1

Introduction to Telecommunications

1.1 What Is Telecommunications?

Telecommunications has been defined as a technology concerned with communicating from a distance, and we can categorize it in various ways. Figure 1.1 shows one possible view of the different sections of telecommunications. It includes mechanical communication and electrical communication because telecommunications has evolved from a mechanical to an electrical form using increasingly more sophisticated electrical systems. This is why many authorities such as the national *post, telegraph, and telephone* (PTT) companies are involved in telecommunications using both forms.

Our main concern here is electrical and bidirectional communication, as shown in the upper part of Figure 1.1. The share of mechanical telecommunications such as conventional mail and press is expected to decrease, whereas electrical, especially bidirectional, communication will increase and take the major share of telecommunications in the future. Hence, major press corporations are interested in electrical telecommunications as a business opportunity.

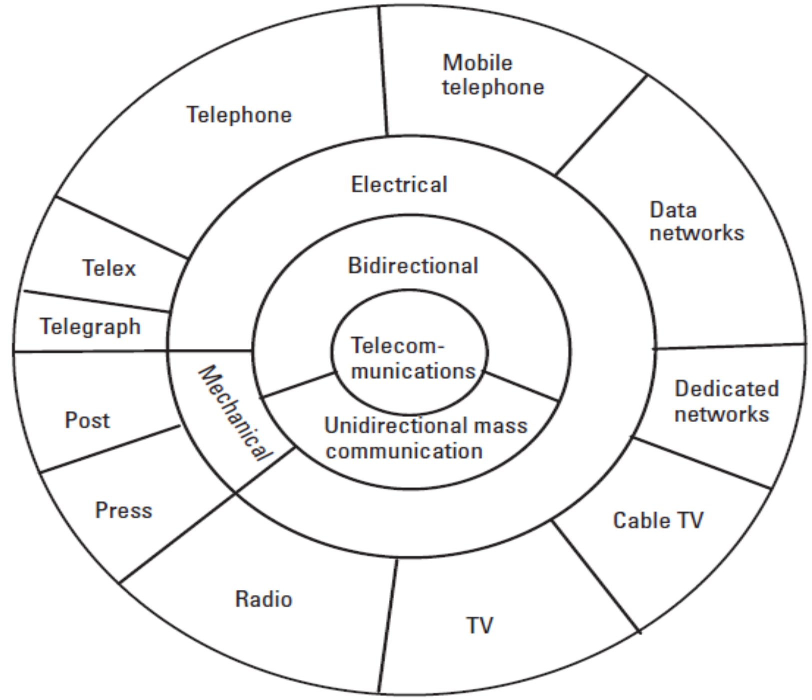

Figure 1.1 Telecommunications.

1.2 Significance of Telecommunications

Many different telecommunications networks have been interconnected into a continuously changing and extremely complicated global system. We look at telecommunications from different points of view in order to understand what a complicated system we are dealing with and how dependent we are on it.

Telecommunications networks make up the most complicated equipment in the world. Let us think only of the telephone network, which includes more than 2 billion fixed and cellular telephones with universal access. When any of these telephones requests a call, the telephone network is able to establish a connection to any other telephone in the world. In addition, many other networks are interconnected with the telephone network. This gives us a view of the complexity of the global telecommunications network—no other system in the world exceeds the complexity of telecommunications networks.

Telecommunications services have an essential impact on the development of a community. If we look at the telephone density of a country, we can estimate its level of technical and economical development. In the developing countries the fixed telephone density, that is, the *teledensity*, is fewer than 10 telephones per 1,000 inhabitants; in developed countries in, for instance, North America and Europe, there are around 500 to 600 fixed telephones per 1,000 inhabitants. The economic development of developing countries depends on (in addition to many other things) the availability of efficient telecommunications services.

The operations of a modern community are highly dependent on telecommunications. We can hardly imagine our working environment without telecommunications services. The *local area network* (LAN) to which our computer is connected is interconnected with the LANs of other sites throughout our company. This is mandatory so that the various departments can work together efficiently. We communicate daily with people in other organizations with the help of electronic mail, telephones, facsimile, and mobile telephones. Governmental organizations that provide public services are as dependent on telecommunications services as are private organizations.

Telecommunications plays an essential role on many areas of everyday living. Everyday life is dependent on telecommunications. Each of us uses telecommunications services and services that rely on telecommunications daily. Here are some examples of services that depend on telecommunications:

- Banking, automatic teller machines, telebanking;
- Aviation, booking of tickets;
- Sales, wholesale and order handling;
- Credit card payments at gasoline stations;
- Booking of hotel rooms by travel agencies;
- Material purchasing by industry;
- Government operations, such as taxation.

1.3 Historical Perspective

Some of the most important milestones in the development of electrical telecommunications systems according to [1] are discussed in this section. Terms and abbreviations used in the chronology are explained in later chapters of this book. The development and expansion of some telecommunications services is also illustrated in Figure 1.2.

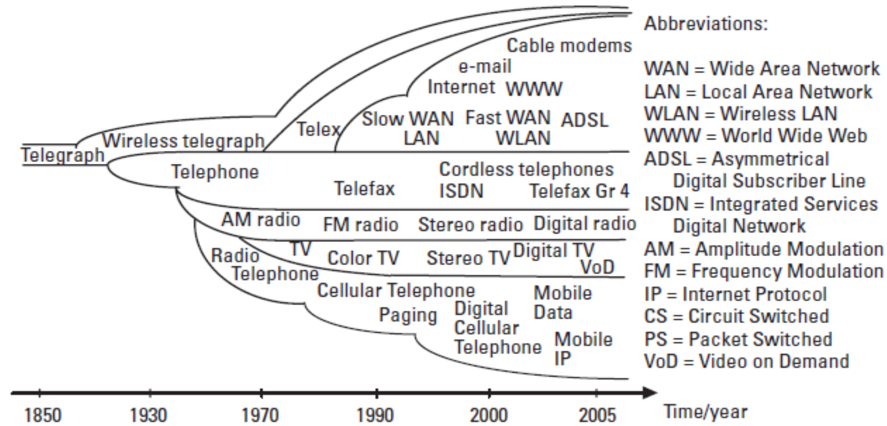

Figure 1.2 Development of telecommunications systems and services.

1800–1837	*Preliminary developments:* Volta discovers the primary battery; Fourier and Laplace present mathematical treatises; Ampere, Faraday, and Henry conduct experiments on electricity and magnetism; Ohm's law (1826); Gauss, Weber, and Wheatstone develop early telegraph systems.
1838–1866	*Telegraphy:* Morse perfects his system; Steinhill finds that the earth can be used for a current path; commercial service is initiated (1844); multiplexing techniques are devised; William Thomson calculates the pulse response of a telegraph line (1855); transatlantic cables are installed.
1845	Kirchoff's circuit laws.
1864	Maxwell's equations predict electromagnetic radiation.
1876–1899	*Telephony:* Alexander Graham Bell perfects acoustic transducer; first telephony exchange with eight lines; Edison's carbon-button transducer; cable circuits are introduced; Strowger devises automatic step-by-step switching (1887); Pupin presents the theory of loading.
1887–1907	*Wireless telegraphy:* Heinrich Hertz verifies Maxwell's theory; demonstrations by Marconi and Popov; Marconi patents complete wireless telegraph system (1897); commercial service begins, including ship-to-shore and transatlantic systems.

1904–1920	*Communication electronics:* Lee De Forest invents the Audion (triode) based on Fleming's diode; basic filter types devised; experiments with AM radio broadcasting; the Bell System completes the transcontinental telephone line with electronic repeaters (1915); multiplexed carrier telephony is introduced: H. C. Armstrong perfects the superheterodyne radio receiver (1918); first commercial broadcasting station.
1920–1928	Carson, Nyquist, Johnson, and Hartley present their transmission theory.
1923–1938	*Television:* Mechanical image-formation system demonstrated; theoretical analysis of bandwidth requirements; DuMont and others perfect vacuum cathode-ray tubes; field tests and experimental broadcasting begin.
1931	Teletypewriter service initiated.
1934	H. S. Black develops the negative feedback amplifier.
1936	Armstrong's paper states the case of *frequency modulation* (FM) radio.
1937	Alec Reeves conceives *pulse code modulation* (PCM).
1938–1945	Radar and microwave systems developed during World War II; FM used extensively for military communications; hardware, electronics, and theory are improved in all areas.
1944–1947	Mathematical representations of noise developed; statistical methods for signal detection developed.
1948–1950	C. E. Shannon publishes the founding papers on information theory.
1948–1951	Transistor devices are invented.
1950	*Time-division multiplexing* (TDM) is applied to telephony. Hamming presents the first error correction codes.
1953	Color TV standards are established in the United States.
1955	J. R. Pierce proposes satellite communication systems.
1958	Long-distance data transmission system is developed for military purposes.
1960	Maiman demonstrates the first laser.
1961	Integrated circuits are applied to commercial production.
1962	Satellite communication begins with Telstar I.
1962–1966	Data transmission service offered commercially; PCM proves feasible for voice and TV transmission; theory for digital transmission is developed; Viterbi presents new error-correcting schemes; adaptive equalization is developed.
1964	Fully electronic telephone switching system is put into service.
1965	Mariner IV transmits pictures from Mars to Earth.
1966–1975	Commercial satellite relay becomes available; optical links using lasers and fiber optics are introduced; ARPANET is created (1969) followed by international computer networks.
1976	Ethernet LAN invented by Metcalfe and Broggs (Xerox) [2].
1968–1969	Digitalization of telephone network begins.
1970–1975	PCM standards developed by CCITT.
1975–1985	High-capacity optical systems developed; the breakthrough of optical technology and fully integrated switching systems; digital signal processing by microprocessors.
1980–1983	Start of global Internet based on TCP/IP protocol [3].
1980–1985	Modern cellular mobile networks put into service, NMT in Northern Europe, AMPS in the United States, OSI reference model is defined by *International Standards Organization* (ISO). Standardization for second generation digital cellular systems is initialized.
1985–1990	LAN breakthrough; *Integrated Services Digital Network* (ISDN) standardization finalized; public data communications services become widely available; optical transmission systems replace copper systems in long-distance wideband transmission; SONET is developed. GSM and SDH standardization finalized.
1989	Initial proposal for a Web-linked document on the *World Wide Web* (WWW) by Tim Berners-Lee (CERN) [2].
1990–1997	The first digital cellular system, *Global System for Mobile Communications* (GSM), is put into commercial use and its breakthrough is felt worldwide; deregulation of telecommunications in Europe proceeds and satellite TV systems become popular; Internet usage and services expand rapidly because of the WWW.
1997–2001	Telecommunications community is deregulated and business grows rapidly; digital cellular networks, especially GSM,

expand worldwide; commercial applications of Internet expand and a share of conventional speech communications is transferred from *public switched telephone network* (PSTN) to Internet; performance of LANs improves with advance of gigabit-per-second Ethernet technologies.

2001–2005 Digital TV starts to replace analog broadcast TV; broadband access systems make Internet multimedia services available to all; telephony service turns to personal communication service as penetration of cellular and PCS systems increases; second generation cellular systems are upgraded to provide higher rate packet-switched data service.

2005– Digital TV will replace analog service and start to provide interactive services in addition to broadcast service; third generation cellular systems and WLAN technologies will provide enhanced data services for mobile users; location-based mobile services will expand, applications for wireless short-haul technologies in homes and offices will increase; global telecommunications network will evolve toward a common packet-switched network platform for all types of services.

1.4 Standardization

Communication networks are designed to serve a wide variety of users who are using equipment from many different vendors. To design and build networks effectively, standards are necessary to achieve interoperability, compatibility, and required performance in a cost-effective manner.

Open standards are needed to enable the interconnection of systems, equipment, and networks from different manufacturers, vendors, and operators. The most important advantages and some other aspects of open telecommunications standards are explained next.

Standards enable competition. Open standards are available to any telecommunications system vendor. When a new system is standardized that is attractive from a business point of view, multiple vendors will enter this new market. As long as a system is proprietary, specifications are the property of one manufacturer and it is difficult, if not impossible, for a new manufacturer to start to produce compatible competing systems. Open competition makes products more cost-effective, therefore providing low-cost services to telecommunications users.

Standards lead to economies of scale in manufacturing and engineering. Standards increase the market for products adhering to the standard, which leads to mass production and economies of scale in manufacturing and engineering, *very large scale integration* (VLSI) implementations, and other benefits that decrease price and further increase acceptance of the new technology. This supports the economic development of the community by improving telecommunications services and decreasing their cost.

Political interests often lead to different standards in Europe, Japan, and the United States. Standardization is not only a technical matter. Sometimes opposing political interests make the approval of global standards impossible, and different standards are often adapted for Europe, the United States, and Japan. To protect local industry, Europe does not want to accept American technology and America does not want to accept European technology.

One example of a political decision in the 1970s was to define a different PCM coding law for Europe instead of the existing American PCM code. (We will explain this terminology in Chapter 3.) A more recent example is the American decision in the 1990s not to accept European GSM technology as a major digital second generation cellular technology.

International standards are threats to the local industries of large countries but opportunities to the industries of small countries. Major manufacturers in large countries may not support international standardization because it would open their local markets to international competition. Manufacturers in small countries strongly support global standardization because they are dependent on foreign markets. Their home market is not large enough for expansion and they are looking for new markets for their technology.

Standards make the interconnection of systems from different vendors possible. The main technological aim of standardization is to make systems from different networks "understand" each other. Technical specifications included in open standards make systems compatible and support the provision of wide-area or even global services that are based on standardized technology.

Standards make users and network operators vendor independent and improve availability of the systems. A standardized interface between a terminal and its network enables subscribers to purchase terminal equipment from multiple vendors. Standardized interfaces among systems in the network enable network operators to use multiple competing suppliers for systems. This improves the availability and quality of systems and reduces their cost.

Standards make international services available. Standardization plays a key role in the provision of international services. Official global standards define, for example, telephone service, ISDN, and facsimile. The standards of some systems may not have official worldwide acceptance, but if the system becomes popular all around the world, a worldwide service may become available. Recent examples of these services are GSM and the Internet with WWW. Internet specifications have no official status, and GSM was originally specified for Europe only. Their specifications have been openly available, which has supported their expansion.

To clarify and understand the influence of standardization on our everyday lives, consider these examples of international standardization:

- *Screw thread pitches (ISO, Technical Committee 1):* This was one of the first activity areas of standardization. In the 1960s, a bolt from one car would not fit another. Currently, bolts are internationally standardized and most often compatible.
- *International telephone numbering and country codes:* Without globally unique identification of subscribers, automatic international telephone calls would not be available.
- *Telephone subscriber interfaces.*
- *PCM coding and primary rate frame structure:* This coding and structure make national and international digital connections between networks possible.
- *Television and radio systems.*
- *Frequencies used for satellite and other radio communications.*
- *Connectors and signals for PC, printer, and modem interfaces.*
- *LANs:* These enable people to use computers from any manufacturer in a company network.
- *Cellular telephone systems:* Enable users to choose a handset from among a large selection with different features from many different vendors.

1.5 Standards Organizations

Many organizations are involved in standardization work. We look at them from two points of view: (1) the players in the telecommunications business involved in standardization and (2) the authorities that approve official standards.

1.5.1 Interested Parties

Figure 1.3 shows some groups that are interested in standardization and participate in standardization work. Let us look at a list of these parties and their most important interests, that is, why they are involved in standardization work.

Network operators support standardization for these reasons:

- To improve the compatibility of telecommunications systems;
- To be able to provide wide-area or even international services;
- To be able to purchase equipment from multiple vendors.

Equipment manufacturers participate in standardization for these reasons:

- To get information about future standards for their development activities as early as possible;
- To support standards that are based on their own technologies;
- To prevent standardization if it opens their own markets.

Service users participate in standardization for these reasons:

- To support the development of standardized international services;
- To have access to alternative system vendors (multivendor networks);
- To improve the compatibility of their future network systems.

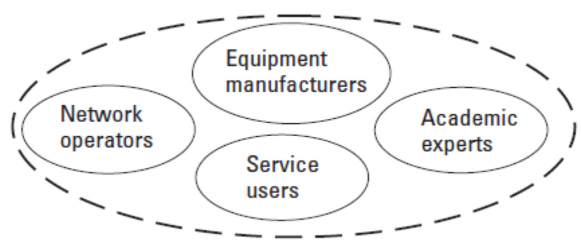

Figure 1.3 Interested parties.

Other interested parties include governmental officials who are keen on having national approaches adopted as international standards and academic experts who want to become inventors of new technological approaches.

1.5.2 National Standardization Authorities

National standardization authorities approve official national standards. Many international standards include alternatives and options from which a national authority selects those suitable for their own national standards. These options are included in cases for which a common global understanding could not be agreed on. Sometimes some aspects are left open and they require a national standard. For example, national authorities determine the details of their national telephone numbering plan, for which international standards give only guidelines. Another example is frequency allocation. International standards define usage of frequency bands (e.g., which frequency ranges are used for satellite and which for cellular networks), whereas the national authority defines detailed usage of frequencies inside the country; for example, they allocate frequency channels for cellular network operators. Some examples of national authorities are shown in the Figure 1.4. They take care of all areas of standardization, and they set up specialized organizations or working groups to work with the standardization of each specific technical area, such as telecommunications and information technology. These example organizations are shown in Figure 1.4: the British Standards Institute (BSI; United Kingdom), Deutsche Industrie-Normen (DIN; Germany), American National Standards Institute (ANSI; United States), and the Finnish Standards Institute (SFS; Finland).

1.5.3 European Organizations

The most important European standards organizations are shown in the Figure 1.5. They are responsible for developing European-wide standards to

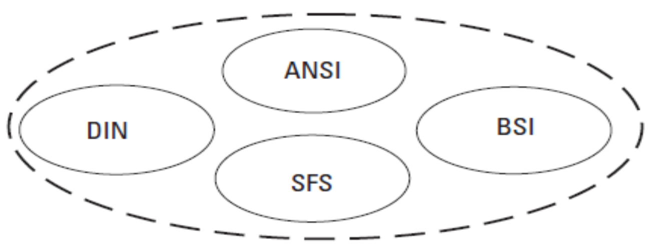

Figure 1.4 Some examples of national standardization authorities.

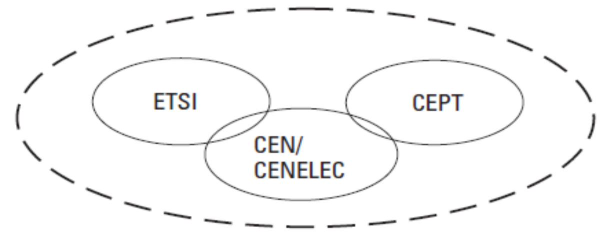

Figure 1.5 European standards organizations.

open national borders in order and improve pan-European telecommunications services.

The *European Telecommunications Standards Institute* (ETSI) is an independent body for making standards for the European Community. Telecommunications network operators and manufacturers participate in standardization work. One example of standards made by ETSI is the digital cellular mobile system GSM, which became a major standard for second generation digital mobile communications all around the world.

The *European Committee for Electrotechnical Standardization/European Committee for Standardization* (CEN/CENELEC) is a joint organization for the standardization of information technology. It corresponds to IEC/ISO on a global level and it handles environmental and electromechanical aspects of telecommunications.

The *Conférence Européenne des Administrations des Postes et des Telecommunications* or European Conference of Posts and Telecommunications Administrations (CEPT) was doing the work of ETSI before the European Commission Green Paper opened competition in Europe within the telecommunications market. The deregulation of telecommunications forced national PTTs to become network operators equal to other new operators and they are not allowed to make standards alone any more.

1.5.4 American Organizations

The U.S. national standards authority American National Standards Institute has accredited several organizations to work for standards for telecommunications. Some of these organizations are shown in Figure 1.6.

The *Institute of Electrical and Electronics Engineers* (IEEE) is one of the largest professional societies in the world and it has produced many important standards for telecommunications. Some of these standards, such as the standards for LANs, have been accepted by the ISO as international

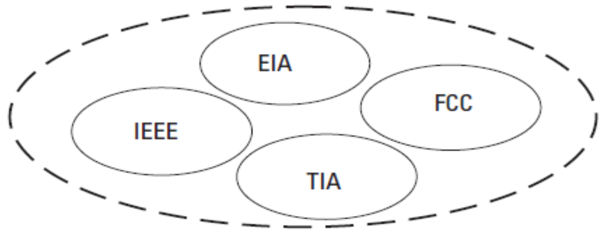

Figure 1.6 American standards organizations.

standards. For example, international standard ISO 8802.*x* for the Ethernet LAN family is currently the same as IEEE 802.*x*.

The *Electronic Industries Association* (EIA) is an American organization of electronic equipment manufacturers. Many of its standards, such as those for connectors for personal computers, have achieved global acceptance. For example, the data interface standard EIA RS-232 is compatible with the V.24/28 recommendations of ITU-T.

The *Federal Communications Commission* (FCC) is not actually a standards body but a regulatory body. It is a government organization that regulates wire and radio communications. It has played an important role, for example, in the development of worldwide specifications for radiation and susceptibility of electromagnetic disturbances of telecommunications equipment.

The *Telecommunications Industry Association* (TIA) has been developing global third generation cellular systems together with ETSI from Europe and the *Association of Radio Industries and Broadcasting* (ARIB) from Japan. Its task is to adapt the global standard to the American environment [4].

1.5.5 Global Organizations

The *International Telecommunication Union* (ITU) is a specialized agency of the United Nations responsible for telecommunications. It has nearly 200 member countries, and standardization work is divided between two major standardization bodies: ITU-T and ITU-R (see Figure 1.7).

The *Comité Consultatif International de Télégraphique et Téléphonique*, or International Telegraph and Telephone Consultative Committee (CCITT/ITU-T) is presently called ITU-T, where the "T" comes from telecommunications. The *Comité Consultatif International des Radiocommunications* or International Radio Consultative Committee (CCIR/ITU-R) is presently known as ITU-R, where the "R" stands for radio.

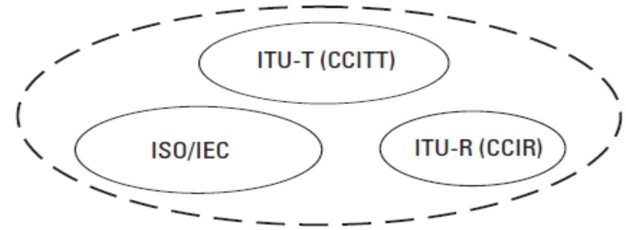

Figure 1.7 Global standards organizations.

ITU-T and ITU-R publish recommendations that are in fact strong standards for telecommunications networks. ITU-T works for the standards of public telecommunications networks (e.g., ISDN), and ITU-R works with radio aspects such as the usage of radio frequencies worldwide and specifications for radio systems. Many parties participate in their work, but only national authorities may vote. ITU-T, formerly CCITT, has created most of the current worldwide standards for public networks.

The International Standards Organization/International Electrotechnical Commission (ISO/IEC) is a joint organization responsible for the standardization of information technology. ISO has done important work in the area of data communications and protocols, and IEC in the area of electromechanical (for example, connectors), environmental, and safety aspects.

The organizations shown in Figure 1.7 work together closely to avoid duplicating effort and to avoid creating multiple standards for the same purpose. As a consequence, some ITU recommendations may contain merely a reference to an ISO standard.

1.5.6 Other Organizations

Many organizations other than those just mentioned are working with standards. Some of these are active in ITU-T and ISO, and many international standards are based on (or may even be copies of) the initial work of these groups. We introduce some of these as examples of standards organizations without official status (see Figure 1.8).

The *Internet Engineering Task Force* (IETF) is responsible for the evolution of the Internet architecture. It takes care of the standardization of the TCP/IP protocol suite used in the Internet.

The *Universal Mobile Telecommunications System* (UMTS) Forum is an open organization of cellular system manufacturers. Its goal is to define a third generation cellular system that will receive worldwide acceptance and

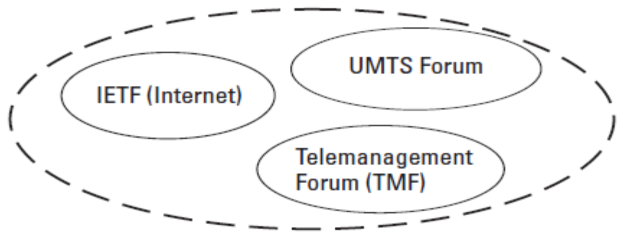

Figure 1.8 Examples of other standards organizations.

ensure compatibility among equipment from different vendors. Unofficial forums are more flexible and can produce necessary standards on a shorter timescale than can official organizations. Their specifications are often used as a basis for later official standards.

The *Telemanagement Forum* (TMF) is an organization of system manufacturers that works to speed the development of network management standards. With the help of these standards, telecommunications network operators will be able to control and supervise their multivendor networks efficiently from the same management center. Proposals are then given to ITU-T and ISO for official international acceptance.

The organizations mentioned here are just examples; many other such organizations and cooperative units exist. New groups appear and some organizations disappear every year.

One important problem in standardization is the question of *intellectual property rights* (IPRs). One company involved in development of a standard may have a patent or copyright for a method or function that is essential for implementation of the standardized system. In such a case, other manufacturers may not be able to implement the standard in an economically feasible manner without interfering with a patent or copyright. There are no fixed rules regarding how to solve this problem, but very often the patent or copyright owner agrees to license the patent or copyright for a standardized system under fair terms [5].

1.6 Development of the Telecommunications Business

In the past, telecommunications has been a protected business area. The national PTTs were once the only national telecommunications operators in most countries. They had control over standardization in international standardization bodies and a monopoly in providing telecommunications services in their home country. For political reasons domestic manufacturers were preferred as suppliers of the systems needed in the network. Competition was not allowed, and the development of services and networks was slow in many countries.

During the latter part of the 1980s the deregulation of the telecommunications business started in Europe and proceeded rapidly in many other areas of the world. Competitive telecommunications services are important for the development of an economy, and governments supported the development of free markets heavily.

In Europe the European Union has paid much attention to the deregulation of the telecommunications business. New operators have obtained licenses to provide local and long-distance telephone and data services and mobile telecommunications services. Previously many standards, such as analog mobile telephone standards, did not even support a multioperator environment. The initial requirement of the digital mobile telecommunications system (GSM) in Europe was the support of multiple networks in the same geographical area. The deregulation of the telecommunications business has reduced tariffs on long-distance calls and mobile calls to a small fraction of the tariffs paid in the mid-1980s. The reduction of fees has further increased the demand for services, which has prompted reductions in the price of terminal equipment, such as mobile telephones, and the fees for calls.

These developments have demonstrated how dangerous it is for manufacturers to be too dependent on a single domestic customer. Many telecommunications manufacturers that were independent in the past do not exist as independent suppliers anymore. This process still continues. At the same time, new small manufacturers are appearing. Their window of opportunity is to produce special equipment, in which the largest vendors are not interested, or systems for brand new rapidly growing services.

Plain old telephone service (POTS) will still be important in the future, but mobile and data communications grow most rapidly in volume. The two main directions of this development are in the areas of voice communications, which will become mobile, and data communications, which will become wideband, high-data-rate communications. Because of deregulation, subscribers can choose which network operator they want to use to get wideband access to the Internet over ordinary telephone lines. Cable TV operators are also providing similar services in competitive terms.

The provision of developing multimedia services in the future will be especially interesting. The expansion of the Internet, with its improving capability to transmit voice in addition to data, presents a new challenge to the public telecommunications network operators. Wideband access to homes will be used for telephone calls in addition to Internet surfing. This requires telecommunications network operators, including cellular network operators, to change their strategies from telephone and data transmission to complete service and information content provision. These services will contain Internet portals and location-based services, such as information on the nearest fast-food restaurant, in cellular networks.

For the future development of the telecommunications business, we must pay attention to customer services that technology can provide, not technology itself. Many good technologies, which we explain in later chapters, have not been successful because ordinary subscribers have not viewed them as attractive. Examples of these technologies are ISDN and *wireless application protocol* (WAP) services. On the other hand, some services, such as the WWW, have grown very rapidly. We have to keep in mind that only attractive services make new technologies successful.

1.7 Problems and Review Questions

Problem 1.1

List two or more electrical telecommunications systems that provide (a) bidirectional and (b) unidirectional service.

Problem 1.2

What were the three main developments in communications technologies during the last 20 years? Explain why you think so because this is a matter of opinion.

Problem 1.3

What are the most important advantages of global telecommunications standards?

Problem 1.4

Why is it often difficult to achieve a common understanding of and approve global standards? Explain both political and business interests.

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