A Digital World

Driven by natural inquisitiveness, and encouraged by scientific discoveries and engineering achievements, the human environment is constantly evolving. The Greek philosopher Heraclitus (c. 540–c. 470 BC) is said to have taught that there is nothing permanent except change. In social, political, and commercial affairs, change is everywhere. Change is an eternal condition of mankind, and so it is with modes of communication. Change is most obvious from generation to generation as the new generation picks up developments made by the previous one. Without personal knowledge of what went before, new generations are free to innovate and discover new uses. Certainly this is true of the current period. Within a lifetime, entire industries devoted to digital devices, such as personal computers, mobile phones, software that performs amazing feats without human intervention, and a worldwide data network that is available to anyone with a connection and a compatible terminal, have been born and are thriving. The confluence of solid state (electronic and optical) components, high-level software, and pervasive digital communications has changed the developed world so that new generations are forging a computer-enabled, data-enriched, social, industrial, and political environment.

The development of the Internet and its global reach surprised most communications experts. In the 1970s the incumbent telephone companies were more interested in voice than in data, perhaps for good reasons: they had quality of service problems. Waiting for several seconds before the overworked common equipment in the central office could return a dial tone was common, and one had to book a time for an intercontinental call. Furthermore, calling across the United States required the intervention of an operator in White Plains, Chicago, or Dallas until direct-distance dialing...
(DDD) could be universally instituted. All that is gone now, but, in the meantime, a facility of the United States Department of Defense (DOD) called ARPAnet (Advanced Research Projects Agency network), developed and built to share government computing resources among research establishments, grew and flourished.\(^1\) De facto it became the national data network. Government property no longer, and now called Internet, it provides digital communication capability to a global audience permitting them to send and receive multimedia messages.

ARPAnet and Internet provided platforms for the conversion of data, voice, audio, and video media\(^2\) to digital signals. This combination of media became known as multimedia and, when the signals were mixed together (multiplexed) the stream was termed broadband. It is important to realize that broadband signals are only alive as speech, music, movies, pictures, and text at their sources and when captured and interpreted by their receivers. In between they are a broadband stream of digital signals with different formats that must be treated properly in order to be moved from place to place. This advance has spawned a cornucopia of digital portable devices. Now, the once monopolistic voice and narrowband data communications establishments are working assiduously and in collaboration to provide broadband services.

Today there are at least four times as many mobile phones as landline phones. In addition, the number of Internet hosts is rapidly approaching one billion, and Internet users around two billion people. To the discomfort of existing landline telephone companies (telcos), fixed-line usage is declining, leaving them with increasing liabilities and underutilized assets. To restore their fortunes they have accepted that communications action is centered on the Internet and its vast array of sites, and they must embrace broadband digital technologies and compete with mobile cell phone companies (cellcos) and cable television companies (cablecos). But the environment is not static; cellcos are expanding wireless services so that mobile users can receive multimedia signals at greater and greater data rates from a range of sources, and cablecos have seized the opportunity to augment their traditional television entertainment businesses with high-speed Internet access and digital voice services. The goals of all of these organizations are to construct a multimedia world that will provide connections to stationary, nomadic, and mobile devices to make the electronic encounter as natural and convenient as possible. This book is a snapshot of a rapidly evolving field that seeks to provide digital multimedia communication on demand, at any time, to anywhere, using any terminal, and to compete with the attractions of the Internet.


\(^2\)The terms voice and audio are included in this list to emphasize the difference between spoken voice and music. They are both audible sounds.
1.1 Digital Natives and Immigrants

A digital native is a person born in the digital age (i.e., after circa 1980) who regards cell phones, laptop computers, mp3 players, and other portable multimedia devices as a natural part of everyday life. They are the principal targets of multimedia companies. Older persons who seek to imitate the ways of digital natives are known as digital immigrants. Both of them seek the technologies and distribution channels that best suit their needs, expectations, and environments. The wide range of devices at their disposal connect to the Internet and many are wireless-enabled to achieve mobility. Digital natives are driving multimedia communications by their urgent need to inform one another about everything they are doing. YouTube, Facebook, instant messaging, texting, tweeting, and so on, are examples of services that are meeting this demand. Different situations require different formats, different terminal capabilities, diverse presentations, and specialized information. Their major communications terminals are:

- **Telephones**: Telephones are interactive devices that are connected to networks by wires, fibers, cables, or wireless. The number of fixed line telephones has been overtaken by the number of cellphones (cellular phones), which are the most used personal communication devices in the world. In addition, they may be the most technologically advanced devices. Besides their original use as a mobile telephone providing voice communication for persons on the move, a glance at the electronics catalog pages of Amazon.com (or another equivalent site) confirms that cellphones combined with proprietary operating systems (smartphones) have the ability to provide Internet access, texting, navigation information, location information, video programming, and other such services. They are truly multimedia portable devices. Similar devices are to be found elsewhere.

- **Televisions**: Until recently, televisions employed analog signals and displayed them in a 4:3 format. Beginning in 2005 in the United Kingdom, and spreading quickly to many European countries, and to the United States in 2009, televisions have begun to employ digital signals received by terrestrial wireless, satellite wireless, fiber, or cable and display them as standard TV in a 4:3 or 16:9 format and as high-definition TV in 16:9 format. Most of the developed world will use digital signals before 2020.

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4 Some have coined the phrase echo boomer for the sons and daughters of baby boomers. Echo boomers can very well be digital natives.


6 I.e., four units wide by three units high.
In addition, digital television is available directly from Internet sites over digital subscriber lines, fibers, cable, or wireless connections. Normally, televisions are interactive only to the extent required to change channels or to order on-demand entertainment. However, in conjunction with personal computers, or as independent browser-enabled devices, they can display Internet information, including streaming video programs. In addition, newly developed TVs can deliver three-dimensional television.

- **Personal computers**: Desktop PCs, laptops, smartphones, and tablet devices are connected to networks by wireless. In addition, laptop and desktop PCs may be connected by wires, cables, or optical fibers. Employing complex operating systems, they perform personal tasks and support browsers to access the Internet and the World Wide Web. Connected to the Internet, PCs support interactive searching (search engines), social networking activities (instant messaging, Twitter, Facebook, MySpace, YouTube, etc.), and a multitude of specialized applications (apps). Browsing can include voice, audio, video, and data media so that the user can employ multimedia and the browsing experience can be interactive.

- **Radios**: Radios employ analog or digital audio signals derived from terrestrial broadcasting stations, direct broadcasting satellites, or audio streaming on Internet. News and entertainment programs are available virtually everywhere to listeners moving at any speed. There is no interaction except for talk-radio programs in which return calls are made over telephones.

- **Media players and recorders**: Portable audio players, such as mp3 devices, provide music, speeches, or lectures on demand to those who wish to listen privately while walking, driving, jogging, or doing other tasks. The content may be manipulated on a computer and new items downloaded from providers over the Internet. Compact discs (CDs) are permanently recorded and can provide similar content. Video players play Digital Video Discs (DVDs), Blu-Ray discs, and video tapes. DVDs and Blu-Ray discs are permanently recorded; video tape can be modified and digital video recorders are available for recording TV programs and other items of interest.

- **Other digital devices**: Digital natives are likely to have one, or more, of the following devices that require support from Internet: Game consoles, navigators, global positioning system (GPS) locators, electronic books (Kindle, Nook, etc.), and much more. In addition they may have a digital camera or camcorder that can download content to a PC.

By no means does this list contain all of the portable electronics available to digital natives. For instance, electronic musical instruments play a

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7Blu-Ray discs are DVDs in which the storage capacity has been boosted from the 4.7 GB of an ordinary DVD to 27 GB through the use of blue-laser recording.
significant role in individual lives. A typical day may begin with radio and television to wake up and get the news, traffic and weather forecast. This may be followed by a ride to school or work punctuated by radio or mp3 players with the possibility of using smartphones for texting, reading email, and telephoning to associates. During the day much use might be made of a laptop or a smartphone for messaging, recalling schedules, providing estimates, and doing many of the normal functions of business. In addition, navigation and location help may be sought from GPS satellites. In the evening television entertainment, video games, CDs and DVDs, and other technologies that provide entertainment become important. So too does Internet browsing, social networking, and electronic reading. In one way or another each of these activities requires the support of some level of communication services.

Of the devices listed above, telephones, televisions, computers, and radios require robust communication facilities. Further consideration makes it apparent that three of them have similar requirements. Smartphones (telephones), televisions, and computers are able to reproduce multimedia contents. As for radios, they may provide voice and audio content with the possibility of data if it is carried on a subcarrier. Their signals are converted to digital signals if the station elects to transmit them over Internet. Thus, thanks to the digital revolution, all of these signals can be intermingled in digital streams. Moreover, they can be delivered by wireless so that all of these devices can be employed anywhere radio signals can be received; the subscriber is no longer tethered to a fixed point. Internet radio can be listened to continuously and is not subject to the fading that affects many radio stations early in the morning as the sun comes up and in the evening when the sun goes down.

The opportunity for mobility has caused many customers to abandon the fixed lines provided by telephone companies (see Section 1.5.1). In the last 20 years, legacy telcos may have lost 50% of actual and potential fixed-line customers. Some have been attracted by the lower charges of alternative providers while others have abandoned the fixed line altogether in favor of wireless, yet others have never considered anything but a mobile phone. The same contraction has been observed in viewers of off-air television programs. Cable TV carries all the off-air channels, and many more created specifically for cable television are available to cableco subscribers. However, in the 3rd quarter of 2010, the Financial Times reported the number of subscribers to cable television services in the United States had dropped by 741,000 as viewers drift to Web-based services. Drops are reported in the number of newspapers and magazines sold; their circulation is falling as more news and events appear in postings and blogs on Internet. Similar effects can be seen in the book and music publishing

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industries. The digital age is changing the old order; there is an elephant in the room called Internet. *Nothing is permanent except change.*

### 1.2 Contemporary Communications

The 20th century witnessed the development of four modes of public communication-at-a-distance. They are:

- Originally, the first, the Public Switched Telephone Network (PSTN), provided narrowband voice connections over fixed lines with electromechanical switches to direct the call to its destination. Later, digital switching and transmission was introduced to provide voice and limited data services. In the later part of the 1970s, the mobile telephone was introduced. Beginning as an analog instrument, it quickly became digital, and proceeded to overtake the number of fixed telephones in service. Today there are billions of mobile terminals around the globe that receive and transmit voice, audio, video, and data signals. PSTN provides interactive point-to-point (P2P) and point-to-multipoint (P2MP) services.\(^9\)

- The second network began as a facility of the United States Department of Defense (DOD) called ARPAnet (Advanced Research Projects Agency network). Now called Internet, it provides digital communication capability to a global audience, permitting them to send and receive multimedia messages. ARPAnet/Internet is discussed in the opening paragraphs of this chapter. Internet services are interactive P2P and P2MP.

- The third is not well organized. It consists of terrestrial broadcasting stations, cable systems, and direct broadcasting satellites (DBS) that distribute television programs to homes and offices. Originally, the individual entities broadcast one-way P2MP television (i.e., video and audio\(^10\)) services. Now, cable television companies offer interactive P2P and P2MP voice, audio, video and data services (including high-speed Internet access). Many cable companies are owned by the same operator (MSO, multiple system operator), and, in the United States, several MSOs operate systems located nationwide.

- The fourth is even less well-organized. P2MP radio has been available for around 100 years. Today, tens of thousands of terrestrial transmitters and some direct satellite services, broadcast news, views, and entertainment to homes, offices, and mobile recipients around the world.

Originally differentiated by the nature of their signals (analog voice or digital data), at the aggregation, core, and international level, PSTN and Internet use separate routing (switching) facilities and are likely to use

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*\(^9\)Multipoint-to-multipoint service (MP2MP), i.e., conferencing, can be considered to be multiple P2MP connections one (or more) at a time.

*\(^10\)Audio is used to signify a variety of sounds, including speech and music.*
separate transmission facilities. In the access network, digital multimedia signals may be carried by shared facilities (wire, fiber, cable and wireless) between user terminals and telephone company end offices or Internet service providers’ (ISPs) points of presences (POPs). The term “point of presence” is used to describe an interface between two communication providers across which they dispatch traffic to one another. One company owns the equipment on one side of the interface and the other company owns the equipment on the other side. In addition, multimedia signals are carried by coaxial cable and fiber between cableco head ends and user terminals. At the head end, television programs are derived directly from television feeds (off-air, fiber, or satellite) and relayed to subscribers; voice and data signals are connected to telco or ISP facilities. Not to be left out, radio stations transmit their signals directly to receivers over the air, transfer them to satellites for broadcasting from space, or stream their programs over the Internet to individual listener’s computers or specialized receivers (Internet radios). Finally, in what is the largest segment of the telecommunication industry, multimedia are being distributed by wireless to smartphones and laptops, through cellular radio, Wi-Fi (see Section 5.4.3), WiMAX (see Section 5.4.6), and satellite radio technologies.

1.2.1 Public Switched Telephone Network

Agencies of national and state governments supervise the activities of the organizations that provide services for the PSTN and control the manner in which they interact with their customers. Industry associations and government organizations develop regional standards. When necessary, they are promulgated as global standards by the International Telecommunication Union (ITU), an agency of the United Nations with headquarters in Geneva, Switzerland. Facilities that make up the PSTN are owned by some twenty or thirty major global carriers and a myriad of smaller ones. They interconnect with one another at well-defined POPs. Providing on-demand local voice services to enterprises and residential customers (usually analog), the carriers also supply an increasing amount of broadband services (usually digital) and lease transmission and switching facilities to commercial entities to support partial or full-capability private networks (enterprise networks). In addition, they operate public data facilities, such as frame relay (FR) and switched multimegabit data service (SMDS) for their commercial users. Frame relay is a P2P connection-oriented data service, and switched multimegabit data service is a high-speed, P2P connectionless service.

In crafting the telephone network, the telcos pursued an architecture in which two channels (unidirectional signal paths) are required for each call. As a result, in a normal conversation, one path or the other is idle while the call is in progress. In fact, because there are times when neither party is speaking, each channel is used only about 40% of the time occupied by a call. On long-distance circuits, to improve channel occupancy and
reduce the cost of each call, channel sharing was used. For instance, on undersea cables, the voices of several callers were interlaced so as to fill the idle time and improve the throughput. Today’s digital and packet technology makes it possible to multiplex signals so as to reduce the idle time and improve throughput on all transmission facilities.

So that users may roam freely while talking, mobile phones use wireless to communicate across the air interface between the user’s instrument and a network access point. Today, many more telephones are served by wireless facilities than are served by landlines. Pervasive mobile communication has been made possible by the rapid development of generations of mobile devices. While the Federal Communications Commission (FCC) and United States organizations debated the merits of competing systems, Japanese and European organizations deployed first generation terminals that provided analog voice service in areas served by overlapping wireless cells. Succeeding generations have been digital. (In February 2008, the FCC told United States operators they need no longer offer analog services.)

The PSTN is pervasive. On demand, and with astonishing ease, I can talk to my neighbor across the street or to an associate in a country on a remote continent. Moreover, more often than not, we can communicate while one or both of us are in cars, or walking along the street. In thirty years, the PSTN has changed from a predominantly landline network serving fixed telephones, to one in which wireless is the principal access technology and the environment is increasingly mobile. On demand, the PSTN can connect most of the billions of stations (landline and mobile) in one-to-one (personal, P2P), one-to-many (announcement, P2MP), or many-to-many (conferencing, MP2MP or ΣP2MP) configurations.

In order to use existing wirelines to open new markets, telcos have installed digital subscriber line equipment (DSL; see Section 5.1) that provides higher-speed data services to subscribers, and major telcos have begun to connect businesses and urban and suburban homes with optical fibers. These connections provide the opportunity for them to bring broadband services (high-speed Internet and television) to their customers in direct competition with cablecos. In addition, major cellcos have adopted third generation (3G; see Section 6.5) designs that make cellphones convenient multimedia terminals, and are reaching for even better performance from fourth generation (4G; see Section 6.6) designs.

The size of the modern PSTN is awesome. In 2009 there were around 1.25 billion landlines installed in the world, and approximately 5 billion mobile telephones were in service. So vast a global network contains a

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13 See Figure 1.1.
smorgasbord of equipment that ranges from aging landline and electromechanical switching devices, to optical fibers, spread spectrum wireless links, and high-speed digital switching devices. Pockets of advanced equipment are to be found in many nations, particularly those that have recently joined the international telecommunications community. Without the burden of legacy networks, they have constructed islands of digital excellence. For the developed world, with legacy networks that used to contain analog telephones and mechanical switches, modernization is more difficult. Nevertheless, it is proceeding apace.

Mobile wireless has changed the face of the PSTN dramatically. For instance, on the basis of the number of mobile cellular telephone subscribers, China Mobile Limited is the largest individual PSTN operator in the world.\textsuperscript{14} The group boasts the world’s largest mobile network and the world’s largest mobile subscriber base (457 million reported at the end of 2008\textsuperscript{15}). It operates the world’s largest GSM (global système mobile; or, in English, global system for mobile telecommunications) network and serves all provinces, autonomous regions, and directly-administered municipalities in mainland China. By way of comparison, for 2009, AT&T Mobility, the largest cellular carrier in the United States, reported 85.1 million subscribers.\textsuperscript{16}

In primitive form, Figure 1.1 outlines the major elements of a contemporary PSTN network. In the bottom left-hand corner are residential, home office, and small business subscribers with telephones and workstations. They are connected to end offices over landlines, and some are connected by optical fiber. Most of them use analog telephones and many of them have digital workstations connected to end offices through modems or digital subscriber line equipment (DSL). For analog voice traffic destined for other regions the signals are converted to digital signals at the end offices and connected to tandem (toll or regional) offices by fibers and cables. Digital data traffic on DSLs is collected at some point by a digital subscriber line access multiplexer (DSLAM, see Section 5.1.2) which distributes the traffic by way of asynchronous transfer mode switches (ATM; see Section 5.1.3) to ISPs or other gateways to digital networks. Mobile subscribers are connected to base stations (cell sites) by wireless. Several cell sites home on a mobile telephone switching center (MSC) that passes traffic to a fixed-line switching center, to another MSC, to another cell site, or back to the same cell site to complete the call.

In urban areas, fiber rings connect several tandem offices to form metropolitan area networks (MANs). Duplicated fiber ring structures allow

\begin{flushright}
\footnotesize
\textsuperscript{15}Http://www.chinamobileltd.com/about.php.
\end{flushright}
timely rerouting around cable cuts and other service interruptions. One of the first real operational applications of optical fibers in the United States is named Synchronous Optical Network (SONET).\(^{17}\) Practically, it operates at speeds from 51.84 Mbps (known as synchronous transport signal level 1 [STS-1]) to 39.812 Gbps (STS-768). In Europe, a similar system is known as Synchronous Transport Network (STN). The signals are designated STM (synchronous transport module); STM-1 = 155.52 Mbps. Practically the highest speed is STM-192, i.e., 29.85984 Gbps. To achieve compatibility

with existing telephone services, STS and STM signals are divided into fixed frames of 125 $\mu$s duration. For instance, an STS-1 frame consists of 810 octets (6,480-bits) that are divided into a header of 36 bits and a payload of 774 bits and an STM-1 frame comprises 2,430 octets that are divided into a header and a payload. As shown in Figure 1.1, to complete long-distance calls, signals are directed around the SONET to a core network that consists of widely-separated, mesh-connected switches (i.e., each switch is connected directly to every other switch in the core network). In the United States, long-distance calls are completed through the use of a pervasive signaling system. Called Signaling System #7 (SS7), it employs packet technology to establish circuits over transmission facilities between the toll offices serving the calling and called parties. To complete international calls, core network switches serve as gateways to international networks.

1.2.2 The Internet

In crafting ARPAnet the developers knew that data communication consisted of the exchange of irregular bursts of precisely timed data bits that could be delayed in bulk in the network until transmission capacity was available to carry them on their way. With a certain amount of additional information (e.g., addresses, priorities, and sequence numbers), the data bursts could be encapsulated in packets and mixed with others on the same transmission facility; further, it was not necessary to dedicate a second channel for a reply. Thus, the concept of a datagram was formed. Later, with the commercialization of data communication, a return channel became important for congestion control and message management.

The Internet has been described as a self-organizing, self-propagating entity whose goal is to provide worldwide, computer-to-computer communication. For those with access to a computer and an appropriate connection, the Internet provides data communication that, among other things, can be used to post or obtain information, send emails, complete financial transactions, advertise products, order goods, exchange pictures and videos, and conduct day-to-day business tasks. The Internet is pervasive in developed countries (see Tables 1.1 and 1.2); in developing countries, it is present in major cities and is growing in rural regions. In third-world countries, coverage is limited or absent. While the early Internet mostly carried nonreal-time data, the contemporary network carries both real-time and nonreal-time messages. The addition of time-sensitive voice and video messages imposes substantial quality of service (QoS) requirements and the development of sophisticated protocols to ensure the QoS objectives are met. From being ignored by telcos and cablecos, the Internet

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is now threatening the livelihood of both parties and has become, de facto, the network of choice for digital natives and immigrants. The Internet consists of interconnected autonomous networks in which the service providers (ISPs) determine the protocols that are used. Between networks, universal consensus standards govern operations. Under the direction of the Internet Engineering Task Force (IETF) ideas for improvements or additional requirements are circulated as a Request for Comments (RFC) document. After discussion and amendments, the RFC is afforded potential standard status, and if there is sufficient support, the RFC is awarded Standard Status. To have the full reach of the network available ISPs will adopt the standard for their external contacts.

In the United States, ISPs are divided in three tiers. Tier 1 networks operate with national and international reach. They peer with all other Tier 1 networks but do not charge each other for transit. Companies such as AT&T World Services, SBC Internet Services, and NTT are major Tier 1 players. Tier 2 networks peer with some networks and purchase transit from others. Tier 3 networks purchase transit for all traffic destined for other

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Table 1.1  Estimated Telecommunications Facilities in G20 Nations

<table>
<thead>
<tr>
<th>Country</th>
<th>Telephone main lines in use (thousands)</th>
<th>Mobile cellular telephones in use (thousands)</th>
<th>Television broadcasting stations** units</th>
<th>Radio broadcasting stations** (AM+FM) units</th>
<th>Internet hosts (thousands)</th>
<th>Internet users: (thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>1,268,000</td>
<td>5,000,000</td>
<td>NA</td>
<td>NA</td>
<td>778,000†</td>
<td>1,966,515</td>
</tr>
<tr>
<td>China</td>
<td>365,000</td>
<td>833,300</td>
<td>3,240</td>
<td>673</td>
<td>14,306</td>
<td>420,000</td>
</tr>
<tr>
<td>U.S.</td>
<td>163,000</td>
<td>285,000</td>
<td>2,218</td>
<td>13,769</td>
<td>316,000</td>
<td>240,000</td>
</tr>
<tr>
<td>Germany</td>
<td>54,000</td>
<td>107,000</td>
<td>8,415</td>
<td>842</td>
<td>22,606</td>
<td>65,000</td>
</tr>
<tr>
<td>Japan</td>
<td>51,000</td>
<td>107,000</td>
<td>7,552</td>
<td>1,180</td>
<td>39,909</td>
<td>99,000</td>
</tr>
<tr>
<td>Russia</td>
<td>43,900</td>
<td>213,900</td>
<td>7,306</td>
<td>1,885</td>
<td>4,822</td>
<td>59,700</td>
</tr>
<tr>
<td>Brazil</td>
<td>41,500</td>
<td>194,439</td>
<td>138</td>
<td>1,822</td>
<td>9,573</td>
<td>76,000</td>
</tr>
<tr>
<td>India</td>
<td>37,000</td>
<td>670,600</td>
<td>562</td>
<td>310</td>
<td>2,707</td>
<td>81,000</td>
</tr>
<tr>
<td>France</td>
<td>36,431</td>
<td>58,730</td>
<td>10,260</td>
<td>3,543</td>
<td>14,256</td>
<td>45,000</td>
</tr>
<tr>
<td>U.K.</td>
<td>33,682</td>
<td>75,750</td>
<td>940</td>
<td>905</td>
<td>8,269</td>
<td>51,000</td>
</tr>
<tr>
<td>Indonesia</td>
<td>30,368</td>
<td>168,264</td>
<td>54</td>
<td>803</td>
<td>753</td>
<td>30,000</td>
</tr>
<tr>
<td>Italy</td>
<td>26,890</td>
<td>88,580</td>
<td>5,086</td>
<td>4,700</td>
<td>17,702</td>
<td>32,000</td>
</tr>
<tr>
<td>S. Korea</td>
<td>23,905</td>
<td>47,000</td>
<td>57</td>
<td>419</td>
<td>334</td>
<td>40,000</td>
</tr>
<tr>
<td>Canada</td>
<td>21,000</td>
<td>21,455</td>
<td>148</td>
<td>833</td>
<td>5,190</td>
<td>28,000</td>
</tr>
<tr>
<td>Mexico</td>
<td>20,667</td>
<td>103,700</td>
<td>236</td>
<td>1,410</td>
<td>10,653</td>
<td>22,812</td>
</tr>
<tr>
<td>Turkey</td>
<td>18,413</td>
<td>66,000</td>
<td>3,269</td>
<td>129</td>
<td>2,667</td>
<td>31,000</td>
</tr>
<tr>
<td>Australia</td>
<td>9,760</td>
<td>19,760</td>
<td>104</td>
<td>607</td>
<td>11,143</td>
<td>11,240</td>
</tr>
<tr>
<td>Argentina</td>
<td>9,630</td>
<td>50,410</td>
<td>486</td>
<td>1,266</td>
<td>3,813</td>
<td>27,000</td>
</tr>
<tr>
<td>S. Africa</td>
<td>4,642</td>
<td>42,300</td>
<td>700</td>
<td>605</td>
<td>1,297</td>
<td>5,100</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>4,100</td>
<td>19,663</td>
<td>117</td>
<td>76</td>
<td>141</td>
<td>6,200</td>
</tr>
</tbody>
</table>


** Includes repeaters.

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networks. Traffic is routed through POPs and, at a higher level, exchanged among networks at exchange points. In February 2010, 330 Internet exchanges (IXCs) were operating in 88 countries. 

Although Peacock Maps published one in 2000, it is impossible today to provide a complete map of Internet; it is just too complex to be represented on a two-dimensional diagram. In primitive form, Figure 1.2a shows a traditional Internet cloud (network) in which ISP facilities provide entry to the global network. The cloud is populated principally by server farms and Internet exchange points connected by high-speed transmission facilities. Figure 1.2b shows two autonomous networks that exchange traffic at an IXP (Internet exchange point). The networks consist of a number of hubs connected in ring fashion. Telco, cableco, and cellco facilities feed traffic to each hub where it is routed to servers and storage devices, or dispatched to other hubs. At a regional hub, traffic for other networks is routed to an IXP.

In October 2010, 778 million hosts were advertised in domain name servers (DNS). Served by more than 10 thousand (10,350 in 2000) ISPs,

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Table 1.2 National Telecommunication Resources in G20 Nations as a Function of Population Older Than 14 Years

<table>
<thead>
<tr>
<th>Country</th>
<th>Estimated population older than 14 years ($P_{14}$) (millions)</th>
<th>Percentage of $P_{14}$ population that has access to main lines</th>
<th>Percentage of $P_{14}$ population that has access to cellphones</th>
<th>Percentage of $P_{14}$ population that has access to Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1,073</td>
<td>34</td>
<td>78</td>
<td>39</td>
</tr>
<tr>
<td>India</td>
<td>804</td>
<td>5</td>
<td>83</td>
<td>10</td>
</tr>
<tr>
<td>U.S.</td>
<td>246</td>
<td>66</td>
<td>&gt;100</td>
<td>91</td>
</tr>
<tr>
<td>Indonesia</td>
<td>172</td>
<td>17</td>
<td>98</td>
<td>17</td>
</tr>
<tr>
<td>Brazil</td>
<td>145</td>
<td>28</td>
<td>&gt;100</td>
<td>52</td>
</tr>
<tr>
<td>Russia</td>
<td>119</td>
<td>46</td>
<td>&gt;100</td>
<td>50</td>
</tr>
<tr>
<td>Japan</td>
<td>110</td>
<td>46</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Mexico</td>
<td>79</td>
<td>26</td>
<td>86</td>
<td>29</td>
</tr>
<tr>
<td>Germany</td>
<td>71</td>
<td>76</td>
<td>&gt;100</td>
<td>59</td>
</tr>
<tr>
<td>Turkey</td>
<td>56</td>
<td>33</td>
<td>&gt;100</td>
<td>55</td>
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<tr>
<td>France</td>
<td>52</td>
<td>69</td>
<td>&gt;100</td>
<td>86</td>
</tr>
<tr>
<td>U.K.</td>
<td>51</td>
<td>66</td>
<td>&gt;100</td>
<td>79</td>
</tr>
<tr>
<td>Italy</td>
<td>50</td>
<td>54</td>
<td>&gt;100</td>
<td>64</td>
</tr>
<tr>
<td>S. Korea</td>
<td>41</td>
<td>58</td>
<td>&gt;100</td>
<td>97</td>
</tr>
<tr>
<td>S. Africa</td>
<td>35</td>
<td>13</td>
<td>100</td>
<td>14</td>
</tr>
<tr>
<td>Argentina</td>
<td>30</td>
<td>32</td>
<td>&gt;100</td>
<td>90</td>
</tr>
<tr>
<td>Canada</td>
<td>27</td>
<td>78</td>
<td>79</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>18</td>
<td>27</td>
<td>&gt;100</td>
<td>33</td>
</tr>
<tr>
<td>Australia</td>
<td>15</td>
<td>65</td>
<td>&gt;100</td>
<td>75</td>
</tr>
</tbody>
</table>

Source: Based on Table 1.1 and CIA World Factbook 2010.

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they support almost 2 billion (1,966,514,816 in 2010) users. Access is obtained over a voice-band modem or a broadband connection (DSL or cable modem). At the end of 2007, the number of broadband subscribers in the world was estimated to be 304 million. In the United States and Canada it was estimated to be 74 million. Approximately 40% of broadband subscribers use digital subscriber lines (DSLs) provided by telcos and approximately 60% use cable modems provided by cablecos.

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For users on the move, wireless access to the Internet is possible at busy locations such as airports, conference centers, multitenancy buildings, and densely populated areas of major cities through Wi-Fi. The service uses unlicensed frequencies to provide downstream access at Ethernet speeds. Centers of Wi-Fi coverage are known as hotspots (<30m [100ft] radius). Another wireless access service, WiMAX (worldwide interoperability for microwave access), uses licensed frequencies. It provides broadband wireless connections over longer distances (practically <16km [10 miles]) for last mile access, hotspots’ cellular backhaul, and enterprise networks. Both Wi-Fi and WiMAX are undergoing vigorous development (further discussion of Wi-Fi and WiMAX is found in Chapter 5). Cellcos now provide Internet access to advanced mobile handsets and, by 2012, Pyramid Research estimates there will be 1 billion global mobile broadband connections. Of this number, by far the majority will use EVDO (see Section 6.5.1) and HSPA (see Section 6.5.2) with HSPA overtaking EVDO by the end of 2010. This move is projected to be due to the greater bandwidth of HSPA-based services. By 2014, mobile WiMAX and LTE (see Section 7.1.1) may account for some 10% of all broadband connections.

The commercialization of the Internet, and the proliferation of ISPs, can be traced to the invention of the World Wide Web (www) by Tim Berners-Lee and Robert Cailliau in 1989. For many people, “the Web” and “the Internet” are synonymous, even though the Web is a service provided through a browser, and Internet is the network that connects the browser to the servers providing the information. The proliferation of sources of Web pages around the world, and the public’s enthusiastic adoption of the Internet, has left the telcos scrambling to keep up and caused serious data users to build a new network devoted to the original objective of the ARPAnet—namely, to provide a means for sharing computing resources for technical purposes. Called Internet2, it is supported by a consortium of over 200 universities, some 115 company and government research institutions, and over 50 international partner organizations. (In December 2006, data is reported to have been sent over the Abilene network on a 20,000 mile path at 9.08 Gbps for a period of five hours.)

The ability of users to build new interactive services on existing services, called “mashing,” has led some to declare them part of a second generation Web known as Web 2.0. Tim O’Reilly describes Web 2.0 services as

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26 Http://www.wimaxforum.org.
29 Http://www.internet2.edu/about/.
30 Http://data-reservoir.adm.s.u-tokyo.ac.jp/lsr=200612-02/.
being able to leverage customer self-service.\textsuperscript{31} Often created by third-party developers, mashups are browser-based applications that draw content from multiple Web sources. Typical Web 2.0 service providers are Google (enables users to search the Web and other networks for information on subjects, locations where to buy, etc.), eBay (enables users to buy and sell electronics, cars, clothing, apparel, collectibles, sporting goods, digital cameras, etc.), and Amazon (enables users to shop for books, magazines, music, DVDs, videos, electronics, apparel, shoes, etc.).

1.2.3 Enterprise Networks

Global competition has changed the way corporations operate. In order to respond rapidly to the changing environment, corporations employ as many technical developments as possible. On their immediate premises, businesses employ wired and wireless local area networks (LANs and WLANs) to interconnect workstations. In addition, they will have conventional telephones, high-speed data, and possibly VoIP service and video conferencing. As appropriate, a specialized switch routes the traffic to telco facilities, ISP facilities, or their own network. The switch combines the characteristics of a conventional private branch exchange (PBX) for analog voice traffic, a Softswitch to interface VoIP with telco facilities, and a router for IP-based traffic. For those organizations with significant data requirements between separated campuses, the telcos provide frame relay and switched multimegabit data services. As an alternative, businesses may use cableco facilities for high-speed data and VoIP. For all kinds of equipment, as enterprises seek to reduce the turmoil created by rearrangements of permanently wired facilities, wireless connections are becoming more important.

Small and mid-sized businesses are primary targets for third-party hosted PBX services based on IP. For many organizations, the demand for storage space has expanded due to more and larger files, including increased use of multimedia files, more sophisticated documents and presentations, and larger and more complex databases. In addition, government regulations and the courts are forcing companies to retain more data, particularly emails, for longer periods of time. Prudent management requires establishing and maintaining tamper-free backup sites. The need for storage space and perhaps for greater capacity computing facilities has produced the concept of cloud computing. Businesses offload their storage and processing needs to facilities situated within the Internet cloud, that is, to third-parties accessed over Internet. The growth of off-site computing is one of the drivers for ever higher speed data connections, causing the expectation that 100 Gbps links will be needed to satisfy user expectations and business needs.

1.2.4 Off-Air and Cable Television

Television came to the public’s attention in the late 1930s and early 1940s. Essentially, it was a one-way P2MP service. With the end of World War II, service became available to the general public. Beginning as over-the-air broadcasting, it quickly spawned cable television (CATV) for those cut off from direct reception by hilly terrain or distance. Now, cablecos provide hundreds of channels in urban, suburban, and rural environments and they have expanded their activities to include Internet access and telephone services.

While observing common signal standards so that consumers can use the same receiver for all stations, most television stations operate independently, although, for programming purposes, they may be affiliated with other broadcasters. In the United States, the Federal Communications Commission (FCC) licenses 2,218 terrestrial television-broadcasting stations.\(^{32}\) In addition, geostationary satellites distribute digital television signals to individual viewers, and provide feeds for broadcast and cable entities. In 2009, to make better use of the radio frequency spectrum, the FCC required television broadcasters to change to a digital signal format (see Section 2.4.4). As a result, many (five or more) digital channels may be carried in a 6 MHz bandwidth channel and the 700 MHz to 900 MHz spectrum is available for other purposes. Digital multimedia broadcasting (DMB), a European development sponsored by ETSI (European Telecommunication Standards Institute), and specified by the DMB forum\(^{33}\) is in use in Europe and Asia. Based on the digital audio broadcasting (DAB) standard, DMB allows a wide range of TV and interactive services (approximately 7) to be broadcast on an 8 MHz channel.

Several operators provide television services using direct broadcasting satellite systems (DBS).\(^{34}\) Parked in geostationary orbit, the footprint of each satellite can cover approximately one-third of the earth’s surface; usually it is shaped to provide coverage of populated land areas only. DBS systems cover North America, parts of South America, Europe, the Middle East, Southeast Asia, and the Southern Pacific, including New Zealand.

Over coaxial cables and optical fibers, cablecos distribute off-air broadcast (linear) television, television using cable-exclusive content, and television using community-generated content. In addition, cablecos are providing broadband access to Internet and voice over IP services. Because the signals are completely contained within the cables and fibers, the FCC does not regulate the frequencies or wavelengths employed. However, unless a cableco is subject to effective competition, the FCC does regulate


\(^{33}\) [http://www.worlddab.org](http://www.worlddab.org).

certain business practices\textsuperscript{35} with the condition that if the cableco provides services to less than 30\% of the homes in the serving area, it is exempt from such regulation.\textsuperscript{36} For most cablecos in the United States the services provided by direct broadcasting satellite television are deemed by FCC to constitute effective competition. Should the market share of television households rise to 70\%, FCC may consider re-regulating the industry. (Cable systems serve some 65 million subscribers\textsuperscript{37} in the United States; this is 58\% of 112 million television households.) FCC is seeking to establish its authority over broadband rules and policies and may consider reclassifying broadband service to the same status as telecommunications.

While some cablecos may be owned and operated locally, it is more likely they are units of a larger group of systems operated by a multiple system operator (MSO). For instance, at the end of 2009, Comcast Communications, the largest MSO in North America, reported its cable systems passed approximately 50.6 million homes in 39 states and the District of Columbia, and served approximately 24 million video customers, 16 million high-speed Internet customers, and 7.6 million telephone customers, over a network that amounted to 599,000 plant miles, of which 147,000 were fiber. Comcast claims to operate the largest 40 Gbps backbone network.\textsuperscript{38}

In primitive form, Figure 1.3 shows a regional cableco network. It consists of nodes that each serve several hundred homes with television and/or high-speed Internet access and/or telephone service. Equipment above the nodes (N) is connected to a hub (H) by fiber, and several hubs are connected together by fiber rings. At a regional hub (RH), Internet traffic is diverted to ISPs in the Internet cloud, and voice traffic is transferred to PSTN facilities or the Internet. The regional hub is the entrance for national television signals by way of satellite feeds, and local signals by way of cable or fiber. Cablecos are experiencing competition from Internet sources. For one thing, sites such as Hulu are offering high quality, legal reruns of some television shows at the user’s convenience. For another, Google is introducing a unit called Google TV that will enable viewers to see television programs and Web programs, and to use Android-based applications on a single Sony television. Older TVs will be able to use Google TV by connecting through a set-top box.\textsuperscript{39}

\subsection*{1.2.5 Radio Broadcasting}

Radio has been available to the public for around one hundred years. Predominantly, it is a one-way P2MP audio service, although talk radio has

\textsuperscript{35}Section 623(1) of the Communications Act of 1934, as amended, and 47 CFR 76.905(b) (1&2).

\textsuperscript{36}47 CFR76.906.

\textsuperscript{37}Http://www.ncta.com/ContentView.aspx?contentId=66.

\textsuperscript{38}Http://www.comcast.com/corporate/about/pressroom/corporateoverview.

found a way to introduce interactivity by employing the telephone for listeners’ questions and comments. Today, in countries around the world, many thousands of transmitters broadcast news, views, and entertainment. In the United States, the FCC licenses 4,789 AM and 8,961 FM terrestrial broadcasting stations. Adhering to common signal standards, stations operate independently. However, for programming or business reasons they may be affiliated with others. In addition, stations make audio feeds available over Internet, and geostationary satellites broadcast a hundred, or more, channels of music and commentary to the North American land mass.

In 2002, the FCC approved digital radio operation by AM and FM broadcast stations. By using subcarriers, a digital broadcast signal is transmitted in the same channel as that assigned to the station’s AM or FM transmission. Called in-band on channel (IBOC) radio, almost 2000 terrestrial stations are now simulcasting analog and digital signals in the United States. Digital audio broadcasting (DAB) technology is the basis for digital multimedia broadcasting (DMB), in which audio, video and

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data signals are combined to provide mobile TV and other multimedia applications.\(^{43}\)

1.3 Triple-Play Services

In the past, PSTN, Internet, television, and radio services were provided by specialized companies, many of whom were regulated by federal and state governments. Now, with competition stimulated by deregulation, incumbent and new-start organizations provide a range of services and employ a mixture of techniques. For instance, the Internet is being used to distribute audio programs from radio broadcasting studios (audio streaming), to distribute movies (video streaming) and still pictures, and to provide alternative telephone services such as VoIP. The PSTN is using Internet techniques to carry and route traffic (e.g., metro ethernet). Both cablecos and telcos are providing high-speed access to Internet and cellcos have added still pictures, audio, video, text messaging, and Internet access to their basic voice services. As a result, today’s subscribers can choose to obtain multimedia services over the facilities of telcos, cablecos, or cellcos. Each company is striving to provide the mix of services that best attracts customers so as to survive in the changing market. The combination of voice, audio, video, and data services has been given the name “triple-play.”

1.4 Contemporary Facilities

At the dawn of the solid-state era the global telecommunication network amounted to perhaps 200 million main lines served by mechanical switching systems, some long-distance radio circuits, and a sophisticated telegraph system. AM and FM radio was available and television was black and white. Since then, digital computers, powerful software techniques, integrated circuits, Internet, communication satellites, fiber optics, semiconductor laser diodes, and spread spectrum wireless have created the telecommunication-rich environment in which we live.

For the world, and the nineteen G-20 countries,\(^{44}\) Table 1.1 provides estimates of the number of: main lines in service, mobile cellular telephones in use, television broadcasting stations, radio broadcasting stations, Internet hosts in place, and Internet users. Strictly, the individual numbers cannot be compared since they were extracted from various reports dated as early as 2006 and as late as 2010; however, most numbers were published in 2009 and 2010. Nevertheless, Table 1.1 serves to illustrate the wide range of communications facilities in the developed world. Led by China, the countries are listed in descending order according to the number of main lines in use.

\(^{43}\)Http://www.t-dmb.org.

\(^{44}\)Number 20 is the European Union—only individual countries are included in the Table.
Certainly the most interesting column shows the number of cellphones in use. In a 6.5 billion-person world there are 5 billion cellphones in use, that is, 77% of the world population has access to a mobile phone. Of course, that analysis is too simple but it underlines the tremendous growth that has occurred over the last thirty years. Moreover, comparison with the column that shows the number of main lines in use leaves no doubt that, given the choice, most people prefer the convenience and mobility of a cellphone. Table 1.2 provides more insight into the distribution and use of telecommunications and Internet facilities among the G-20 nations. For each country it provides the estimated population over 14 years old \( P_{14} \), and gives the percentage of \( P_{14} \) that have main lines, cellphones, and Internet access facilities available to them. In all of the G-20 countries it is immediately apparent that cellphones are the dominant terminal, Internet access is substantial in seven of them, and that main lines (i.e., fixed-line telephones) take third place. The total \( P_{14} \) population in Table 1.2 is just over 3 billion people. If we assume that the majority are technically literate to some degree and are likely to become more so, and in addition many individuals under 14 years old have become so, as an order of magnitude we might place the number of digital natives and digital immigrants at more than 2 billion worldwide.

1.5 Competition

In countries in which competition is permitted, new entrants are offering services that compete with traditional telco, cableco, and cellco activities. Without the burden of legacy equipment, they are able to compete on price, claim their advanced technology will give improved performance, and offer new options such as multimedia services. The complexity and cost of implementing multimedia facilities depends on whether they are new builds (greenfield) or overbuilds of existing facilities (brownfield). For greenfield operations, the new infrastructure is expected to significantly reduce capital expenditures and operating expenses compared with contemporary networks. For brownfield operations, deploying new platforms from scratch is a luxury most incumbents cannot afford; they must modify existing (legacy) facilities. This requires more diversified engineering expertise, more planning, and more time, making their facilities more expensive. To compete, operators of legacy networks will have to find ways to evolve them so as to achieve new revenues from the services they will be able to offer, and to take advantage of cost savings in existing services by gradually converting them to packet-based operation.

1.5.1 Legacy Telcos

The telcos are facing significant structural changes in the communications market as customers cancel their fixed-line voice service in favor of
alternative suppliers. Interested in retaining narrowband voice while pioneering a broader approach combining television, personal computers, and mobile devices, major telcos are beginning to offer broadband multimedia services. For instance, as customers substituted wireless, VoIP, broadband, and cable services for traditional voice landline services, Verizon reported declines in residential switched access lines in service of 11.4% (3,722,000 lines) in 2008 and 9.5% in 2007. For AT&T, switched access lines fell by 9.3% in 2008 and 4.5% in 2007. Revenues are being made up by increases in broadband services offered over digital subscriber lines (DSLs), by the growth of cellular mobile services, and by the substitution of optical fibers for copper connections. In 2009, Verizon reported an increase in wireless customers of 9.7% to 72.1 million, and they added 975,000 new fiber optics system (FiOS) TV customers.\footnote{Verizon Communications 2008 Annual Report, http://investor.verizon.com/financial/annual/2008/index.html.} In 2009, AT&T reported a 9% increase in wireless customers to 77 million, and an additional 921,000 broadband connections and 814,000 U-verse TV customers.\footnote{CommsUpdate, “AT&T Profit Up on Back of Mobile Performance,” Telegeography, 24 July 2008.} Billed as digital voice, Verizon is providing fixed VoIP service in all areas covered by its FiOS network. Thus, it is in direct competition with Comcast in offering mass-market IP telephony.\footnote{CommsUpdate, “Verizon Launches VoIP over Fibre Service,” Telegeography, 4 June 2010.}

In the United Kingdom, BT Group (British Telecom) is phasing out its traditional circuit-based PSTN facilities and replacing them with a multiservice, IP-based network (called 21st Century Network [21CN]). In a release in May 2010,\footnote{Ray LeMaistre, “BT Ramps FTTx Plans, Turns a Profit,” Light Reading Europe, May 13, 2010.} BT announced an acceleration of its broadband and TV plans using a mix of FTTH (fiber-to-the-home) and FTTC (fiber-to-the-cabinet) so that two thirds of UK households and businesses will be within reach of superfast broadband by 2015. BT expects revenues to continue to decline before starting to grow again in 2012/2013. In France, France Telecom (FT) began to phase out legacy switches in 2008. In 2010, FT announced a five-year strategy for the development of next-generation broadband access networks.\footnote{Ray Le Maistre, “FT Unveils New Action Plan,” Light Reading Europe, July 5, 2010.} In the Middle East, liberalized telecom markets are stimulating competitive activities. In Saudi Arabia, the first phase of the Saudi National Fiber Network (SNFN) has been completed and a mobile WiMAX network is being deployed.\footnote{This paragraph is a summary of several newsletters from Telegeography and Light Reading.} In Japan, NTT plans to have as many as 30 million subscribers with access by fiber by 2010; it had 2.7 million FTTH subscribers in 2005. In addition, NTT DoCoMo will offer a variety of content such as movies, sporting events, and electronic books directly to handsets and other hand-held devices.\footnote{CommsUpdate, “Cellcos in Battle for Rights to Single Next Generation Mobile Broadcasting Permit,” Telegeography, June 4, 2010.}
1.5.2 Legacy Cellcos

Recognizing their vulnerability, cellcos are deploying mobile data and video services. Whether independent or associated with a major telco, cellcos are the most advanced in taking advantage of the potential of multimedia services. The mobile phone has evolved into a technology center able to fill the roles of telephone, calculator, camera, electronic notebook, calendar, email and instant messaging terminal, music player, digital video player, video game console, and much more.

1.5.3 Legacy Cablecos

For cablecos, their investment in television entertainment and set-top boxes (STBs) is important. In addition to entertainment television, major MSOs are deploying high-speed data and digital voice services and are looking to serve the total communication needs of small and medium-sized firms with enhanced broadband offerings. In 4Q09 Time Warner Cable reported 14.6 million customers, of whom 8.8 million were digital video customers, 8.9 million were residential high-speed data customers, and 4.1 million were residential digital phone customers. Time Warner Cable, Comcast Communications, and other MSOs have introduced triple-play bundles of services, that is, television, digital voice, and high-speed Internet.

Using 4G wireless, Wi-Fi, or WiMAX, Internet video browsers allow users to watch Web videos on television, thus encouraging some users to cancel their cable TV subscriptions. There is a clear parallel with subscribers abandoning fixed line telephones for mobile phones earlier. As an example, Google TV, a platform developed by Google and Sony, is aimed at delivering Web video and other applications to residential television receivers. To abandon cable and use an Internet feed would require that the customer have access to broadband wireless. Comcast and other MSOs are expected to combine forces with WiMAX operators to retain the traffic in the system.

1.5.4 The Dominance of the Internet

The giant in the communications space is the Internet. Without a great deal of fanfare it has become the global digital network that can do anything and it shows no sign of ceasing to expand in coverage or capability. It is the main communication network for digital natives and digital immigrants. Telcos, cellcos, and cablecos provide access to Internet and may carry large fractions of the ISPs’ network traffic. However, the major profits associated with Internet are not made by the corporations that provide access and transmission facilities. Rather, they are made by corporations

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52 Http://www.timewarnercable.com/Corporate/about/highlights/default.html.
that supply computer-based services. Application service providers (ASPs) produce content while ISPs provide transport. ASPs support search engines, games, peer-to-peer videos, music, and a host of other applications (apps) available for download. In addition, they may make storage space and computer power available so that users can perform specialized tasks on demand. Without having to make billion-dollar network investments, ASPs range the entire world. Furthermore, as quickly as they can write software, they can invent new services to cater to the interests of their audiences. Many entrepreneurs and venture capitalists are seeking to corner some of the ASP market. Incumbent telcos must find ways to provide applications, too. Can the telcos compete convincingly with Google, Amazon, Yahoo, Skype, and Microsoft? One way is through mergers and acquisitions that will forever erase the traditional face of the PSTN. Of course, single-play (as opposed to triple-play) cellcos and cablecos face much the same future as telcos, and successful ISPs will find they have to provide more than fast access and passage across the Internet.

1.6 The Business of Multimedia Services

In business schools, during studies of new products and services, it is customary to raise the question: Technology push or market pull? Is there a real consumer need that multimedia communication can satisfy? Will its satisfaction persuade people to pay enough money to allow the offer or to make a profit? Or is it a glitzy application of technology that is too expensive, too complex, or may have other handicaps? The technology push for multimedia communications began forty years ago. In the early 1970s, we planned “new towns” and “wired-cities,” and in the late 1970s telcos began experimenting with optical fiber transmission systems. In 1977, in Higashi-Ikoma New Town in Japan, a fiber optic broadband demonstration system was installed by NTT. It was followed by trials in Yokosuka and Kobe.54 Other telcos fielded smaller developments. These demonstrations were hailed as enablers of what we now call triple-play services. It has taken thirty years to develop the equipment and economic conditions that cannot be ignored by the communications establishment. They must determine whether technology push can be converted to market pull. If they build multimedia networks will enough consumers come to save the day?

1.6.1 Residential Market Development

Market development for broadband multimedia residential services is confused and the winning strategy is not clear. Some candidates for increasing revenues are: video-on-demand (VOD) premiums, broadcast content

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subscriptions, interactive service premiums, and advertising. All providers agree that sports will bring loyal subscribers and can differentiate the provider from others. They expect their residential customers to emphasize telephony, Internet access, television entertainment, gaming, VOD, information services, audio and video recording, and mobile bundling. Their enterprise customers are expected to emphasize virtual private networks (VPNs), broadband access, and mobile convergence. At the same time there is a demand for cheaper telephone and television services and for more multimedia services on mobile terminals. These pressures produce significant opportunities for the development of integrated multimedia networks. Putting all of the services together in profitable packages will require time and there will be many false starts.

1.6.2 Evolving Networks

Transmission facilities with almost limitless bandwidth are rapidly becoming available. For instance, NTT announced the successful demonstration of transmission of 14 Tbps over a single fiber. Some 160 km (100 miles) long, it employed 140 channels of 111 Gbps each. In addition, Lucent Technologies announced the transmission of 100 Gbps over 2000 km (1250 miles) and Ericsson announced the transmission of 43 Gbps over 1000 km (625 miles). These developments make it possible to conceive of backbone networks that will support all existing telecommunication services and new, as yet undefined, bandwidth-hungry services.

Affordable access, overwhelming computing power, and ever-increasing storage capacity have made the delivery of broadband entertainment a reality—but not in a coordinated manner. Provider communities are trying several approaches. One, the grown-up successor to cable television (CATV), distributes video, voice, and data services to rural, suburban, and urban communities. Cablecos are well established in the race to provide triple-play services. The second approach, called IP television (IPTV; see Section 7.1), is the delivery of TV and video content over telco-managed IP networks. It provides video services and supports additional interactive services over IP-based platforms. It is a key component in many telcos’ multiservice offerings. The third, IP multimedia system (IMS; see Sections 6.5.1 and 6.5.2), was developed for 3G mobile telephones and has been adopted as the core of TISPAN’s Next Generation Network (see Section 7.3.1). All of these approaches are built around an Ethernet (i.e., IP-based) architecture (see Section 5.1.3) that provides unicast (P2P), multicast (P2MP), and broadcast (ΣP2MP) connections.

The growth of multimedia and mobile communications services means that incumbent providers must manage more diverse platforms, as well as

55 Terabits per second, i.e., $10^{12}$ bits per second.
coordinate a much higher volume of information about the network and the customers (locations, identities, permissions, etc.). They must compete effectively in a landscape populated by new entrants (both providers and customers) while maintaining a healthy return on capital and reducing operating expenses. In addition they must introduce next-generation transmission technologies (wireline, fiber, and wireless) to improve customers’ connection bandwidth and mobility, and provide voice, high definition TV, mobile voice, video, data, and high-speed Internet service bundles.

Telco TV services offer content such as news, prime-time network shows, and new and mainstream VOD titles, and augment that content with a broader selection of less popular and less mainstream videos. Demand for higher quality Internet video services is being met by a growing number of specialist providers. An increasing number of Web sites offer YouTube-style user contributed video. Usually of lower quality and shorter duration, these videos do not lend themselves to viewing on large screens. High-definition video is becoming increasingly important as consumers buy HDTV sets. Some technology companies are outfitting IPTV set-top boxes with Web browsers for video searching and the decoding software needed to locate and play broadband video completely independent of the desktop PC.

The first generation of IPTV services that make it to market will likely be of the “walled garden” variety. Such networks deliver a pre-set menu of broadcast and VOD content over a closed IP network. In the long run, IPTV carriers will be forced to recognize the importance customers place on the ability to watch almost anything at any time. They will have to offer video content that is delivered using the open Internet. The addition of a broadband video service to a walled garden IPTV service should give subscribers all the video they can handle. The viewer’s biggest challenge will be finding something to watch when they do not know what to watch! However, a significant stumbling block could be the legal battle over obtaining some, or all, of the contents of channels that are presently presented exclusively by cablecos.

1.6.3 New Business Models

For telcos it is apparent that simply providing P2P narrowband transport and specialized data services is a prescription for disaster. The great disadvantage of services delivered to fixed points is that digital natives want to be engaged anywhere (i.e., nomadic or mobile, not just tethered to a

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59 Light Reading, Survey: Internet Video Content, Light Reading Daily, November 29, 2006.
As we saw in Table 1.1, given a choice, the majority of customers prefer mobile phones to fixed phones. There is no doubt that the favorite terminal devices are the mobile phone in all of its embodiments, augmented by iPods and laptop and tablet PCs. Thus the pressure is on for the fixed line telcos to yield the access network to wireless-enabled devices. The residential telco business is rapidly splitting into four parts: one provides expanded bandwidth services to a diminishing number of residences over wires or fibers; the second provides broadband services to an increasing number of nomadic and mobile customers over wireless; the third provides the broadband core IP network that links digital natives to their favorite pastimes; and a fourth part should be to provide revenue-producing apps. For enterprises, the business components are somewhat different: they may well consist of contemporary voice services (fixed line and mobile), multimedia mobile services, and P2P and P2MP high-speed data connections.

Cablecos will defend their current position vigorously and take up the challenge of fixed-line telephony and high-speed Internet access. In fact, their current ability to provide broadband Internet access is a decisive plus for many subscribers. Cablecos have a second advantage: the large, flat-screen, high-definition, television receiver that they serve so well. In spite of the fact that its contents will be available on an assortment of nomadic and mobile devices, it will be the premier terminal for viewing sporting events and public spectacles and will remain the gathering point for families and other groups with a common interest. This should bode well for cablecos. They provide more than 100 channels of entertainment, news, and commentary, as well as on-demand videos, and have pioneered triple-play bundles. A third immediate advantage for cablecos is the ability to provide high-speed data connections. The question yet to be answered is: Can the majority of these services be carried by wireless so as to provide mobility to the customers? Certainly, it will not be possible for the full complement of channels to be delivered simultaneously; but channel by channel is a possibility. An associated question is: Will cablecos be able to retain the audiences they have when subject to intense competition for content from telcos and cellcos? Probably not; competition and exclusion are incompatible. With regard to enterprises, cablecos may have an expanding opportunity to supply P2P and P2MP high-speed data connections.

1.7 Next Generation Networks

In an attempt to achieve coordination among fixed and mobile connections, a convergence is taking place among telecommunication services and facilities. Proponents expect that such a convergence will extend to all present and future telecommunication services. While it remains to be seen whether this is possible, or indeed necessary, it is certain that the
future networks will be compatible with the Internet. It will be digital and IP-based, and will run a wider range of applications on a simpler infrastructure containing a very high-speed core network, high-speed aggregation and international networks, and a multifaceted access network that will accommodate a multitude of terminal types.

1.7.1 Current Activities

Around the world, communication research laboratories and standards bodies are pursuing next generation networks (NGNs). Several current activities address the convergence of PSTN and Internet so as to provide common networks for voice and data. Others are wrestling with the problems of large-scale audio and video streaming. The advent of mobile terminals and pervasive wireless networks, the need to carry voice, data and video signals, and growth that doubles the number of hosts attached to the Internet every five years, or so, presents major challenges for network providers. Will there be over one billion hosts in another ten years, and can NGNs scale to cope? Shall we see the establishment of special networks for specialized users on top of multipurpose public networks? The investment in facilities will be enormous. The Telecommunications Industry Association (TIA) reported United States broadband access spending of $36.8 billion in 2009 and projects it will be $49.2 billion in 2012.

As pointed out by Keith Cambron, the term “next generation” is somewhat unfortunate since it implies a time scale, and the occurrence of successive generations. Certainly, the description of “next generation” can be applied to components and devices (such as cellphones) that are replaced with relative frequency as new technologies are perfected and higher performance is achieved. Networks too, are subject to replacement, but usually only in pieces. New generations of networks do not spring forth fully formed to spread out and dominate the world. Rather, they evolve incrementally as new ideas are developed, new technologies become available, and new capital resources can be committed. In the 21st century, telecommunications networks will continue to evolve under the influence of changing traffic patterns, advances in component and device technologies, and opportunities to reduce complexity, as well as demands from users, and, most importantly, their willingness to pay for new services.

NGNs must deliver a variety of multimedia services to a mass population, members of which will have very different interests. Key to the implementation of these services is the availability of powerful technologies, flexible software, and robust, cheap hardware. The end of the 20th century saw the availability of terminals with extraordinary computing power. To paraphrase David Isenberg, this made it possible to replace dumb terminals

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and intelligent networks with intelligent terminals and dumb networks.\textsuperscript{61} With very smart terminals at the edges of the network he saw that signaling services such as custom local area signaling services (CLASS) could be implemented without dedicated, network-resident, facilities. Furthermore, substituting Internet addressing and routing techniques could eliminate circuit-based switching and signaling.

NGN and multimedia services mean different things to different carriers. Each of them will choose to optimize current capabilities, conserve assets, reduce liabilities, make a profit, and conform to their individual corporate vision and business objectives. The availability of robust, cheap hardware and powerful software is key to the implementation of NGNs and the provision of triple-play services. Incumbent carriers recognize that new telecommunication horizons have been opened for a significant fraction of the public by the diffusion of the Internet. It delivers information, messages, pictures, videos and games, and demand is robust.

\subsection*{1.7.2 EUIST Wireless World Initiative}

The European Union (EU) Information Technologies Society (IST) is pursuing a series of studies directed to the provisioning of existing and new services over any access technology, and over any type of network. To do so they have developed a network concept that consists of a set of functional entities to implement control-layer functions such as QoS, context management, media delivery, multiradio access, composition, and network advertisement and discovery. Part of EU’s Wireless World Initiative (WWI), the concept is called an ambient network. It contains three major components: ambient control space (ACS), ambient connectivity, and ambient interfaces, and delivers composable, context-aware services.\textsuperscript{62} Other initiatives deal with different aspects of: Beyond 3G, Mobilife, Service platform for innovative communication environment (SPICE), WWI New Radio (WINNER), and End-to-end reconfigurability (E2R). Work is continuing to develop these concepts. The questions all providers are asking themselves are

- Will the enormous capital investment next generation networks require provide the technologies and distribution channels that best match the behavior, needs, expectations and desired environment of present and future generations of digital natives and digital immigrants?
- Will digital natives (and others) embrace these networks enthusiastically and so contribute to the business success of the ventures?

Only time will tell.
