CHAPTER

1

INTRODUCTION TO NETWORK CABLING

After reading this chapter and completing the exercises, you will be able to:

- Understand the need for certification and registration in telecommunications
- Summarize the history of standardization efforts
- Explain networking specifications and communications
- Understand the major developments in network technology
- Determine which type of network cable to use
- Define cabling documentation

As network technology continues to mature, the demand to connect more people to networks also continues to grow. Because the foundation of any network is its cabling, the demand for trained network cable specialists is growing as well. Networking and its related equipment have become more complex; a good network cable specialist now needs a comprehensive understanding of cabling as it relates to network access methods and network management. Specialists must also understand how different forms of cabling compare in terms of reliability, transmission speeds, and serviceability.

In addition to teaching concepts and theory, this book provides a practical, hands-on approach to the installation of all types of cable. The labs throughout this book provide you with experience working with a variety of termination devices, patch panels, cable media, connectors, splices, and relevant test equipment.

This chapter introduces you to the origins of cabling standards, standards organizations, and popular network cable systems. You will learn some of the standards required by industry and be introduced to structured cabling practices.

THE NEED FOR CERTIFICATION AND REGISTRATION IN TELECOMMUNICATIONS

The worldwide deregulation of the telecommunications industry began with the divestiture of AT&T in 1984. This divestiture resulted in the breakup of the Bell systems, and eventually to the establishment of standardization. AT&T was required by judicial decree to sell its local operating companies and restrict itself to providing long-distance telephone service and manufacturing and selling telephone products.

Divestiture caused mass confusion and problems for customers, manufacturers, long-distance carriers, and **service providers (SP)**, companies that provide telecommunications services for other companies. After deregulation, anyone could design, install, and maintain telephone systems, giving rise to many fly-by-night companies whose names became synonymous with shoddy work.

To add to the confusion, computer technology was maturing, and more organizations were installing computer systems. Each system required its own unique cable and connectors, and customers were displeased that their wiring needs changed each time their computer platform changed. In the past, local telephone companies had always looked after basic cabling needs, and companies that used mainframes had relied on their vendors to install the appropriate cable for their system. These practices didn't work anymore, and many customers who had been victimized by bad installations began seeking certified industry professionals.

BICSI Certifications and Registrations

In the wake of deregulation, one of the only organizations providing standards in telecommunications was the **Building Industry Consulting Service (BICS)**. AT&T and Bell Canada created BICS in the late 1960s, and it became responsible for identifying construction projects during the planning stage and working with architects, contractors, and engineers to create a project design. The design included all the pathway elements used in telecommunications cabling, such as raceways, equipment ducts, and **conduits**, the pipes that carry cable through a ceiling, wall, or floor. BICS worked with building contractors to implement the design, and helped operating companies install the necessary infrastructure (wires, cables, and termination hardware) to provide telephone facilities for commercial buildings.

In 1974, **Building Industry Consulting Services International (BICSI)** was founded to serve telecommunications consultants around the world. BICSI, a non-profit organization, began publishing its manuals to share standards-based design, installation guidelines, and methods that were accepted by the telecommunications industry. As the association grew, its programs and interests expanded to cover the broad spectrum of voice, data, and video technologies. BICSI offers courses, conferences, publications, and registration programs for cabling distribution designers and installers.

BICSI has established registration programs that provide a level of assurance to the industry and to consumers that a person is proficient in a designated area. Candidates for these registrations are required to pass rigorous exams and keep their knowledge current through continuing education. Some of the professional registration programs offered by BICSI are:

- **Registered Communications Distribution Designer (RCDD)** — RCDDs demonstrate proficiency in the design, integration, and implementation of telecommunications transport systems and related infrastructure components.
- **RCDD/LAN specialist** — In addition to their RCDD foundation, these specialists demonstrate proficiency with **local area networks (LANs)** and internetworking design. A LAN is a network of computers and other devices confined to one building, or even one office.
- **Installer, Level 1; Installer, Level 2; and technician** — Installers and technicians demonstrate their proficiency in conducting site surveys and pulling wire, cable, and optical fiber to the highest level of specification. This three-level career advancement program is designed to meet the diverse needs of the industry.

Standardization Bodies

Standards are specifications that guarantee a minimum level of performance. As defined in the *Telecommunications Industry Association Engineering Manual*, a standard is "a document that establishes engineering and technical requirements for processes, procedures, practices, and methods that have been decreed by authority or adopted by consensus. Standards may also be established for selection, application, and design criteria for material." Standards are used to quantify and qualify a given material or component. Because of the wide array of available hardware and software, standards are especially important in telecommunications.

Standardization of cabling systems was nonexistent until 1985, when the Computer Communications Industry Association (CCIA) approached the Electronics Industry Association (EIA) about developing cabling standards. The associations agreed that standards were required for voice and data communications designed for commercial and residential use. EIA assigned the task of developing cabling standards to a committee called TR-41.

Subcommittees and work groups were established to deal with the wide-ranging issues involved in developing cabling standards for commercial and residential buildings. In 1991 TR-41 split into two committees: TR-41 was still responsible for User Premise Equipment standards, but a new engineering committee, designated as TR-42, was now responsible for User Premise Telecommunications Cabling Infrastructure standards. TR-42 was charged with ensuring that the standards remained as an open system in support of voice, data, video, building control, and other low-voltage, **power-limited applications**. These applications use a circuit that limits power (generally to 50 volts and under) to the external wiring in the event of an overload condition.

Several more organizations have evolved within the telecommunications industry to set and oversee standards. You should become familiar with the following groups, which set standards referenced by manuals, articles, and books:

- **International Organization for Standardization (ISO)** — Headquartered in Geneva, Switzerland, the ISO is a collection of standards organizations that represents 130 countries. Its goal is to establish international technological standards that facilitate the global exchange of information. In addition to information processing and communications, ISO's authority applies to the fields of textiles, packaging, distribution of goods, energy, shipbuilding, banking, and financial services. Only about 500 of the ISO's nearly 12,000 standards apply to computer products and functions.
- **American National Standards Institute (ANSI)** — ANSI has more than 1000 representatives from industry and government, who together determine standards for the electronics industry and other fields. ANSI also represents the United States in setting international standards. ANSI does not dictate that manufacturers comply with its standards, but asks them to comply voluntarily. This compliance assures potential customers that systems are reliable and can be integrated with an existing infrastructure. To earn ANSI's approval, new electronic equipment and methods must undergo rigorous testing.
- **Electronic Industries Alliance (EIA)** — This trade organization has representatives from electronics manufacturing firms across the United States. EIA began as the Radio Manufacturers Association (RMA) in 1924; it has evolved to include manufacturers of televisions, semiconductors, computers, and networking devices. EIA not only sets standards for its members, it helps write ANSI standards and lobbies for legislation that favors the growth of the computer and electronics industries.
- **Telecommunications Industry Association (TIA)** — A subgroup of EIA, TIA is best known for developing cabling standards used in the design and installation of structured cabling systems that support a wide range of applications.
- **International Telecommunication Union (ITU)** — The ITU is a specialized United Nations agency that regulates international telecommunications, including radio and TV frequencies, satellite and telephony specifications, networking infrastructures, and tariffs applied to global communications. The ITU began as the Comité Consultatif International Télégraphique et Téléphonique (CCITT). You may still see references to CCITT standards in some manuals and texts.

- **Institute of Electrical and Electronics Engineers (IEEE)** — The IEEE is an international society of engineering professionals that promotes development and education in electrical engineering and computer science. IEEE establishes its own standards for the electronics and computer industries and contributes to the work of other standards-setting bodies such as ANSI. IEEE technical papers and standards are highly respected in the networking profession.

Codes and Regulations

In addition to standards, telecommunications professionals must understand and follow numerous codes and regulations in everyday business. From distribution design to final installation, the telecommunications field encompasses a variety of industries, each governed by its own rules.

A **code** is a body of law that is enforced by a local jurisdictional agency and systematically interpreted by the courts. A code's general purpose is to safeguard people and property from hazards, and to ensure the quality of construction. Codes and standards encompass almost all aspects of the building and construction industry. All installation methods and electrical products must conform to local electrical codes, building codes, fire codes, and other safety codes. However, these codes do not ensure that a system will function correctly or guarantee a minimum level of performance.

For example, the **National Electrical Code® (NEC)** is one of the most thorough and widely adopted sets of electrical safety requirements in the United States. The NEC is issued to minimize the risk of electrical shock, fires, and explosions. If state, municipal, or local codes are more restrictive than the NEC's, then the most restrictive code takes precedence.

A **regulation** reflects a local authority's ability to enforce codes and standards to regulate the building and construction industry. For example, service providers are regulated by the Federal Communications Commission (FCC) and state public service or public utility commissions.

Networking Specifications and Communications

Besides the necessary hardware and software, sets of rules were needed to enable truly networked computer communications. The IEEE and the ISO both responded by creating specifications that standardized network communications.

Developed in 1980, the IEEE's "Project 802" standardized the physical elements of a network and addressed networking specifications as they apply to connectivity, networking media, encryption, emerging technologies, and **error-checking algorithms**, the process used in a frame to check for errors in data transmission. Meanwhile, in the early 1980s the ISO began work on a universal set of specifications that would enable computer platforms across the world to communicate openly. The result was a helpful model for understanding and developing computer communications, called the **Open Systems Interconnection (OSI) model**. The IEEE 802 standards were developed before the

ISO standardized its OSI model, but the 802 standards can be applied to the layers of the OSI model.

The IEEE 802 standards are listed in Table 1-1, and the OSI model is summarized in Table 1-2.

Table 1-1 IEEE 802 standards

Standard	Name	Explanation
802.1	Internetworking	Covers routing, bridging, and internetwork communications
802.2	Logical Link Control	Relates to error and flow control over data frames
802.3	Ethernet LAN	Covers all forms of Ethernet media and interfaces
802.4	Token Bus LAN	Covers all forms of Token Bus media and interfaces
802.5	Token Ring LAN	Covers all forms of Token Ring media and interfaces
802.6	Metropolitan Area Network (MAN)	Covers MAN technologies, addressing, and services
802.7	Broadband Technical Advisory Group	Covers broadband networking media, interfaces, and other equipment
802.8	Fiber-Optic Technical Advisory Group	Covers use of fiber-optic media and technologies for various networking types
802.9	Integrated Voice/Data Networks	Covers integration of voice and data traffic over a single network medium
802.10	Network Security	Covers network access controls, encryption, certification, and other security topics
802.11	Wireless Networks	Covers standards for wireless networking for different broadcast frequencies and usage techniques
802.12	High-Speed Networking	Covers a variety of 100-Mbps-plus technologies, including 100BASEVG-AnyLAN

The OSI model divides network architecture into seven layers, as shown in Table 1-2. Each layer has its own set of functions, and interacts with the layers directly above and below it. The OSI model is a theoretical representation of what happens between two nodes (computers) on a network.

Table 1-2 OSI model and layer functions

Layer Number, Function, and Interaction	Layer Name
Layer 7 — Provides services directly to applications. The applications can vary, but they include electronic messaging.	Application
Layer 6 — Formats the data to provide a common interface for applications. This can include encryption services.	Presentation
Layer 5 — Establishes end connections between two nodes. Services include establishing whether a connection can be set at full- or half-duplex, although duplex is actually handled at Layer 4.	Session
Layer 4 — Handles general data delivery, whether connection-oriented or connectionless. Includes full- or half-duplex, flow control, and error recovery services.	Transport
Layer 3 — Establishes the connection between two nodes through addressing. It includes routing and relaying of data through an internetwork.	Network
Layer 2 — Frames data and handles flow control. Specifies the topology and provides hardware addressing.	Data Link
Layer 1 — Transmits the raw bitstream (data), electrical signaling, and hardware interface.	Physical

IEEE 802 defined many rules for how networks should transfer data. These rules, or **protocols**, are primarily directed at the two lowest layers of the OSI model—the Physical and Data Link layers. These layers are sometimes referred to jointly as the hardware level (Figure 1-1), because hardware and software work together at these layers to specify how data is handled by Ethernet and Token Ring networks. These layers also dictate how electrical signals are amplified and transmitted over the wire.

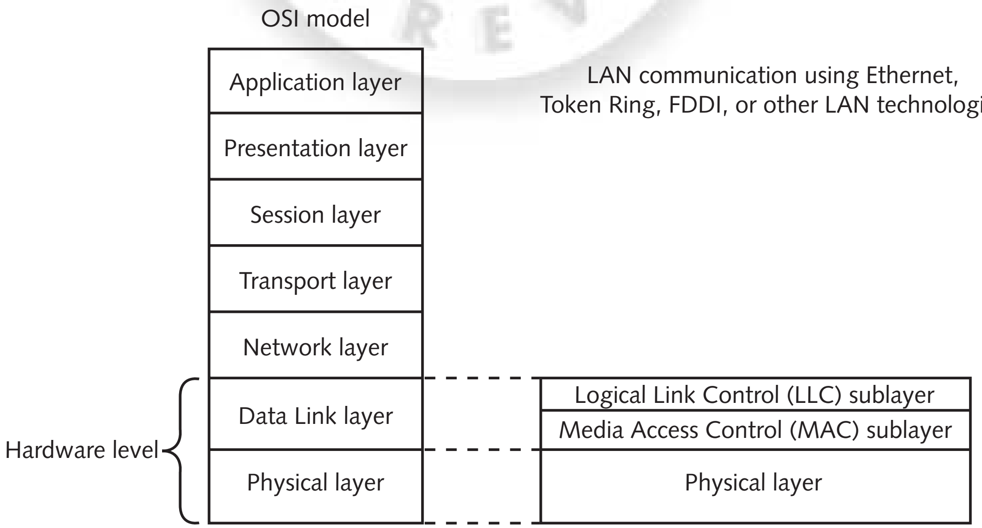

Figure 1-1 OSI model and LAN communications

The Physical layer defines the actual mechanical specifications and electrical data bitstream, the data transmission rate, the maximum distance, and the physical connectors. The Data Link layer consists of two sublayers. The upper level is the Logical Link Control (LLC), which provides a common interface and supplies reliability and flow control services. The lower level is the Media Access Control (MAC), which appends the physical address of the destination computer onto the frame. The physical address of every computer is a unique number that is hard-coded onto the **network interface card (NIC)** by the manufacturer. This card enables a user **workstation** to communicate with the network and other computers. Additional information on the OSI model and the services provided by each layer is shown in Figure 1-2.

Layer	Equipment and Functions	Data Format	Service Provided
Application	Interface	Messages	The service that identifies the message and processes it
Presentation	Translation and encryption	Messages	Message is presented to correct service; data translated as necessary
Session	Remote procedural calls (RPCs), error checking	Messages	Establishes connection dialog; provides reliable delivery of user requests to appropriate network service
Transport	Reliability, error checking	Segments	Logical WAN definition, error checking to ensure message is delivered correctly
Network	Software (logical) address, routers	Datagrams	Provides internetworking pathway for WAN communications
Data Link	Hardware (physical) address, bridges, intelligent hubs, NICs, error checking	Frames	Provides pathway for message to travel on
Physical	Pins, RS232, wires, cards, volts, cables, repeaters, hubs	Bits	Provides pathway for message to travel on

The Application, Presentation, and Session layers provide the vehicle for delivering network services.

The Transport and Network layers provide the logical pathway for communications among LANs.

The Data Link and Physical layers provide the transmission media and protocols for local network communications. Due to the physical nature of these layers, they rely on cabling boundaries for station-to-station communications.

Figure 1-2 Detailed OSI model

DEVELOPMENT OF NETWORK TECHNOLOGY

The original **Ethernet** was developed in the 1970s by Xerox Corporation as an experimental coaxial cable network with a data rate of 3 **megabits per second (Mbps)**. The network used the **Carrier Sense Multiple Access/Collision Detection (CSMA/CD)** protocol for LANs, which allows nodes to listen for traffic on the network before sending data.

The success of this project attracted the attention of Digital Equipment Corporation and Intel, who joined forces with Xerox to develop the 10-Mbps Ethernet Version 1.0 specification in 1980. As the holder of the Ethernet trademark, Xerox established and published the standards. Ethernet uses a thick, usually yellow, coaxial backbone cable known as "Thick Ethernet," "ThickNet," or 10Base5. The "10" refers to the data speed of 10 Mbps. The "Base" refers to **baseband**, which means it uses all of its bandwidth for each transmission. The "5" is short for 500, which refers to the maximum cable length of 500 m.

The original IEEE 802.3 standard was closely based on the Ethernet Version 1.0 specification. The draft standard was approved by the IEEE 802.3 working group in 1983 and published as an official standard in 1985. Since then, a number of supplements to the standard have been defined to take advantage of improvements in technology and support additional network media and higher data rates. The first type of cable used was a thin coaxial backbone cable known as "Thin Ethernet," "ThinNet," or 10Base2. The "10" and "Base" are the same as in 10Base5 above, and the "2" refers to the maximum cable length of 185 m.

In 1984, IBM introduced **Token Ring**, which was able to transmit data at 4 Mbps. This networking technology employs a ring topology using a token to allow data transmission, and is still the primary LAN technology used by IBM today. The IEEE 802.5 standard is almost identical to the Token Ring network, and completely compatible with it. Token Ring uses a thick, shielded twisted-pair cable and a special data connector developed by IBM called an IDC (IBM data connector) or UDC (universal data connector).

At the same time, numerous other networks were in use, and each used different types of cable and connectors. As the market for network communications continued to grow and the technology advanced, it became clear that a standard was needed. Three of the organizations discussed earlier—ANSI, TIA, and EIA—stepped in to fill the void.

Structured Cabling and ANSI/EIA/TIA-568-A

The TR-41 and TR-42 work groups developed the first telecommunications cabling standard, ANSI/EIA/TIA-568, which continues to evolve as network speeds increase and cable improves. The ANSI/EIA/TIA-568 Commercial Building Wiring Standard gave birth to the **structured cabling** system, whose primary focus was uniform, enterprise-wide, multivendor cabling. Structured cabling suggests how telecommunications media can best be installed to maximize performance and minimize upkeep.

Structured cabling divides the infrastructure into six subsystems that are then integrated to provide consistent, reliable networks. There are several advantages to using a structured cabling system:

- **Consistency** — A structured cabling system uses the same cabling for data, voice, and video.
- **Support for multivendor equipment** — A standards-based system supports numerous applications and hardware for all vendors.
- **Simplified additions, moves, and changes** — The system is designed to support any changes within it.
- **Simplified troubleshooting** — The wiring scheme makes it difficult for a single problem to bring down the network. Problems are easier to isolate and repair.
- **Support for new applications** — Structured cabling systems support new applications such as multimedia and video conferencing with little or no upgrade difficulty.

The ANSI/EIA/TIA-568-A standard identifies the six subsystems of the building infrastructure. The primary focus of this standard is to provide specifications and guidance for the installation of telecommunications cabling systems and components in commercial buildings.

The six sublayers are:

- **Entrance facility** — The place where the **telecommunications service** enters a building. This service is the cabling from the local service provider. If applicable, the entrance facility is where backbone pathways link with other buildings. It is also the place where the building's internal wiring begins. The division between the telecommunications service cabling and the building's internal cabling is the **demarcation point (d-mark)**.
- **Equipment room(s)** — The location of telecommunications equipment common to building occupants. This common equipment can include large telephone systems called **private branch exchanges (PBXs)**, servers, and mainframes. The cabling in this room usually connects to telecommunications rooms.

- **Telecommunications room (TR)** — Also known as the telecommunications closet, the TR is the space within the building that provides the common access point between the backbone and horizontal cabling. The TR houses the telecommunications cabling equipment, mechanical terminations, and **cross-connect** wiring, a group of connections used to mechanically terminate and administer building wiring.
- **Backbone pathways and cabling** — A backbone is essentially a network of networks. Backbone cabling provides interconnection among telecommunications rooms, equipment rooms, and entrance facilities. The backbone cabling consists of the feeder field of the horizontal cross-connect, **intrabuilding** and **interbuilding** cabling (which runs within the same building and between buildings, respectively), and the main and intermediate cross-connects. Distance limitations for backbones are application-dependent. In Table 1-3 the distance limits are based on voice and data transmission for unshielded twisted-pair cable (UTP) and data transmission for fiber.

Table 1-3 Backbone distance limits

Cable Type	Maximum Backbone Distance
100-ohm UTP (24 or 22 **American Wire Gauge**, or **AWG**)	800 m (voice specification) 90 m (data specification)
Single-mode fiber (independent of speed)	3000 m (data specification)
Multimode fiber (independent of speed)	2000 m (data specification)

- **Horizontal pathways and cabling** — The wiring that connects workstations to the TR. These pathways must be able to handle all types of cable. The pathways that are recognized by the ANSI/EIA/TIA-569 standard include underfloor duct, access floors, conduit, ceiling pathways, perimeter raceways, cable trays, and wire trays. The maximum allowable distance for horizontal cabling is 100 m (Figure 1-3). This span includes 90 m to connect the work-area jack on the wall to the TR, plus a maximum of 3 m to connect a workstation to the jack on the wall, and a maximum of 6 m for patch cords or cross-connects at the horizontal cross-connect.
- **Work area** — An area where building occupants use telecommunications devices. The work area includes **patch cables** that connect network or telecommunications devices to data jacks on the wall.

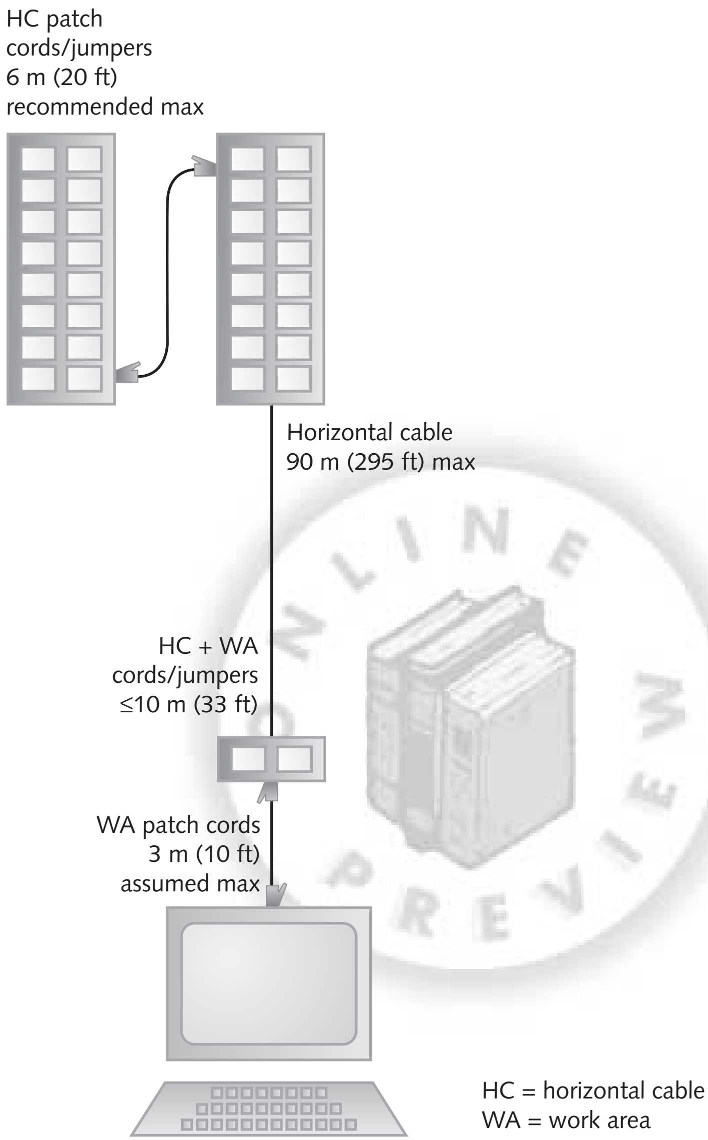

Figure 1-3 Horizontal cross-connect and maximum distances

Network Cables

A **cable** is the medium that provides the physical foundation for data transmission. Several types of cable are commonly used. Some networks use only one type of cable, while others employ several cable types in the same network. The type of cable you choose depends on the size of the network, the protocol(s) being used, and the network's physical layout, or **topology**.

To develop a successful network, you must understand the different types of cable you can use, and how each relates to other aspects of the network. The following sections explain your options.

Twisted-Pair Cable

Twisted-pair cable is the most common form of cabling used on LANs today. It is relatively inexpensive, flexible, easy to install, and capable of spanning a significant distance before additional equipment is required. Twisted-pair cable can accommodate several different topologies, but is most often implemented in a **star topology**, in which every node is connected through a central device. Twisted-pair cable can also handle the faster networking transmission rates in use today. This cable is available in unshielded, shielded, and screened forms.

Unshielded Twisted-Pair

Unshielded twisted-pair (UTP) cable comes in a variety of grades, from voice grade to extremely high-speed grade. The cable contains color-coded pairs of insulated copper wires inside a plastic jacket, as shown in Figure 1-4. Each pair has a different number of twists per inch, depending on the grade, to help eliminate interference from adjacent pairs, adjacent cables, and other electrical devices. The more twists per inch a pair of wires has, the more resistant it will be to all forms of noise.

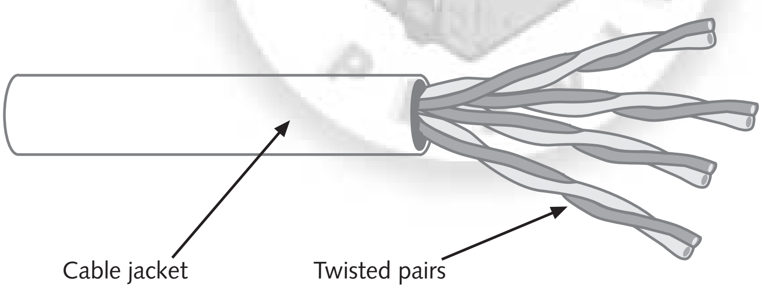

Figure 1-4 Unshielded twisted-pair cable

UTP cable has been designated as 10BaseT. The "10" represents its minimum transmission rate of 10 Mbps. The "Base" refers to baseband, which means that UTP uses all of its bandwidth for each transmission. The "T" represents UTP.

Table 1-4 lists the various grades of UTP, along with its cable transmission speeds and specifications provided by the ANSI/EIA/TIA UTP standard.

Table 1-4 ANSI/EIA/TIA UTP specifications by category

Cable Category	Data Rate	Bandwidth	Application
Category 1 (CAT1)	20 Kbps		Analog voice, doorbell wiring
Category 2 (CAT2)	4 Mbps	1 MHz	Voice
Category 3 (CAT3)	10 Mbps	16 MHz	Voice and data on 10BaseT Ethernet
Category 4 (CAT4)	16 Mbps	20 MHz	Token Ring and 10BaseT Ethernet
Category 5 (CAT5)	100 Mbps	100 MHz	100BaseT Ethernet, 10BaseT Ethernet, ATM
Enhanced CAT5	1.2 Gbps	200 MHz	Same as CAT5, Gigabit Ethernet
Category 6 (CAT6)	2.4 Gbps	250 MHz	Same as Enhanced CAT5, but better performance
Category 7 (CAT7)	Unknown at this time	600 MHz	Same as Enhanced CAT5; standard was still in testing at press time

Shielded Twisted-Pair

Shielded twisted-pair (STP) cable consists of insulated wire pairs that are surrounded by a metallic shielding such as foil (Figure 1-5). If the wire is properly grounded, the shielding acts as an antenna, converting noise into current. The effectiveness of the shield depends on the environmental noise to which the STP is subjected, the grounding mechanism, and the material, thickness, symmetry, and consistency of the shielding.

STP is more expensive than UTP. On the other hand, shielded cable provides better immunity to **electromagnetic interference (EMI)** and **radio frequency interference (RFI)**. EMI is the noise generated when stray electromagnetic fields induce currents in electrical conductors, and RFI is interference caused by electrical devices or broadcast signals.

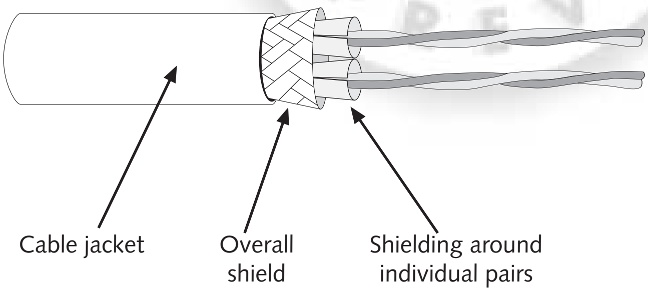

Figure 1-5 Shielded twisted-pair cable

Screened Twisted-Pair

Screened twisted-pair (ScTP) cable is commonly used in Europe, but has recently received more attention in North America as various organizations attempted to harmonize their telecommunications cabling standards. ScTP specifications are based on those for UTP cabling, but there are notable differences. For example, the maximum distance for a horizontal ScTP cable is 98 m. Also, the size of its screen makes ScTP unable to fit into a standard modular plug, so stranded 26 AWG must be used instead of the standard 24 AWG. Finally, when ScTP is installed correctly, its immunity to radio frequency fields is superior to that of UTP.

Coaxial Cable

Coaxial cable (coax) was the foundation for Ethernet networks in the 1980s and remained a popular transmission medium for many years. Coax comes in several types, but they are all similar in their construction: a central copper core is surrounded by an insulator, a braided metal shielding, and an outer cover called the sheath or jacket (Figure 1-6). Because of its construction, coax has a high immunity to interference from EMI and RFI.

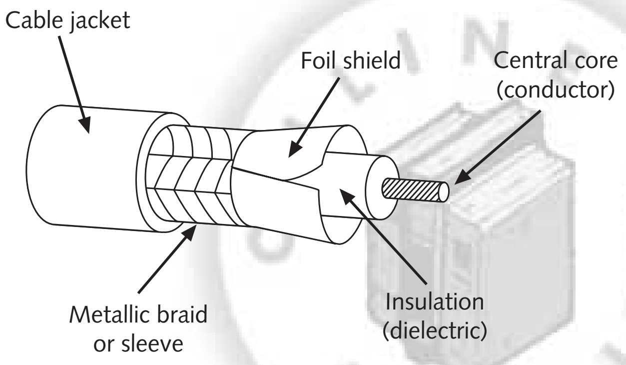

Figure 1-6 Coaxial cable

Fiber-Optic Cable

Fiber-optic cable (fiber) contains one or more glass fibers in its core, surrounded by a layer of glass called cladding. The glass and cladding are covered by layers of plastic, also referred to as the buffer coating. Buffer coatings are available in two basic designs: loose-tube and tight-tube. Loose-tube buffer has an inner diameter that is much larger than the fiber. The interior of the buffer tube is filled with a gel that protects the fiber. Tight-tube buffer is a direct extrusion of plastic over the fiber. The buffer coating is covered by a braiding of Kevlar®, which in turn is covered by a plastic jacket (Figure 1-7). Data is transmitted by a pulsing light sent from a laser or light-emitting diode (LED) through the core. The cladding acts as a mirror, reflecting the light back to the core in patterns that vary depending on the transmission mode. The reflection allows the fiber to bend around corners without diminishing the integrity of the signal. Fiber can reliably transmit data at rates as high as 1 Gbps, and because it transmits light rather than electrical signals, it is immune to EMI and RFI.

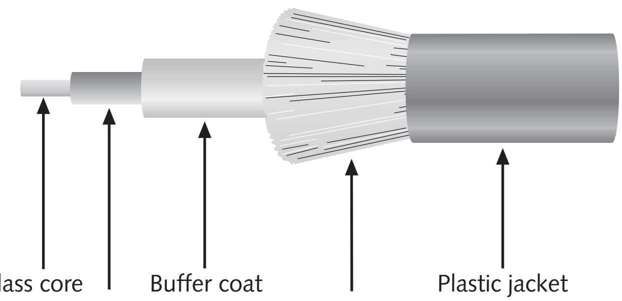

Figure 1-7 Optical fiber

Fiber can transmit signals over much longer distances and carry information at significantly greater speeds than coax or twisted-pair cable. Thus, fiber can expand a company's communications to include video conferencing and other interactive services. The biggest drawback to fiber is its cost and the associated costs of its connectors, patch panels, jumper cables, testers, and network interface cards. Fiber is also more difficult to install and modify than other cabling, and it can only transmit in one direction at a time unless each cable contains two strands—one to send data and one to receive it.

Fiber comes in two categories: single-mode and multimode. Single-mode fiber carries a single wave of light at a time, to transmit data from one end of the cable to the other. Data can travel faster and farther on single-mode fiber, but the cost is extremely high. Multimode fiber can transmit multiple waves of light simultaneously over one or more fibers, and is the type of fiber used by most data networks.

Comparing Cable Media

Before choosing the type of cable you will use, you must compare the characteristics and costs of each type (Table 1-5). Note also that the cable type you need depends on its implementation, such as network interface cards, hubs, and other devices. For example, a **hub** is a multiport repeater containing one port that connects to the backbone and multiple ports that connect to a group of workstations. The cabling for a hub would require the use of UTP installed in a star topology.

You would also need to compare cable media before installing a cable that spans many kilometers. For example, although fiber is more costly than copper cable on a per-foot basis, using copper for long distances would require **repeaters** to be installed at many points along the cable, to amplify and regenerate the analog or digital signal. The cost of the repeaters could easily exceed the cost of the fiber for the same distance.

Table 1-5 Cable comparisons

Cable Type	Cost	Installation	Capacity	Range	EMI/RFI
Coaxial ThinNet	Less than STP	Easy and relatively inexpensive	10 Mbps typical	185 m	Less sensitive than UTP
Coaxial ThickNet	More than STP, less than fiber	Easy	10 Mbps typical	500 m	Less sensitive than UTP
STP	More than UTP, less than ThickNet	Fairly easy	16 Mbps typical, up to 500 Mbps	100 m	Less sensitive than UTP
UTP	Lowest	Easy and relatively inexpensive	10 Mbps typical, up to 4.8 Gbps	100 m	Most sensitive
Fiber-optic	Among the highest; differs by application	Expensive and difficult	100 Mbps to 200 Gbps	2000 to 3000 km	Insensitive

Cabling Documentation

In the field of network cabling, documentation is like a road map. It provides the locations and routes for every cable in your network. Documentation also functions like an inventory, providing a reference for each network element and each item used to create the network. Good documentation saves you time and can make your job easier in the long run.

Although network administrators and telecommunications professionals are happy to acknowledge the importance of documentation, they often are unable to provide any of their own. Most professionals want to provide documentation, but it takes extra time that they never seem to have. Besides, documentation is rarely recognized as an accomplishment, and its absence doesn't keep others from doing their work.

This book elaborates on the importance of documentation in each subsequent chapter. You'll learn how to create a documentation project, what to include in it, the best formats to use for it, and how documentation will make your job easier and more secure.

Chapter Summary

- The worldwide deregulation of the telecommunications industry began with the divestiture of AT&T in 1984. Divestiture resulted in the breakup of the Bell systems, and eventually to the establishment of standardization.
- Several organizations have evolved within the telecommunications industry to set and oversee standards, including the ISO, ANSI, EIA, TIA, ITU, and IEEE.

- The protocols defined by IEEE 802 are primarily directed at the Physical and Data Link layers of the OSI model, because hardware and software work together at these layers to specify how data is handled by Ethernet and Token Ring networks. These layers also dictate how electrical signals are amplified and transmitted over the wire.
- The original Ethernet was developed in the 1970s by Xerox Corporation as an experimental coaxial cable network. Today, two types of coaxial cable are used in Ethernet networks: ThinNet and ThickNet.
- Twisted-pair cable is classified into five grades, from Category 1 through Category 5. Only Category 3 and Category 5 are acceptable for use on an Ethernet LAN. UTP Category 5e, Category 6, and Category 7 are the newest standards for copper cable. They can support bandwidths of 1000 Mbps or more. Their cable segment length is limited to 100 m, but their range can be extended with the use of repeaters.
- Fiber-optic cable is immune to EMI and RFI, has a faster data rate than other cable types, and can be run over greater distances than copper cable. It is still more costly than any other cable, but it continues to gain industry acceptance for all uses.
- In the field of network cabling, documentation is like a road map. It provides the locations and routes for every cable in your network. Documentation also functions like an inventory, providing a reference for each network element and each item used to create the network.

KEY TERMS

American Wire Gauge (AWG) — The standard for measurement of wire.

baseband — A coaxial cable that uses all of its bandwidth for each transmission.

Building Industry Consulting Service (BICS) — An organization of telephone company engineers created by AT&T and Bell Canada. BICS works with architects, building contractors, and engineers to design and implement cabling plans for pathways and spaces in commercial buildings.

Building Industry Consulting Services International (BICSI) — A not-for-profit telecommunications organization founded to serve BICS.

cable — An assembly of one or more insulated conductors within a sheath, constructed to permit use of the conductors singly or in a group.

Carrier Sense Multiple Access/Collision Detection (CSMA/CD) — An Ethernet protocol that allows nodes to listen for traffic on the network before sending data.

code — A law designed to protect people and property from hazards, and to ensure the quality of construction.

conduit — A pipe that carries cable through a ceiling, wall, or floor.

cross-connect — A group of connections used to mechanically terminate and administer building wiring.

demarcation point (d-mark) — The point where the service provider's cabling ends and the customer's cabling begins.

electromagnetic interference (EMI) — Noise generated when stray electromagnetic fields induce currents in electrical conductors.

equipment room — An enclosed space for housing equipment, cable terminations, and cross-connects.

error-checking algorithm — The process used in a frame to check for errors in data transmission.

Ethernet — A networking technology originally developed by Xerox and improved by Digital Equipment Corporation, Intel, and Xerox. Used on most LANs.

hub — A multiport repeater containing one port that connects to the backbone and multiple ports that connect to a group of workstations. Hubs regenerate digital signals.

interbuilding — Refers to connections between one building and other outlying buildings.

intrabuilding — Refers to connections within the same building, usually on different floors.

local area network (LAN) — A network of computers and other devices confined to a single building, or even one office.

megabits per second (Mbps) — A measurement of a network's data rate based on the network's physical characteristics.

National Electrical Code (NEC) — The most comprehensive book on electrical codes in the United States.

network interface card (NIC) — A device that enables a workstation to communicate with a network and other computers.

Open Systems Interconnection (OSI) model — A model for understanding and developing computer-to-computer communication. It divides network architecture into seven layers.

patch cable — A relatively short section of cable (3 to 50 feet) with connectors at both ends that connect network devices to data jacks, or horizontal cables to the horizontal cross-connect.

power-limited applications — Applications with a circuit that limit power (generally to 50 volts and under) to the external wiring in the event of an overload condition.

private branch exchange (PBX) — A large telephone system that switches calls among users on local lines while allowing all users to share a certain amount of external lines.

protocols — The rules that a network uses to transfer data.

radio frequency interference (RFI) — A type of interference that may be generated by motors, power lines, televisions, copiers, fluorescent lights, or broadcast signals from radio or TV towers.

regulation — A local authority's ability to enforce codes and standards to regulate the building and construction industry.

repeater — A connectivity device that regenerates and amplifies an analog or digital signal.

service provider (SP) — A company that provides telecommunications service to a building.

standard — A document of specifications that guarantee a minimum level of performance.

star topology — A physical topology in which every node is connected through a central device.

structured cabling — A method for uniform, enterprise-wide, multivendor cabling specified by ANSI/EIA/TIA-568.

telecommunications service — The cabling and services available from a local service provider.

Token Ring — A networking technology developed by IBM. It employs a ring topology using a token to allow data transmission.

topology — The physical layout of a computer network.

twisted-pair cable — The most common form of cabling used on LANs. Each pair has a different number of twists per inch, depending on the grade, to help eliminate interference.

workstation — A computer intended for individual use.

Review Questions

1. According to industry specifications, what is the maximum allowable length of a horizontal cable?
   a. 15 meters (50 feet)
   b. 30 meters (100 feet)
   c. 100 meters (328 feet)
   d. 333 meters (1000 feet)
2. What is the ANSI/EIA/TIA-568 standard responsible for?
   a. structured cabling
   b. shielded cable
   c. Project 802
   d. manufacturing and quality-control procedures

3. The protocols defined by IEEE 802 are primarily directed at which layers of the OSI model?
   a. Session and Data Link
   b. Data Link and Network
   c. Physical and Data Link
   d. Network and Transport
4. What type of cable is used in the Ethernet 10Base2 specification?
   a. coaxial cable
   b. unshielded twisted-pair cable
   c. shielded twisted-pair cable
   d. fiber-optic cable
5. What type of cable is used in the Ethernet 100BaseT specification?
   a. RG-58 AU coaxial cable
   b. Category 3 cable
   c. Category 4 cable
   d. Category 5 cable
6. What type of cable is used in the Ethernet 10BaseT specification?
   a. RG-58 AU coaxial cable
   b. Category 3 cable
   c. Category 4 cable
   d. Category 3, Category 4, and Category 5 cable
7. Fiber-optic cable offers the possibility of very high bandwidth and immunity to noise. True or False?
8. What is the maximum effective segment length for twisted-pair cable?
   a. 800 meters
   b. 2000 meters
   c. 50 meters
   d. 100 meters
9. The Physical layer provides the foundation for a reliable, high-performance LAN. True or False?
10. The telecommunications room is always in the same location as the main or intermediate cross-connect. True or False?

11. The cabling found in older data networks would most likely be ________________.
    a. fiber-optic
    b. coaxial
    c. twisted-pair
    d. four-pair
12. A standards-based cabling system will support only one application and hardware vendor. True or False?
13. One purpose of a standard is to ensure a minimum level of performance. True or False?
14. The types of media that can transmit information in the telecommunications world are ________________.
    a. copper wire, coaxial cable, fiber, and wireless
    b. hybrid fiber/coax and copper wire
    c. wireless and copper wire
    d. copper wire, coaxial cable, fiber, and hybrid fiber/coax
15. The advantages of structured cabling include ________________.
    a. support for multivendor equipment and simplified changes
    b. simplified troubleshooting and support for future applications
    c. both of the above
    d. none of the above
16. The backbone cabling provides interconnection among telecommunications rooms, equipment rooms, and entrance facilities. True or False?
17. In Canada and the United States, building codes and standards regulate ________________.
    a. service providers
    b. how a system functions
    c. quality of manufacturing
    d. the construction industry
18. Ethernet was developed in the late 1960s by AT&T and Bell Canada. True or False?

19. Coaxial ThickNet cable has the same 10-Mbps capacity as coaxial ThinNet but has a shorter range. True or False?
20. Fiber-optic cable offers higher bandwidth and can operate at greater distances than ______________.
    a. coaxial cable
    b. UTP cable
    c. neither a nor b
    d. both a and b
21. There are two types of fiber-optic cabling: multistrand and single-strand. True or False?
22. Gigabit Ethernet can be implemented ______________.
    a. as a backbone interconnect
    b. to the desktop
    c. between switches and servers
    d. all of the above
23. The term "Category" describes the performance characteristics of UTP cabling systems. True or False?
24. In 1984, IBM introduced Token Ring, which was able to transmit data at ______________.
    a. 2 Mbps
    b. 4 Mbps
    c. 10 Mbps
    d. 20 Mbps
25. A telecommunications closet is the area within a building that houses telecommunications cabling equipment, including mechanical terminations and/or cross-connect for the horizontal and backbone cabling system. True or False?

HANDS-ON PROJECTS

HANDS-ON PROJECTS

Project 1-1

Outline the process and standards required to begin installing a telecommunications system in a 10-person, ground-floor business. What are the required components of this system? What components would you require if the business were on the fourth floor?

Project 1-2

To help you decide whether to become BICSI Level 1 certified, go to *www.bicsi.com* and click **RCDD/Installation**. Scroll down the next page to the Telecommunications Cabling Installation Program heading. In the Program Overview section, click **Installer, Level 1**. Read the Course Overview section and then print it. This overview provides an outline of the main objectives for the Level 1 Certification exam.

Optionally, you can go back to the Telecommunications Cabling Installation Program heading on the previous page. In the Exam Requirements section, click **Installer, Level 1**.

Project 1-3

Go to *www.webopedia.com* and search by keyword for definitions of the following terms, which you will use throughout your career in telecommunications and networking.

- Crosstalk
- Patch cord
- Patch panel
- Attenuation
- Local area network
- Wide area network
- CAT5
- Telecommunications
- Ethernet
- Gigabit Ethernet

Project 1-4

Go to the IEEE Web site at *www.standards.ieee.org* and search the 802 standards. Create a report that lists each standard by number and briefly defines each one. Print your report and turn it in to your instructor. Also print a copy for your files; the information will be helpful throughout this course and your telecommunications career.

Project 1-5

Find information about structured cabling systems and the standard that defines them. Go to *www.anixter.com/techlib*, select **Standards Guides**, then select **ANSI/TIA/EIA-569-A, Pathways and Spaces**.

HANDS-ON PROJECTS

Project 1-6

Check with the appropriate departments for your city and state, such as the registrar of contractors, the building inspector, and the fire marshal, to find out what local regulations and major building codes you should know before installing cable. Write a brief report that summarizes your findings.

CASE PROJECTS

CASE PROJECTS

Case Project 1

The XYZ Company is planning to relocate its corporate office. In a planning session, managers and representatives from each department raise several concerns. You have been asked to address these concerns in the next planning session.

1. Managers don't know which types of cable are available. List the different types of cable and the differences among them.
2. Each department has its own cabling requirements. One user from each department is responsible for administering the department's requirements. What could some of these requirements be?
3. What type of system would you recommend to address these requirements?

CASE PROJECTS

Case Project 2

ABC Engineering has just landed a large contract and requires six workstations to be installed two floors up from the server. The managers are concerned that the new users will slow down the network by transferring large files to and from the server. You have been asked to create a document that addresses these concerns.

1. Outline each of the issues you need to address.
2. EMI is a major issue and has been emphasized by your managers. Document the various materials you will use to address EMI.
3. Document the type of cabling you recommend, and how it will address each issue.

CASE PROJECTS

Case Project 3

You have been hired by the LB Company to evaluate its telecommunications system and make recommendations for a proposed expansion of 20 workstations and telephones. The company currently has 55 workstations. Based on your reading of this chapter, create a report that summarizes what cabling equipment the company might have, and where it might be located (for example, the equipment room or the telecommunications room).

Case Project 4

The LB Company has also asked you to provide information about newer cabling technology. Create a report that includes the most current information on Category 5e, 6, and 7 cabling standards. Use this book, the Internet, and other sources for assistance.