.

gigabits per second

Billions of bits per second (Gbps). Fiber-optic cables carry signals at this speed.

GPRS (General Packet Radio Services)

A cellular data-packet network service. Upgrades to digital cellular networks are required to provision the service. This is an "always on" data service that users do not have to dial into to access. Its data rates are lower than EDGE and 3G protocols.

GPS (Global Positioning System)

Used for locational tracking purposes. For example, many wireless E-911 systems are based on GPS satellites along with equipment at a carrier's cell stations and special handsets.

GSM (Global System for Mobile Communications)

The most widely deployed cellular service, worldwide. It is a digital service that was first used in Europe in the 1990s.

H.320

The standard for enabling video conference equipment from multiple vendors to communicate with each other by using ISDN service.

H.323

An ITU-based standard for sending voice via IP. H.323 was originally developed for video conferencing.

H.324

An ITU standard for sending video, voice, and data between devices over a single analog, dial-up telephone line using a 28.8Kbps modem. Compression is used on the voice, video, and data.

HBA (Host Bus Adapter)

Used to connect Ethernet switches to networks running Fibre Channel protocols. *See also* **Fibre Channel protocol**.

headend

The control center of a cable television system where incoming video signals are received and converted into a format compatible for transmission to subscribers and combined with other signals onto the cable operator's fiber infrastructure.

HDTV (High-Definition Television)

A standard for digital high-resolution television video and surround sound audio.

home page

The default first page of an Internet web site. A home page is analogous to the first page and table of contents of a book.

hotspot

A public area where people with Wi-Fi–equipped laptops or personal digital assistants can access the Internet. Access might be free or available for monthly or daily rates.

HTML5 (Hypertext Markup Language 5)

A language for structuring browsers and web sites. The World Wide Web Consortium (W3C) specifies the standard. Its goal is to make browsing the Web from mobile devices faster, particularly for accessing video and other applications directly from browsers without using specialized plug-in languages. Apple uses it on its mobile devices in competition with the proprietary Adobe Flash.

hub

Prior to the use of switches on LANs, each device (such as computers and printers) was wired to the hub, generally located in the wiring closet. Hubs enabled LANs to use twisted-pair cabling rather than more expensive, harder-to-install and move coaxial cabling. Hubs are sometimes referred to as concentrators.

HTTP (HyperText Transfer Protocol)

The protocol used to link Internet sites to one another. For example, HTTP provides links to servers containing text, graphical images, and videos.

ILECs (Incumbent Local Exchange Carriers)

The former Bell and independent telephone companies that sell local telephone service. This term differentiates incumbent telephone companies that were the providers of telephone service prior to 1996 from competitors such as Paetec, XO Communications, and tw telecom.

IMS (Internet Protocol Multimedia Subsystem)

Enables applications for voice, video, and online games to be stored, billed for, and accessed on a common IP platform available from mobile as well as wired networks.

Indefeasible Right of Use (IRU)

Long-term lease for fiber-optic cable runs. IRUs are analogous to condominium arrangements. One organization lays the cable and leases it to another carrier for its exclusive use.

independent telephone company

An incumbent local telephone company that was never a part of the former AT&T's Bell system. Examples of independent telephone companies are Frontier Corporation and Cincinnati Bell, Inc.

instant messaging

The ability to exchange e-mail in near-real time without typing in an address. Users merely click an icon representing the user to whom the message is intended, type a message, and then click Submit (or press the Return key) to send the message.

intermodal competition

Competition between services based on different media and technology. For example, mobile services compete with wireline services for local and long-distance calling. Cable TV companies compete with telephone companies such as AT&T and CenturyLink.

Internet

The Internet—with a capital I—is an entity composed of multiple worldwide networks, tied together by a common protocol, TCP/IP.

intranet

The use of web technologies for internal operations. Intranets are used by organizations as a way to make corporate information and applications readily accessible by employees. An example is a corporate telephone directory that can be accessed by a browser.

inverse multiplexer

Instead of combining individual channels into one "fat" pipe, which is what a multiplexer does, an inverse multiplexer separates out channels into smaller "chunks." Inverse multiplexers are used for video conferencing, where the 24 channels might be transmitted in groups of six channels at a speed of 386Mbps.

IPv4 (Internet Protocol version 4)

An older addressing format for networks. Each device on an Internet network is assigned a 32-bit IP address. This limits the total number of addresses available.

IPv6 (Internet Protocol version 6)

A newer Internet protocol format that specifies 32-bit IP addresses. This increases the number of addresses available in networks and on the Internet. IPv6 also has additional security.

IPsec (Internet Protocol Security)

A protocol that establishes a secure, encrypted link to a security device at the carrier or the enterprise. It is used for remote access to corporate services (such as e-mail) in conjunction with VPNs.

ISDN (Integrated Services Digital Network)

A digital network standard that lets users send voice, data, and video over one telephone line from a common network interface.

ISP (Internet Service Provider)

An organization that connects end users to the Internet via broadband, mobile networks, and dial-up telephone lines. ISPs often own Internet backbone networks. ISPs supply services such as voicemail, hosting, and domain name registration.

IXCs (Interexchange Carriers)

The long-distance companies that sell toll-free 800, international, data networking, and outgoing telephone service on an interstate basis. They now also sell local telecommunications services.

Java

A programming language created by Sun Microsystems. Multiple types of computers can read Java programs. They increase the power of the Internet because programs written in Java (called applets) can be downloaded temporarily by client computers. They do not take up permanent space on the client hard drive. Interactive games can use Java programs.

LAN (Local Area Network)

Enables computer devices such as personal computers, printers, alarm systems, and scanners to communicate with one another. Moreover, LANs allow multiple devices to share and have access to expensive peripherals such as printers, firewalls, and centralized databases. A LAN is located on an individual organization's premises.

LATA (Local Access Transport Area)

Upon divestiture in 1984, LATAs were set up as the areas in which Bell telephone companies were allowed to sell local telephone services. LATAs cover metropolitan statistical areas based on population sizes. For example, Massachusetts has two LATAs and Wisconsin has four, but Wyoming, which has a small population, has one LATA. LATAs are sometimes used for billing telephone calls in the United States.

Layer 4
One of the seven layers of the OSI model. Layer 4 is the Transport layer that routes and prioritizes packets, based on the source of the packet, the destination port number, the protocol type, and the application. For example, Layer 4 devices can prioritize voice and video so that networks using IP for voice and data can handle voice without the delays and lost packets associated with lower-level protocols.

LDAP (Lightweight Directory Access Protocol)
A directory protocol that describes a uniform way of organizing information in directories. Examples of LDAP directories include the address books in e-mail systems. LDAP enables companies to use one central directory to update multiple corporate directories. They also facilitate single sign-on to access different applications on corporate intranets.

leased line
Analogous to two tin cans with a string between two or more sites. Organizations that rent leased lines pay a fixed monthly fee for the leased lines that are available exclusively to the organization that leases them. Leased lines can be used to transmit voice, data, or video. They are also called private or dedicated lines.

LEC (Local Exchange Carrier)
Any company authorized by the state public utility commission to sell local telephone service.

local loop
The telephone line that runs from the local telephone company to the end user's premises. The local loop can use fiber, copper, or wireless media.

LUN (Logical Unit Number)
An identifier in Storage Area Networks (SANs). It identifies the particular database stored in a computer disk. LUNs are part of the Fibre Channel protocol used in SANs.

LTE (Long-Term Evolution)
A 4G mobile protocol that uses packet switching to carry voice, data, and multimedia traffic more efficiently than earlier protocols. It will eventually support broadband speeds of up to 100Mbps. LTE was developed by the 3rd Generation Partnership Project.

MAN (Metropolitan Area Network)
A network that covers a metropolitan area such as a portion of a city. Hospitals, universities, municipalities, and large corporations often have telephone lines running between sites within a city or suburban area.

Mbps (millions of bits per second)
A transmission speed at the rate of millions of bits in one second. Digital telephone lines measure their capacity or bandwidth in bits per second.

media gateways
Contain Digital Signal Processors (DSPs) that compress voice traffic to make it smaller so that it can be carried more efficiently. In addition, media gateways are equipped with circuit packs with ports for connections to traditional circuit-switched analog and T1 trunks. Thus, they are used to link converged IP networks to Public Switched Telephone Networks.

media servers
Specialized computers that play announcements and generate ring tones in corporate telephone systems and converged public networks. In corporate VoIP systems, they control call processing.

media servers for homes (home servers)
PCs or separate devices that store content, music, photos, movies, or TV shows that can be distributed over home networks to home entertainment equipment.

mesh networks
Networks in which every device is connected to every other device. Community wireless networks and sensor networks often use variations of mesh networks, as does the military when it sets up communications facilities in war zones. Mesh networks are also referred to as multipoint-to-multipoint networks.

microwave wireless services
Wireless services with short wavelengths operating in the frequency range of about the 890MHz to 60GHz bands. It is a fixed point-to-point wireless technology used to connect two points. Line of sight is required between microwave towers. For example, if there is a tree blocking the view between the towers, the service is inoperable.

middleware
Software used to translate between disparate systems. It translates between the hardware (set-top devices) and network protocols and the applications in satellite TV and cable TV networks. Middleware also enables interactive television applications from different developers to work with set-top box hardware from a variety of manufacturers. Thus, applications don't have to be designed differently for each type of device with which they interact.

millimeter wireless services
Operate at microwave and higher frequencies. Millimeter refers to the very short wavelengths of high-frequency services. Some next-generation mobile services are implemented on millimeter airwaves. The wavelength is the distance from the highest or lowest point of one wave to the highest or lowest point of the next wave.

MIMO (Multiple-Input Multiple-Output) antennas
MIMO antennas simultaneously transmit multiple streams at different frequencies within a single channel. This improvement is analogous to the increased capacity on a multilane highway versus a road with a single lane. MIMO antennas are used on 802.11n (Wi-Fi) WLANs, LTE, and WiMAX networks.

mobile wireless services
Provide mobility over wide areas by using services such as cellular, as in cities, states, countries, and in some instances, internationally.

MPLS (Multi-Protocol Label Switching)
Used to increase router speeds and prioritize packets. Short, fixed-length "labels" instruct routers how to route each packet so that the router does not have to examine the entire header of each packet after the first point in the carrier's network. Voice and video can have tags that classify them with a higher priority than data bits.

MSOs (Multiple System Operators)
Large cable TV operators, such as Comcast and Time Warner Cable, with cable franchises in many cities.

MTA (Major Trading Area)
A region that includes multiple cities or states. They are made up of some of the 491 BTAs. The FCC auctions off spectrum in both BTAs and MTAs.

MTSO (Mobile Telephone Switching Office)
A central office used in mobile networks. They connect cellular network calls to the PSTNs, and vice versa.

multicasting
The transmission of the same message from a single point to multiple nodes.

multiplexing (muxing)
A technique in which multiple devices can share a circuit. With multiplexing, carriers do not have to lay cabling for each computer that communicates. T1 multiplexers and fiber multiplexers enable many devices to share strands of fiber, air waves, and copper cabling.

MVNOs (Mobile Virtual Network Operators)
MVNOs such as Tracfone and cable TV operators resell cellular service on cellular carriers' networks.

NAT (Network Address Translation)
Translates external IP addresses to internal IP addresses, and vice versa. Carriers and enterprises use different internal and external IP addresses to conserve public addresses and to shield IP addresses from outside sources.

NEBS (Network Equipment Building Standards)
Requirements published in a Bellcore (now Telcordia) technical reference for products placed in a central office environment. Bellcore is the former Bell Telephone central research organization. There are eight standards referring to issues such as environmental, electrical, and cabling requirements, as well as resistance to natural disasters such as earthquakes.

network
An arrangement of devices that can communicate with one another. An example of a network is the PSTN over which residential and commercial telephones and modems communicate with one another.

NAS (Network-Attached Storage)
The use of servers for storing files that can be accessed directly by computers located on the LAN. NAS is less costly than traditional SANs.

nonblocking
Switches that have enough capability for each connected device to communicate at the same time up to the full speed of the port to which it is connected.

number pooling
Allows local carriers to share a "pool" of telephone numbers within the same exchange. Number pooling is a way to allocate scarce telephone numbers more efficiently. Without pooling, a single local telephone company has rights to the entire 10,000 block of telephone numbers, but it might only use a portion of the block.

OSS (Operation and Support Service)
Hardware and software that carriers use for billing, maintenance, and changes to customer features.

packet switching
A network technique that routes data in units called packets. Each packet contains addressing and error-checking bits as well as transmitted user data. Packets from a transmission can be routed individually through a network such as the Internet and be assembled at the end destination.

PAN (Personal Area Network)
Operates over small areas within rooms and buildings. Bluetooth and RFID are examples of PANs.

Petabyte (PB)
A unit of measurement. One petabyte equals 1,000,000,000,000,000 bytes or 1,000 gigabytes. A byte equals eight bits.

PBX (Private Branch Exchange)
Computerized, onsite telephone system located at an organization's premises. PBXs route calls both within an organization and from the outside world to people within the organization, and vice versa.

PCMCIA (Portable Computer Memory Card Industry Association)
An industry group that has developed a standard for peripheral cards for portable computers. PCMCIA cards are used for functions such as modems and Wi-Fi services, and for additional memory.

PCS (Personal Communications Service)
Originally referred to 2G digital mobile services that use spectrum in the higher frequencies. PCS (or DCS in Europe) is now used in the industry to refer to all 2G cellular access technologies.

peer-to-peer network
Distributes intelligence over devices in the network instead of relying on central computers. Peer-to-peer networks are often used to download free music and movies from the Internet. In addition, companies such as Skype use the technology for voice calls and other services.

photonics
All of the elements of optical communications. This includes fiber, lasers, and optical switches and all elements involved in transmitting light over fiber.

ping (Packet Internetwork Groper)
A software protocol used to test communications between devices. To "ping" means to send a packet to another device or host to see if the device sends back a response. The ping also tests round-trip delay, the time it takes to send a message to another device.

PON (Passive Optical Network)
Technologies deployed to extend fiber to homes, businesses, and neighborhoods. PONs use nonelectrical devices located in the access network that enable carriers to dynamically allocate capacity on a single pair of fibers to multiple homes, buildings in a campus, apartments, and small and midsize businesses.

POP (Point of Presence)
A long-distance company's equipment that is connected to the local telephone company's central office. The POP is the point at which telephone and data calls are handed off between local telephone companies,

long-distance telephone companies, and the Internet.

POTS (Plain Old Telephone Service)
Telephone lines connected to most residential and small-business users. POTS lines are analog from the end user to the nearest local telephone company equipment. People using POTS for data communications with modems are limited in the speed at which they can transmit data.

POE (Power over Ethernet)
A standard that defines how power can be carried from wiring closets on floors to the computers and other LAN-connected devices using the same cabling that transmits packetized voice and data. Thus, every device does not need its own power or backup power.

presence
The ability of users to know when someone within their community of users is available for realtime or near-realtime messaging.

PRI (Primary Rate Interface)
A form of ISDN with 23 paths for voice, video, and data and one channel for signals. Each of the 24 channels transmits at 64Kbps.

protocol
Defines how devices and networks communicate with one another. For example, a suite of protocols known as TCP/IP spells out rules for sending voice, images, and data across the Internet and in corporate networks.

proxy server
Authenticates callers to ensure that they are who they say they are before they are sent to their destination. They serve as intermediaries between callers and applications or endpoints, telephones, and other devices connected to the LAN. For instance, a proxy server in a VoIP environment ensures that external devices requesting to communicate with an IP telephone are who they say they are.

PSAP (Public Safety Answering Point)
Groups of agents that answer and dispatch 911 and E-911 calls for their town, county, or cluster of towns. They are often located at police stations.

PSTN (Public Switched Telephone Network)
The global network of circuit-switched telephone services that telephone companies operate. The PSTN comprises traditional copper-based telephone lines, central office switches, fiber-optic cabling, undersea cable systems, cellular systems, microwave connections, communications satellites, and any other system connected via public telephone switching centers. It does not include the Internet or carriers' private data networks.

push-to-talk
A walkie-talkie type of service pioneered by Nextel (now part of Sprint Nextel) in which customers can reach one another by pushing a button on the side of their phone. They also dial an abbreviated telephone number. Push-to-talk can be used to reach individuals or predefined groups.

QoS (Quality of Service)
The ability to offer a number of priorities for various types of communications including voice, e-mail, and video on LANs and WANs.

radio
A wireless device with an antenna that converts signals to and from formats compatible

with the airwaves. Wireless handsets are radios.

RBOC (Regional Bell Operating Company)

At Divestiture in 1984, the Justice Department organized the 22 Bell telephone companies into seven Regional Bell Operating Companies. As a result of mergers and name changes, the former RBOCs are now part of AT&T, CenturyLink, or Verizon.

reverse channel

In cable TV systems, this carries signals from the customer to the cable operator's equipment. Reverse channels are required for Internet access, on-demand TV, and VoIP.

RFID (Radio Frequency Identification)

A non-line-of-sight wireless technology used to control, detect, and track objects. Two common applications are merchandise tracking and automated tollbooth collection.

roaming

The capability in mobile networks to use the same handset on another carrier's network. Carriers set up roaming agreements to define terms such as per-minute fees that carriers charge one another.

router

A device with routing intelligence that connects local and remote networks together. Routers are also used to forward packets in the Internet.

RPKI (Resource Public-Key Infrastructure)

An Internet security protocol for routing packets on the Internet. It adds encryption between databases called Internet registries (centralized databases with Internet addresses) and network operators. Encryption is the use of mathematical algorithms to scramble data.

RSS (Really Simple Syndication)

A series of software standards that automates feeding updates from news sites such as Forbes.com and blogs to other sites and users. The use of RSS means that people don't have to continually check to see news headlines or updates to blogs.

RTMP (Real-Time Messaging Protocol)

A realtime streaming protocol developed by Adobe for using Flash servers to improve streamed audio, video, and data over the Internet. It is now used with other Adobe programs. According to Adobe, most of the RTMP specifications are open to developers to create applications compatible with Adobe Flash Player.

RTP (Real-Time Transport Protocol)

An IETF standardized protocol for transmitting multimedia in IP networks. RTP is used for the "bearer" channels, the actual voice, video, and image content.

SDH (Synchronous Digital Hierarchy)

A world standard of synchronous optical speeds. The basic SDH speed starts at 155Mbps, also called STM-1 (Synchronous Transport Mode-1) in Europe. SONET is a subset of SDH.

server

A specialized, shared computer on the LAN or in a carrier's network containing files such as e-mail or applications. It can be used to handle sharing of printers, e-mail, and other applications.

set-top box
A device connected to a television that allows access to various content, including pay-per-view programming. Set-top boxes can be used to distribute content to other TVs and devices. Newer models contain hard drives and multiple tuners. They can be used to watch one program while recording a different show, and to pause and rewind programs.

signaling gateway
A type of media gateway that converts signaling from IP networks to that compatible with traditional, circuit-switched networks, and vice versa.

SIM (Subscriber Identification Module)
A clip-on or internal card with microchips in mobile handsets that store user identity and other information such as speed-dial lists and e-mail addresses. CDMA phones do not have SIM cards.

SIP (Session Initiation Protocol)
A signaling protocol used to establish sessions over IP networks, such as those for telephone calls, audio conferencing, click-to-dial from the Web, and instant message exchanges between devices. It is also used to link IP telephones from different manufacturers to SIP-compatible IP telephones. It is used in landline and mobile networks.

SLA (Service-Level Agreement)
Often provided to customers by carriers that sell MPLS. The SLA defines service parameters such as uptime and response time.

smart grids
Upgraded utility networks for metering that can carry two-way messages on cellular networks between customers and electric utilities. A goal is to use energy more efficiently by monitoring usage patterns.

SMS (Short Message Service)
Short, 160-character (including header address information) text messages that can be transmitted between digital cellular telephones.

SMTP (Simple Mail Transfer Protocol)
The e-mail protocol portion of TCP/IP used on the Internet. Having an e-mail standard that users adhere to enables people on diverse LANs to send e-mail to one another.

softphone
Telephone functionality on a personal computer in VoIP systems. People with softphone-equipped laptops can use their VoIP remotely.

softswitch
Used in converged enterprise and carrier networks that carry VoIP traffic. Softswitches are built on standard computer processors and use standards-based protocols, which makes them less costly than proprietary switches based on circuit-switched technology. Softswitches manage and control traffic in IP networks.

SONET (Synchronous Optical Network)
An older standard for multiplexing high-speed digital bits onto fiber-optic cabling. SONET converts electronic impulses to light impulses, and vice versa. Telephone companies use SONET to transmit data from multiple customers over the same fiber cables.

spectrum
Made up of frequency bands or airwaves that carry either analog or digital wireless signals.

Spectrum consists of the multitude of invisible electric energy in frequency bands that surround the Earth and are used to transmit segregated radio waves. Radio waves carry signals as electrical energy on unseen waves.

SSL (Secure Sockets Layer)

A newer type of security for VPNs than IPsec. It is embedded in browsers so that organizations aren't required to install special client software in each user's computer.

statistical multiplexing

Assumes that not all devices are active all the time. A statistical multiplexer does not save capacity for each device connected to it. It operates either on a first-come, first-served basis or on a priority basis in which certain streams of traffic have higher priority than others.

streaming video and audio

A means of starting to play a message while the rest of it is being received. Streaming uses compression to make the voice, video, and data files smaller so that they can be transmitted in less time. Streaming video and audio is used in broadcasting video and audio over the Internet.

switching

Equipment with input and output ports that transmits traffic and sets up paths to destinations based on digits dialed or addressing bits.

T.120

The ITU-defined standard for document sharing and white boarding. People using T.120-adherent software can participate in document-sharing conferences with one another over the Internet. For example, vendors can demonstrate their products to potential customers via computers connected to the Internet at dispersed sites.

T1

A North American and Japanese standard for communicating at 1.54Mbps. A T1 line has the capacity for 24 voice or data channels.

T3

A North American standard for communicating at speeds of 44Mbps. T3 lines have 672 channels for voice and/or data. Fiber-optic cabling or digital microwave is required for T3 transmissions.

tandem central offices

Used in the core of traditional, traditional Public Switched Telephone Networks (PSTNs). Tandem central offices switch traffic between central offices. End users are not connected to tandem offices. Tandem central offices are being replaced by lower-cost, more efficient softswitches.

TCP (Transmission Control Protocol)

Includes sequence numbers for each packet so that the packets can be reassembled at their destination. The sequence numbers ensure that all of the packets arrive and are assembled in the proper order. If some packets are discarded because of congestion, the network retransmits them. The numbering and tracking of packets make TCP a connection-oriented protocol. Router-based LAN internetworking uses TCP.

TCP/IP (Transmission Control Protocol/Internet Protocol)

The suite of protocols used on the Internet and also by organizations for communications among multiple networks.

TD-SCDMA (Time-Division Synchronous Code-Division Multiple Access)
China Mobile uses TD-SCDMA, which is a homegrown version of UMTS TDD (3G mobile protocol), for its 3G mobile service.

tether
The ability to connect laptop or tablet computers that don't have Internet access to the Internet via a mobile handset's Internet connection. This is generally done by connecting the computer and mobile handset together through USB ports via USB-compatible cables.

throughput
The actual amount of user data that can be transmitted on a telecommunications link or on wireless networks. Throughput does not include headers, for example, bits used for addressing, error correction, or prioritizing packets with voice and data bits.

tier 1 provider
A loosely defined term for Internet service providers that own Internet backbone fiber-optic facilities in addition to ISP services such as hosting and e-mail. Examples include AT&T, Level 3, Sprint Nextel, and Verizon.

TDM (Time-Division Multiplexing)
TDMs, such as T1/E1 equipment, save capacity for each device that is connected to the multiplexer. This is less efficient than other methods such as statistical multiplexing because capacity is unused when the device is not transmitting.

topology
The geometric shape of the physical connection of the lines in a network—or, the "view from the top"—which is the shape of the network, the configuration in which lines are connected to one another.

traffic shaping
A way for carriers to manage traffic to control congestion. Techniques include providing better QoS for particular types of traffic such as video, prioritizing traffic for higher fees, and throttling traffic (decreasing speeds) for subscribers who exceed allotted amounts.

transponder
Fiber-optic transponders receive, amplify, and retransmit optical signals on different wavelength channels on fiber cabling. They also convert electrical signals to optical signals and optical signals back to electrical signals where they connect twisted-pair copper or coaxial cabling.

trunking gateway
Converts packet network circuits (such as T1/E1 and T3/E3), to those compatible with the Public Switched Telephone Network (PSTN), and vice versa, so that voice traffic can be transferred between IP networks and traditional, circuit-switched networks.

trunks
The circuits (electrical or fiber paths) between telephone companies and enterprise telephone systems and between central office switches. A T1 is a trunk.

tuner
Used in televisions, radios, and set-top boxes to filter out all channels (frequencies) except the particular one at the frequency the tuner is designed to accept. The tuner then adapts the frequency to ones compatible with the TV or radio. Newer set-top boxes are equipped with multiple tuners so that one channel can be recorded while another is being viewed.

tunneling
A method of securely transferring data between sites connected by networks such as a VPN, the Internet, an intranet, or an extranet. Tunneling puts a new header in front of the data. This is a way of separating data from multiple companies using the same network.

UDP (User Datagram Protocol)
Part of the TCP/IP suite of protocols. UDP has less overhead because it does not have bits with packet numbers and acknowledgments. UDP is considered a connectionless protocol because packets arrive at their destination independently from various routes without sequence numbers. There is no assurance that all of the packets for a particular message arrive. UDP is suited for applications such as database lookups, voice, and short messages.

UMTS (Universal Mobile Telecommunications System)
A European standard for 3G mobile wireless networks that GSM networks generally use when they are upgraded. WCDMA is a UMTS technology.

UMTS TDD (Universal Mobile Telecommunications System/Time-Division Duplexing)
A high-speed wireless technology used for 3G cellular and broadband wireless access to the Internet. It is also referred to as TD-CDMA. It uses the same channel for sending and receiving, with small time slots to separate the sending and receiving streams rather than the larger guard band used in other 3G technologies.

UNE (Unbundled Network Element)
Parts of the incumbent local telephone company infrastructure required to lease out to other local exchange carriers. Examples of UNEs are the copper lines to customers' premises. Many UNE requirements have been eliminated.

unicasting
The transmission of one message from a single point to another point. This is also referred to as point-to-point communications.

unified messaging
Computing platform that contains voicemail, facsimile, e-mail, and sometimes video mail on a single system. Users can access all of these services from their computer inbox.

unlicensed spectrum
Governments specify portions of the airwaves for unlicensed services at no charge to companies; 802.11 services are an example. Most governments issue certification, signal-spreading, and power-limitation rules to protect adjacent licensed spectrum bands from harmful interference from transmissions within the unlicensed spectrum.

Uplink (UL)
On broadband and mobile networks, the uplink carries traffic from the customer to the carrier's equipment.

URL (Universal Resource Locator)
An address on the World Wide Web. The address is made up of strings of data that identify the server, the folder location, and other information indicating the location of information on the Internet.

USF (Universal Service Fund)
Used to fulfill the commitment made by the United States government to affordable universal telephone service to all residential consumers. The Telecommunications Act of 1996 expanded universal service to rural healthcare organizations, libraries, and educational institutions for Internet access, inside wiring, and computers. The library and educational subsidies are a part of universal service known as the e-rate. Every interstate carrier, cell phone, and paging company must pay a percentage of its interstate and international revenues to the fund. A separate fund, The Connect America Fund, has been established for residential broadband.

UTP (Unshielded Twisted-Pair)
Most inside telephones and computers are connected to one another via unshielded twisted-pair copper cabling. The twists in the copper cables cut down on the electrical interference of signals carried on pairs of wire near one another and near electrical equipment.

UWB (Ultra-Wideband)
A wireless service that supports higher data rates than RFID and can be used for some of the same applications. However, widespread adoption is held up by a lack of an agreed-upon standard. It is also used by the military and by governments for tracking and for finding people trapped under rubble.

VLANs (Virtual Local Area Networks)
Groups of devices programmed in Layer 2 switches for special treatment in enterprise networks. They are not grouped together in physical networks; rather, they are grouped together in software for common treatment and programming purposes. They are "virtual" networks that act as if they were separate LANs.

VoIP (Voice over Internet Protocol)
The process of sending voice traffic in packets on IP-based data networks. VoIP digitizes analog voice, compresses it, and puts it into packets at the sending end. The receiving end does the reverse. Unlike circuit switching, no path is saved for the duration of the voice session. However, voice packets can be prioritized.

VOLTE (Voice over LTE)
A 3rd Generation Partnership Program protocol used to carry packetized voice (VoIP) on LTE networks.

VPN (Virtual Private Network)
Provides the functions and features of a private network without the need for dedicated private lines between corporate sites or between corporate sites and remote users. Each site connects to the network provider's network rather than directly to another corporate location.

VRU (Voice Response Unit)
Provides information to callers based on their touch-tone or spoken commands. VRUs query computers for responses and "speak" them to callers. For example, people often can call their bank or credit card company to find out their balance or to learn if a payment has been received.

WAN (Wide Area Network)
Connects computers located in different cities, states, and countries.

WAP (Wireless Application Protocol)
A protocol that defines how Internet sites can be displayed to fit on the screens of cellular

devices and how devices access and view these sites.

WCDMA (Wideband Code-Division Multiplexing)
The 3G service that most GSM operators install.

WDM (Wavelength-Division Multiplexing)
Also known as *dense wavelength-division multiplexing*, this enables multiple colors or frequencies of light to be carried on single pairs of fiber. WDM greatly increases the capacity of network providers' fiber-optic networks.

Wi-Fi (Wireless Fidelity)
Wireless networks based on 802.11 IEEE standards. The Wi-Fi Alliance tests and certifies that products meet IEEE 802.11 standards.

WiMAX (Worldwide Interoperability for Microwave Access)
A forum whose goal is to facilitate interoperability of equipment based on 802.16 standards for high-speed fixed wireless service using the 2GHz to 11GHz frequency bands. Newer versions are used for mobile wireless service. WiMAX fixed wireless service is used for Internet access and for backhaul networks, which connect cellular towers to mobile central offices.

WiMAX 2
A 4G mobile protocol developed by the IEEE. It is not as widely used as LTE, but was available earlier.

wire speed
The capability of switches to forward packets equal to the full speed of their ports. Ports are the interfaces to which cabling is connected. Wire speed is achieved with powerful switch processors, the computers that look up addresses and forward packets.

wireless local loop
Uses wireless media to bring telephone service to a customer's premises rather than copper or fiber cabling.

WISP (Wireless Internet Service Provider)
Provides Internet access using noncellular wireless technology.

WLAN (Wireless Local Area Network)
Local Area Network (LAN) in which devices are connected to other devices or the LAN wirelessly rather than with cabling; 802.11-based Wi-Fi networks are WLANs.

worms
Viruses that are programmed to start infecting networks and other computers at a predetermined future time and date. These time-released viruses are also referred to as *bots*.

WWW (World Wide Web)
Connects users from one network to another when they "click" links. It was developed in 1989 to make information on the Internet more accessible. A browser is required to navigate and access the World Wide Web.

XML (Extensible Markup Language)
A software language that was developed to make it easy for disparate computers to exchange information. XML uses tags to identify fields of data. XML is like a data dictionary in that uniform *tags* are attached to elements so that diverse programs can read the tags. For example, tags can be used to

identify elements such as prices, model numbers, product identities, or quantities ordered.

ZigBee
Based on the IEEE 802.15.4 standard for wireless networks with devices that operate at low data rates and consume small amounts of power. The ZigBee Alliance is developing specifications for higher-level services to be used in sensor networks such as those that monitor and control heating and electrical systems in businesses.

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Index

Numerics

A

D

F

G

H

I

J

K

L

N

O

Q

R

T

W

X

Y

Z