SECTION EIGHTEEN
COMMUNICATIONS SYSTEMS

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The communications systems within the building design and construction enterprise has taken on a large role in the achievement of profitability and efficiency. A basic understanding of communications systems is beneficial to all building professionals and trades, as they all play a part in the success of the communications systems. Success is defined here as the occupants being able to use the communications systems effectively and efficiently for years after the installation is complete. A building today is not functional if the communications systems are impaired. A typical communications system may be broken down into logical segments, (1) infrastructure, (2) cabling and connectors, (3) electronic equipment, and (4) software applications. The infrastructure, cabling and connectors greatly affect the entire system. The communications systems may be enhanced by good building design and construction by providing some flexibility and room for growth.

Knowing a few definitions is key to understanding the principles of communications systems. A glossary is provided. The reader should try not to feel overwhelmed by the terms. Some fundamental terms are provided as well as some advanced terms. Once a basic understanding is reached, learning new terms will follow. Keep in mind that the sheer amount of jargon in this industry weighs down even the professionals. One observation of the industry is that the professionals rely heavily on glossaries but do not often share them with each other or use them in public. A collection of glossaries is an important part of a professional's personal library. Black Box Corporation provides an excellent glossary, ''Pocket Glossary of Computer Terms,'' which includes technical reference material at a reasonable cost.

18.1 GLOSSARY

ADSL. Asymmetrical digital subscriber line, a relatively new method of transmitting data over a single copper telephone line; 8 Mbps download, 1 Mbps upload. Sectors of the industry hope to use ADSL over existing utility phone lines (see POTS) to deliver high-speed Internet service to the home. Check with

the local utility, about whether ADSL is available in a particular area and about the connection and service details. Keep in mind that not all ASDL is alike. In the office, the equipment would appear as an ADSL modem at the PC or in a communications closet or room. ADSL equipment would also be located at the phone company central or remote office.

ANSI. American National Standards Institute.

ATM. Asynchronous transfer mode, an emerging technology and a high-speed network that can carry and switch data, real-time voice and real-time video. The data rate is scalable 1.5 Mbps, 25 Mbps, 50 Mbps, 100 Mbps, 155 Mbps, 622 Mbps, pushing towards gigabyte speeds. ATM is a high-end alternative to Gigabit Ethernet. Several emulated ethernet networks can run on a single ATM network. The ATM equipment would appear as rack-mounted gear located in communications closets and rooms. Cabling between ATM gear is typically single-mode and multimode fiber. Cabling to the PC is only as fast as the cable used in other parts of the network. Category 5 (CAT 5) or fiber is typically used. ATM service is also available from some phone companies, LECs, and their competitors, CLECs. This makes it possible to run an ATM WAN.

Backbone. The cabling that connects the main communications room to the closets.

BICSI. Building Industries Consulting Services International. A telecommunications association that writes standards, provides training, and registers communications designers.

BOCA. Building Officials Code Administrators International, an organization that writes a model building code which has been adopted in whole, or in part, by many jurisdictions.

Bridge. A piece of network gear that connects or bridges between two different types of LAN segments. The equipment would appear as rack-mounted gear located in communications closets usually, but not necessarily, next to the gear of one of the LAN segments it is bridging.

Closet. This is the room where all of the cabling from the telephones and PCs is joined. This room also contains expensive network gear and phone equipment. There is supposed to be at least one closet per floor, more if the floor is large. Most people are not allowed in these closets, so they do not understand why so much room is needed, what is in there, or how important the room is. Also the term closet brings to one's mind a 2 ft by 3 ft residential coat closet. This did suffice 50 years ago. Today, a 3-ft clearance is needed on all sides of electronic equipment, so think past a walk-in closet to a large walk-around room.

Cable. An assembly of wires or glass fibers with insulation and jacket; cable can be plenum and non-plenum rated. An outside-plant cable may have water-blocking gel or tape, metallic or nonmetallic strength members, armoring, and over-jacket.

Carrier. In communications, a continuous frequency that is capable of carrying an imposed signal. The company that provides the continuous frequency.

Category. The Commercial Building Telecommunications Cabling Standard, ANSI/TIA/EIA-568-A defines categories for 100-Ω unshielded twisted-pair cables.

Category 3. This designation applies to cables and hardware up to 16 MHz (16 Mbs).

Category 4. This designation applies to cables and hardware up to 20 MHz (20 Mbs).

Category 5. This designation applies to cables and hardware up to 100-MHz (100 Mbs).

Category 5e. This designation applies to cables and hardware over 100 MHz (over 250 Mbs).

Category 6. This designation applies to cables and hardware over 250 MHz (over 500 Mbs).

Central Office. The office of the carrier where all lines in the local exchange are terminated. The electronic equipment that processes, switches, multiplexes, and interfaces the local exchange traffic with the long-haul system.

Channel. A channel, when referring to horizontal cabling, refers to the cabling from the PC to the communications closet network gear, including all of the patch cables and the patch-panel connectors. (Compare to the definition of a Link.)

Channel Bank. A piece of electronic equipment usually located in the main communications room that multiplexes or de-multiplexes lines into T1 lines or other high-speed lines.

CLEC. Competitive local exchange carrier. The phone company is a local exchange carrier (LEC). CLECs operate private communications networks that compete with each other and the LEC. CLECs are found primarily in cities.

Cross Connects. In the communications closet, voice lines that come from the main communications room are terminated on blocks. Voice lines that come from wall and system furniture outlets are also terminated on blocks. The interconnecting wiring between the blocks are called *cross connects*. The term is well suited; cross connects are recognizable at first sight.

CTI. Computer telephone integration; an example of CTI is a PC with telephone-soliciting software and phone headgear so that the operator may use the PC to dial the phone and process data. Databases may be searched automatically and information may pop up (screen pop) on the screen for operator use.

CSU. Channel service unit, a piece of electronic equipment found near the demarcation point used to terminate the digital service at the customer's premises. It serves as a point of diagnosis and testing.

DCE. Data communications equipment, the electronic equipment that establishes, maintains, and terminates a connection to a network. The DCE may be a part of a modem, but not necessarily.

de facto Standard. A standard because it is widely accepted in the industry, a standard "from fact."

de jure Standard. A standard because it has been approved by a standards organization, a standard "by right."

Distribution Frame. A physical structure that holds telephone distribution blocks, either rack mounted or wall mounted. The distribution blocks on the building's main distribution frame serve to connect wires from the building's PBX, or the telephone company's central office, to the remote distribution frames or to the local extensions through cross connects.

Duct. Duct, or conduit, is used to protect and install cabling. Types include electrical metallic tubing (EMT), intermediate metallic tubing (IMC), rigid galva-

nized steel (RGS), electrical nonmetallic tubing (ENT), polyvinyl chloride (PVC) schedule 40, and polyvinyl chloride (PVC) thin wall. Innerduct is a corrugated PVC, or plenum-rated material, used to protect fiberoptic cables or to group fiber cables in a duct; i.e., three 1¼-in innerducts may be installed in one 4-in duct.

DSU. Data service unit, electronic equipment that interfaces a digital service network such as a T1 carrier to the DCE (data communications equipment). DSUs are usually located in the main communications closet on the wall or in a rack.

DTE. Data terminal equipment, the source or destination of signals on a network. Data terminals or display terminals that had no integral computing power were used as the destination of signals from mainframe computers. Data terminals became known as dumb terminals as personal computers were developed. PCs are smart DTEs.

Edge Equipment. Electronic equipment that interfaces ATM and Ethernet networks.

EIA. Electronic Industries Alliance, a trade organization representing the United States' high-technology community.

Electronic Industries Association. A standards-writing body.

ELAN. Emulated LAN on an ATM network.

Entrance Facility. The entrance to the building for communications cables, including the point at the wall or floor and the conduit or path to the building's main communications room.

Entrance Facility, Fiberoptic. The box in a building's main communications room where the outside-plant cable is spliced or connected to the building's fiberoptic cable.

Ethernet. A local area network, LAN, as defined by Standard IEEE 802.3, where computers or stations are connected together. The most common arrangement today is where twisted-pair cable, CAT 5 or CAT 5e, connects PCs to network hubs with speeds of 10 Mbps and 100 Mbps (fast Ethernet). Thick coaxial cable, thin coaxial cable, and fiberoptic cable may also be used. Faster speeds of 1000 Mbps will be common soon.

FDDI. Fiber distributed data interface, an ANSI standard for token ring networks using fiberoptic cabling and special FDDI connectors and patch panels.

Fiberoptic Connectors. Types include SC, ST, FC, Biconic, FDDI, ESCON, MTRJ, LC, and Volition.

Fiberoptic Cable. Fiberoptic cable comes in two main types, multimode and single mode. Multimode fibers are sized by the core dimension and the cladding dimension. The most common multimode cable is the 62.5/125 micron. An enhanced version is the 50/125 micron. Hybrid cables are available with varying counts of multimode and single-mode fibers, such as 12/6 cable or 24/12 cable.

File Server. A modified computer or PC that holds programs and files for common use by the PCs on the network. Modifications may include multiple processors, redundant power supplies, RAID (redundant array of inexpensive disks) drives, etc. Servers may be classified by function such as a mail server or drawing file server.

Frame Relay. A high-speed protocol used in WANs. A frame alignment signal is sent as well as the frames. Frames are actually consecutive time slots.

FM. Factory Mutual, a building and industrial insurance underwriter who provides guidance and approval of building products. FM also has a nonprofit research center and writes standards.

Gateway. Electronic equipment or computer that converts protocol from one network or system to another.

Gigabit Ethernet. Ethernet network transmitting over 1 Gbps or 1000 Mbps.

Hub. A piece of electronic LAN equipment located in a communications closet that connects to the desk PCs. Like a wheel, the hub is at the center, the spokes are the cabling to desk PCs. Hubs may be intelligent or dumb. If a hub is not labeled as intelligent, it is dumb. An intelligent hub has processing electronics to manage the network, sometimes to bridge, route, and switch. If the hub is too smart, it is not a hub, it is a switch. The industry is increasing the use of switches and decreasing the use of hubs.

Interface. A device, or group of devices, that allow two incompatible systems to communicate. A protocol that allows two incompatible systems to communicate.

ISDN. Integrated Services Digital Network is a digital transmission standard and service. Basic-rate ISDN provides two switched B channels (64 kbps for voice and data) and one D channel (16 kbps for control). Primary-rate ISDN provides 23 B channels and one D channel for a capacity of 1.544 Mbps. ISDN may be provided over a T1 line (two twisted-pair cables). ISDN was never embraced by the public or the industry; it was too confusing. The most common use in commercial buildings is for video–teleconferencing where a two-pair ISDN cable is terminated in a conference room. An ISDN terminal adapter is used to connect to a computer and phone. The owner will hire a vendor to provide and set up a video–teleconferencing package. Some training and user assistance is usually provided.

IEC. International Electrotechnical Commission, a standards-making body.

IEEE. Institute of Electrical and Electronic Engineers, a standards-making body.

IEEE 802.2. LAN protocol standard, written by IEEE.

IEEE 802.3. Ethernet physical layer standard, written by IEEE.

Ink-jet. A type of printer that sprays ink onto the page. Ink-jet printers are used in offices, mostly as personal printers connected directly to the PC. They provide inexpensive black and white and color prints.

IT. Information Technology.

Jack. A female communications connector into which a plug is inserted. Jacks fall into three groups: voice, data, and network channel equipment (network-channel equipment jacks are not discussed here). Jacks are found in office wall plates, in office system furniture, on the back of PCs, on patch panels in the communications closet, and on the network equipment. The most common data jack is the eight-position modular jack defined by ANSI/TIA/EIA Standard 568, designated as T568B. A T568A is also defined. The standard defines the position of the cable pairs and their color. Please note that the government publication FIPS PUB 174 only recognizes T568B. If you are renovating an office, look out for re-termination costs.

The most common telephone jack is the USOC six-position modular jack. The industry, however, is moving toward eight-position modular jacks. If you are renovating an office, again, you should look out for re-termination costs.

The best and most complete place the author has found to identify jacks for

building construction is the chapter in BICSI's Telecommunications Distribution Methods Manual, titled "Telecommunications Service Entrance and Termination."

J-hooks. Named because they resemble the letter "J", these hooks are fastened to building steel and sometimes extended with a threaded rod, or anchored to the deck above and extended. J-hooks are available in a CAT 5 version where the bottom is flat and smooth so that the cable minimum-bending radius is not exceeded. They are also available in various sizes and are rated for a maximum number of wires and spacing. Look out for installations where the contractor straps the cable to the steel and then installs the J-hooks, the cable may be damaged. Look out for over-filling of the J-hook and also for exceeding the spacing requirements. Testing does not identify all cable damage.

Juke Box. An electronic box with multiple compact disks (CDs). The application is similar to a file server. A juke box serving a LAN will provide the users access to the multiple CDs.

Local Exchange. A system of one or more central offices and associated equipment that operates under one administration. A geographical area of a local exchange usually follows the layout of a town or city.

Laser Printer. A type of printer that uses a laser for printing. Laser printers are more expensive, faster, and of a higher-duty cycle than ink-jet printers and are more often found connected to a network, so that several people may share one printer.

Link. A link, with reference to horizontal wiring, includes the workstation outlet, the horizontal cabling, and the communications-closet patch panel. (Compare to definition of channel.)

NFPA. National Fire Protection Administration, a code-making body.

NEC. National Electrical code, NFPA 70 (often referred to as "The Code"), that most jurisdictions follow for electrical and communications work.

NIC. Network interface cards are installed in PCs so that the PC may be connected to the LAN by patch cable.

OTDR. Optical time domain reflectometer, a fiberoptic cable test tool that locates fiber breaks and can determine loss per connection, splice, or segment.

OC. Optical carrier, a definition of optical transmission rate for SONET. The OC-1 transmission rate is 52 Mbps. The OC-3 transmission rate is 156 Mbps.

Patch Cable. The cable used to connect PCs to wall jack or system furniture jack. They are also used to connect network gear to patch panels in the communications closets.

Patch Panel. A rack-mounted panel of 12, 24, or 48 jacks. Cables from wall or system furniture outlets are terminated on the back. Patch cables are used to connect the patch panel directly to network gear or to the network gear patch panel.

Pathway. The path devised to take a cable or group of cables to a destination, including the support method, such as conduit, cable tray, wall sleeve, J-hooks, poke-through device, system furniture wireway, communications pole, surface raceway, or cable tied to steel. Cable tied to steel is mentioned because it is quite common, even though it is not a good practice. The cable tied to steel is strained, and the minimum-bending radius of the cable is easily exceeded.

PBX. Private branch exchange, other names which are, for all practical purposes, synonymous include: PABX, private automatic branch exchange; CBX, computerized branch exchange; telephone switch; or switch. A PBX is electronic gear that provides voice switching, processing, and other services, on the private voice network.

PETs. Protected-entrance terminals are lightning or surge protectors. They are provided by the LEC, or they are provided by the building owner, in accordance with the minimum requirements of the LEC. The protectors themselves are either carbon blocks, gas tubes, or solid-state devices. An individual protector is provided on each line. PETs are a combination of protectors and terminal. The terminals may be 66 type or 110 type for individual line connection or a high-density type connector for connection to a PBX. A ground cable is connected to the PET to take the surge to ground.

Plenum Cable. Cable certified to be fire resistant and low-smoke producing. It can be installed in the ceiling cavity, between the false ceiling and the floor or ceiling above. The ceiling cavity is called a *plenum.* The plenum is often used for conveying air for heating and air conditioning. NEC requires plenum cable for cables passing through air plenums.

POTS. Plain old telephone service; the cable is referred to as a POTS line.

Protectors. They are either carbon blocks, gas tubes, or solid-state devices used to protect against lightning or electrical surges (see PETs). Any communication line which goes outside should be protected so that if a surge is induced in the line by a nearby lightning strike or a short circuit, the surge will not damage expensive electronic equipment. Protectors for data lines should be rated for the speed and type of line.

Protocol. A formal set of rules that allow data transmission. Format, timing, signal initialization, verification, addressing, poling, and error correction are included.

Punch-down Block. A device located in communications closets to terminate voice cable. A punch-down tool is used to make the termination. The action of the tool is similar to a punch, thus the name. The most common styles of punch-down blocks are the 66 type which are older and the 110 type which are newer and of higher density. The blocks are rated by category. Category 5 blocks are most commonly used in new construction.

Rack. An open frame to mount equipment or to mount patch panels and manage cables. The frames are usually an EIA/TIA 19-in wide standard, measured from center to center of the equipment mounting holes. Racks are found in the communications closets and the main communications room. EIA/TIA 23-in standard racks are sometimes found in the main communications room for PBX, voice communications gear, or other LEC gear. Enclosed racks are sometimes provided, typically by the CLEC or LEC to protect the equipment. Rack-mounted backup power supplies are common (see UPS system).

Rectifier. A rectifier is a piece of electrical power equipment that turns 120 V, or higher ac current, to dc current. Old PBXs, and some new ones, require 48 to 52 V dc. The rectifier charges the batteries, the batteries feed a regulated power supply, and the power supply feeds the PBX. If the ac power fails, the batteries continue to power the system. It is like the battery charging system in a car. Rectifier systems are usually found in the main communications room. The batteries may be quite large and heavy. Some buildings built prior to knowing the

tenant's requirements may not have the floor rating to support large battery racks without damage. Rectifier systems are being replaced by UPSs.

SBCCI. Southern Building Code Congress International provides technical, educational, and administrative support to governmental departments and agencies engaged in building codes administration and enforcement. SBCCI also provides similar support to others in the building design and construction industry.

SONET. Synchronous optical network is a high-speed, high-survivability network. The topology is a ring where if one fiber fails, the other will continue to provide service. The equipment would appear as a minimum 23-in wide, 30-in deep, 72-in high enclosed rack or cabinet in the main communications room. Two distinct and separate pathways are needed for the fiber. Two separate sets of manholes and ducts are required. SONET speeds may be OC-3 (156 Mbps), OC-12 (624 Mbps), and OC-48 (2.496 Gbps). Almost all types of services are available from a SONET cabinet because they are built to order.

STP. Shielded twisted-pair cable.

T1. A digital carrier formatted to transmit 1.544 Mbps divided into 24 channels. A fractional T1 carries two to 23 channels. Cables used to transmit T1 service are two twisted pair which are separated or screened. A T1C transmits 3.152 Mbps divided into 48 channels. T1 on fiber is also used. (See DSU for interfacing copper T1s.)

TIA. Telecommunications Industry Association a trade organization representing the companies that provide communications and information technology products and services.

UL. Underwriters Laboratories Inc.

UPS. Uninterruptible power supplies, often provided to maintain the power supply to critical equipment. UPSs usually provide 120 V ac and derive their power from integral sealed batteries. They are rated for the amount of power and the duration in minutes at which rated power is sustained during an outage. UPSs may be floor mounted or rack mounted, or small units may be located at the PC. Some UPSs have network connections so they may communicate to the outside world when there is a power problem. (See Rectifier.)

USOC. Universal Service Order Code.

UTP. Unshielded twisted-pair cable.

WAN. Wide-area network, a network covering a wide geographical area using LEC or CLEC facilities.

18.2 GROUNDING

Proper grounding is essential for safety of personnel, for the proper operation of equipment, and for the protection of property.

References Literature

a. The IEEE Green Book which contains IEEE Standard 142, Recommended Practice for Grounding Industrial and Commercial Power Systems.

b. The IEEE Emerald Book which contains IEEE Standard 1100, Recommended Practice for Grounding Sensitive Electronic Equipment.

FIGURE 18.1 Lucent 489A-type multipair building entrance protector panel. (*Copyright © 1999, Lucent Technologies, used by permission.*)

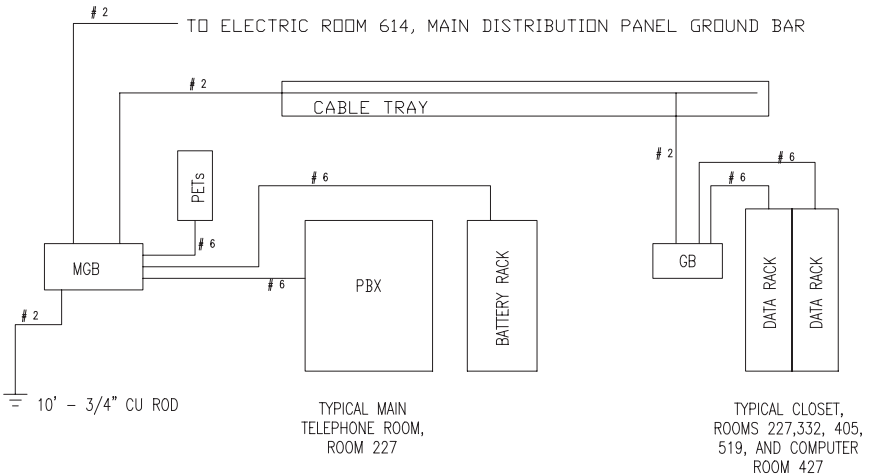

FIGURE 18.2 Typical communications grounding detail. (*Nevling.*)

c. ANSI/TIA/EIA Standard 607, Commercial Building Grounding and Bonding Requirements for Telecommunications.

d. NEC, Article 250 concerning grounding.

e. NEC, Article 800, Section D concerning communications circuits grounding.

f. NFPA 780, Lightning Protection Code.

Typical communications grounding includes bonding all metal frames and equipment in a communications room or closet to a ground bar in the room and connecting all rooms together. At the main communications room, a ground rod is provided as well as bonding to the electrical system. Protected entrance terminals (Fig. 18.1) are grounded so that a lightning strike or surge will be taken to ground. Please note that the diagram in Fig. 18.2 is an example only and does not portray all of the requirements of the above-mentioned codes.

18.3 COMMUNICATIONS ROOM AND COMMUNICATIONS CLOSET LAYOUT

One of the biggest problems today in the construction of communications facilities is the layout and size of rooms and closets. During planning of buildings, the people who are to operate the communications systems, information technology (IT) people, are rarely involved. When IT people are involved in the planning and design stage, they should be informed by the design team of minimum code requirements for room layout, equipment clearances, and HVAC. IT people should also be informed of the construction schedule, including the various subcontractors. Typically, the communications systems are not determined at the time the building planning takes place. The IT industry likes to determine and buy the equipment at the last minute prior to installation. This is very prudent on IT's part, because the technology and the equipment costs change so rapidly. By delaying the purchases, they are able to get the best equipment at the least cost. The solution is to involve the IT people in the building planning process, to design the layout based on the best known information, and to plan for several alternatives.

References Literature

a. ANSI/TIA/EIA Standard 569A, Commercial Building Standard for Telecommunications Pathways and Spaces.

b. EC, Article 110—Requirements for Electrical Installations and particularly the paragraph in Article 110 concerning working space.

c. NEC, Chapter 8 Communications Systems.

d. BICSI, Telecommunications Distribution Methods Manual, Chapter 6 Telecommunications Closets and Rooms.

e. BICSI, Telecommunications Distribution Methods Manual, Chapter 7 Equipments Rooms.

f. OSHA concerning work spaces.

A typical communications closet arrangement would be 10 ft wide allowing for 30-in deep equipment, 36-in working space on both sides, ¾-in plywood backboard on both walls and 6 in of board-mounted equipment on both sides, with 4½ in to spare. A closet with two open racks, one for patch panels and one for network gear would be 7½ ft in length allowing 22 in for each rack (19-in EIA/TIA rack), two vertical-cable managers at 4 in each, a 3-ft walk, and 2 in to spare. The preferred closet is a three-rack closet which would require 10 ft in length. They are preferred because you can install two racks with a space for a future rack, or install all three and leave space in each rack based on the equipment arrangement. Keep in mind, during planning, of how difficult it is to get another 2½ ft in the room during construction. Check and allow space for any required dedicated air-conditioning units. Locate the unit and piping so that a leak will not ruin wiring or equipment. Punch-down blocks may be arranged on the plywood.

The arrangement of closets within a building is critical to the performance and cost of the wiring to the workstations. Closets must be located so that the horizontal cabling does not exceed 295 ft (90 m) in length from the patch panel to the outlet. One closet should be located on each floor. One closet should not serve more than 10,000 ft^2.

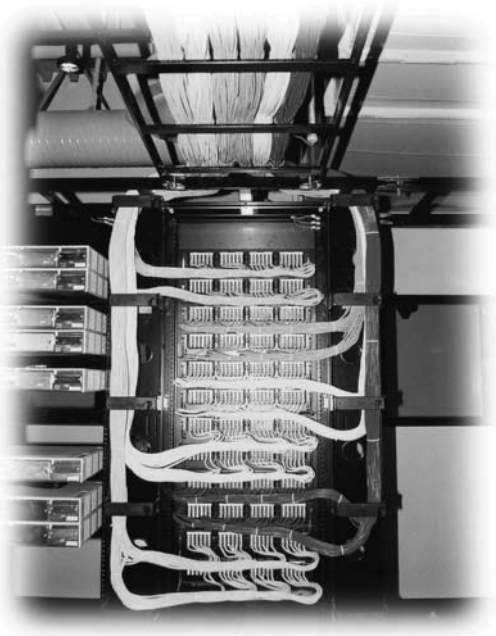

FIGURE 18.3 Lucent SYSTIMAX GigaSPEED Installation, rear view of patch-panel rack. (*Copyright © 1999, Lucent Technologies, used by permission.*)

The layout of the main communications room follows the same principles as that of a closet: a 3-ft space for working and walking, space for future equipment, and plywood backboards for mounting equipment are still employed. The equipment sizing becomes more difficult. Telephone equipment is based on 23-in racks or custom sizes. Punch-down blocks may be wall or rack mounted; different styles of punch-down blocks for high density may be used. A PBX may not be required because Centrex lines may be purchased where the switching is done remotely at the central office. Space for a future PBX should still be provided. If a PBX is installed, it may be leased rather than purchased. In some facilities, where the PBX and maintenance is contracted out, a separate room may be desired to keep the telephone contractor out of the main communications room. Enclosed racks may be considered for security reasons. Storage space for valuable electronics should be provided. A preliminary layout should be prepared and reviewed to see how the room will accommodate all of the alternatives. (See Figs. 18.3 and 18.4.)

18.4 WIRING DIAGRAMS

Wiring diagrams (Figs. 18.5 and 18.6) should be prepared at the planning stages of a project. And they should be carried throughout the project through construction contract drawings and as-built record drawings. They provide a great deal of insight

FIGURE 18.4 Lucent SYSTIMAX GigaSPEED Installation, rear angle view of patch-panel rack. (*Copyright © 1999, Lucent Technologies, used by permission.*)

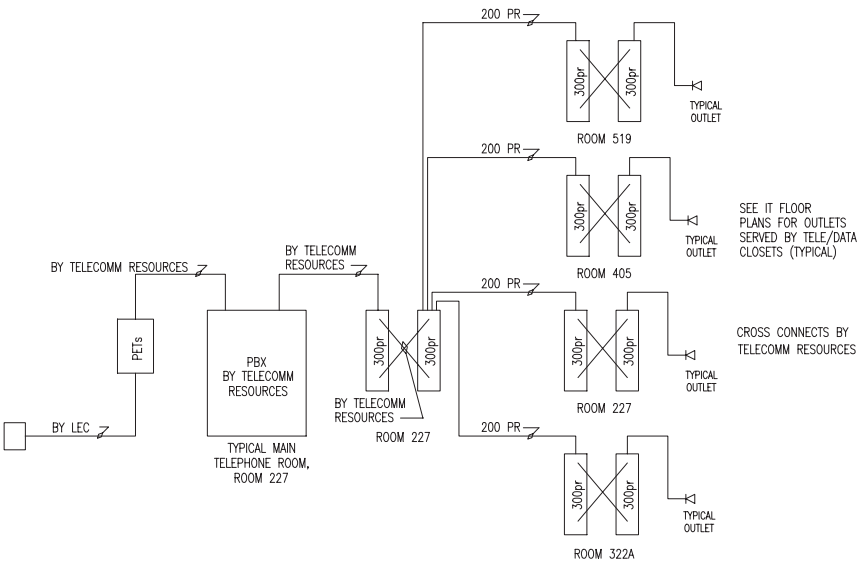

FIGURE 18.5 Typical telephone wiring diagram. (*Nevling*).

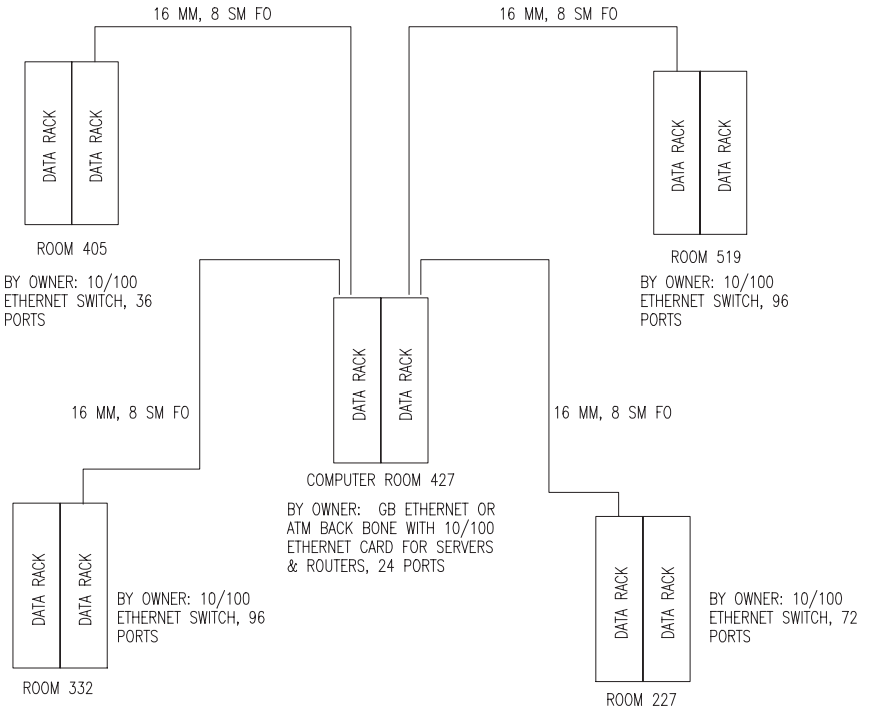

FIGURE 18.6 Typical data wiring diagram. (*Nevling*.)

during planning. They help to define who is providing materials and who is installing materials. They may provide points of demarcation between installers and subcontractors which will require connectors and testing.

18.5 FIBEROPTIC CABLE

Fiberoptic cable comes in two main types, *multimode* and *single-mode*. Multimode fibers are sized by the core dimension and the cladding dimension. The most common multimode cable is the 62.5/125 micron. An enhanced version is the 50/125 micron. Multimode transmission uses inexpensive LEDs. Light in multimode transmission is propagated in several modes; i.e., multimode. Transmission distance is limited. Connecting multimode is easier and faster. Multimode is used to the desktop and in the building backbone. Single-mode transmission is by laser. Large amounts of data over long distances may be handled. Single-mode fiber is found in long-haul work, campus distribution, and in large-system building backbones. Hybrid cable may be purchased with varying counts of single-mode and multimode fibers, such as a 12/6 cable or a 24/12 cable. The first number being the quantity of multimode fiber, the second being the number of single-mode fibers. (See Figs. 18.7–18.9.)

Fiber selection, particularly the selection of multimode or *enhanced* multimode cable, is based on network design, because the network gear will be ordered with

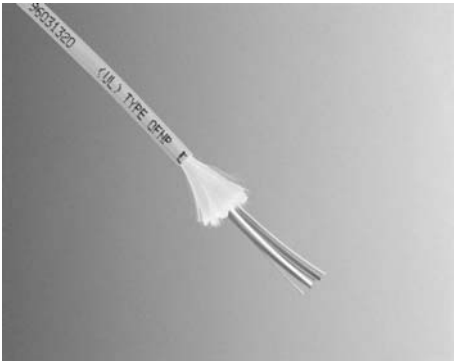

FIGURE 18.7 Lucent Multimode ACCUMAX plenum-rated building cable. (*Copyright © 1999, Lucent Technologies, used by permission.*)

FIGURE 18.8 Lucent Multimode DSX LXE metallic outdoor cable. (*Copyright © 1999, Lucent Technologies, used by permission.*)

a specific multimode light source for the cable. There are different types of single-mode fibers, but the higher grades are presently used only in long-haul work. the selection of the number of fibers is based on network design, but more importantly on cost, availability, future growth, and future network type. Fibers are cheap compared to the jacket cost and the installation cost, so, if the planned network needs eight-multimode fibers, good practice would be to use a 12/6 hybrid cable; leaving four spare multimode and six spare unterminated single-mode. The single-mode fibers could be used if they upgrade from Ethernet to ATM, or for a special circuit. Cost is also a big factor in cable selection. The prices from distributors fluctuate greatly based on the availability of the product. The IT owner will take advantage of these wide price shifts to purchase the best equipment at the lowest total cost.

Cable jackets are based on their application and there are many from which to choose. Outdoor cables may be gel-filled to repel water, but the gel is hazardous and the cable must terminate within 50 ft of entering the building. Cables needing

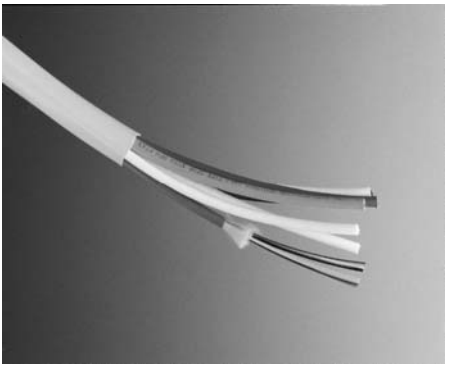

FIGURE 18.9 Lucent Singlemode ACCUMAX riser-rated high-fiber-count building cable. (*Copyright © 1999, Lucent Technologies, used by permission.*)

protection from rodents and lightning can have jacketing of aluminum, steel, or stainless steel. Strength members in the cable are available in steel and nonmetallic. The NEC requires specific cable construction for specific applications in buildings. Plenum, riser, and tray are a few of the rated applications. Because the costs vary so widely with distributor stock, it is good practice to check costs during design and during construction to review cable selection.

Installation of fiberoptic cables takes a little more care than other cables. The installer can not exceed the manufacturer's published tensile strength or the minimum-bending rating. Tensile strength ratings include pulling and vertical rise. Typically, only two 90° bends are permissible (180° total) between pull points when installing communications cable in conduit. Innerduct, thin corrugated plastic tubing, is often used to protect fiberoptic cable above ceilings and in cable tray. It is used in large ducts to segregate cables and to allow for future installations. A tension meter or a rated breakaway knuckle is used to pull fiberoptic cables.

Fiber connections are made by splicing or mechanical connector. Splicing is only permitted in splice trays or LIUs (Figs. 18.10 and 18.11). Splicing provides a lower light loss than connectors. The best method of splicing is called *fusion splicing,* but it is expensive and should only be used in construction where the high number of connectors would impact the light-loss budget. As a facility owner, a cheaper splice method is often preferred for single splices where the light-loss budget is not threatened.

Testing of fiberoptic cables is done by two methods. The optical time domain reflectometer (OTDR) is used primarily after initial installation. It sends light down the cable, and reflects light back wherever anomalies exist, providing a profile of the cable for the entire length. OTDR testing is expensive but worthwhile when purchasing under a construction contract. Fiberoptic meters are usually used to determine light loss, and suffice most of the time, but if a problem exists where the location cannot be found, an OTDR may be rented to find the exact point. Fiberoptic meters can be standalone equipment or an accessory to a UTP cable meter.

There is one type of media converter worth mentioning, it changes multimode to copper at the workstation. Two versions of the media converter are the Alcatel

FIGURE 18.10 Lucent 600B one-unit high-sliding combination shelf, splice tray, and patch panel. (*Copyright © 1999, Lucent Technologies, used by permission.*)

FIGURE 18.11 Lucent Lightguide Interconnection Unit, LIUs. (*Copyright © 1999, Lucent Technologies, used by permission.*)

and the 3M. The Alcatel version fits in a junction box and has two 8-pin modular jacks. The 3M version plugs into a fiber jack at the workstation and is then plugged in on, or under, the desk. The expense for the two versions is allocated differently in accounting. The Alcatel version would typically be a capital expense in the construction budget; the 3M product, typically an office expense. Previously, making a media conversion in the PC would be an expense for the IT department, along with the PC. Since fiberoptic cable is presently comparable in price with copper UTP, we may finally see a fiber that is practical for use up to the desktop.

18.6 FIBEROPTIC CONNECTORS

Fiberoptic connector types include SC, ST, FC, Biconic, FDDI, ESCON, MTRJ, LC, and Volition (e.g., Figs. 18.12, 18.13, and 18.14). Connectors and cables are

FIGURE 18.12 Lucent STll fiberoptic connectors. (*Copyright © 1999, Lucent Technologies, used by permission.*)

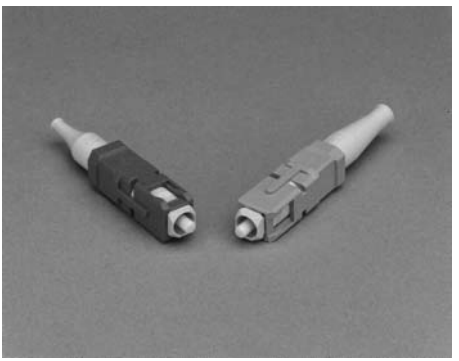

FIGURE 18.13 Lucent SC fiberoptic connectors. (*Copyright © 1999, Lucent Technologies, used by permission.*)

in constant evolution. The author prefers to use ST connectors for all connections except to network gear and the network patch panel which must be coordinated with the network gear manufacturer. Initially, ST connectors were popular with the manufacturers, then SC connectors saw an increase in use. Presently, the MTRJ and the LC connectors are becoming popular; both are excellent connectors. Patch cables, with different connectors on the ends, are available if needed. Occasionally IT people like to use different connectors to organize or classify their systems and equipment.

18.7 HORIZONTAL CABLING

The Commercial Building Telecommunications Cabling Standard, ANSI/TIA/EIA-568-A, defines categories for 100-Ω unshielded, twisted-pair cables. The Category

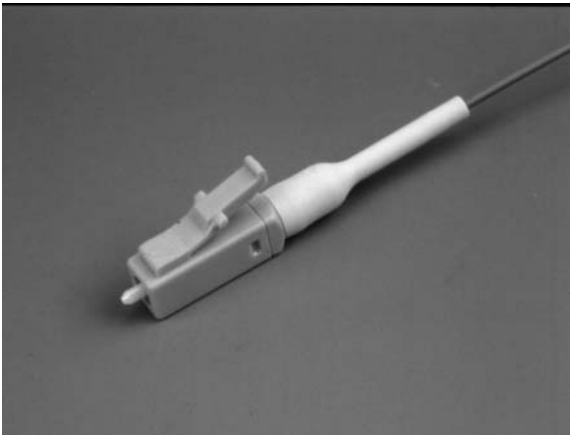

FIGURE 18.14 Lucent LC fiberoptic connectors. (*Copyright © 1999, Lucent Technologies, used by permission.*)

3 designation applies to cables and hardware up to 16 MHz (16 Mbs). The Category 4 designation applies to cables and hardware up to 20 MHz (20 Mbs). The Category 5 designation applies to cables and hardware up to 100 MHz (100 Mbs). The Category 5e designation applies to cables and hardware over 100 MHz (over 250 Mbs). The Category 6 designation applies to cables and hardware over 250 MHz (over 500 Mbs). Practically speaking, CAT 3 cable is used for high-pair count outdoor and high-pair count backbone voice cable, and occasionally for station cable (from the closet to the phone). CAT 4 cable is nonexistent, at 20 MHz it is too close to CAT 3 to warrant manufacture. CAT 5 cable is used for low-end data installations and voice cable. CAT 5e, where "e" stands for enhanced, and CAT 6 are not ANSI/TIA/EIA standards at this writing, so it is necessary to look at the cable and system specifications and test results to determine performance. Most new installations should be CAT 5e or CAT 6 for economic reasons. One of the differences between CAT 5e and CAT 6 will be that the patch cable will be required to be CAT 6 and coordinated with the system. Using CAT 5e or CAT 6 for new installations is good for the industry, because currently there are many poor patch cables in use choking the speed of PCs.

Horizontal cabling generally refers to cabling run from the communications closet to the workstation. A **link** specifically refers to the workstation outlet, the horizontal cabling, and the communications closet patch panel. A **channel** specifically refers to the cabling from the PC to the communications closet network gear, including all of the patch cables and the patch-panel connectors. Standard channel and link performance warranties are offered by the manufacturers for 15 years. Where the cable and jacks are made by different manufacturers, the jack manufacturer administers the warranty. It is extremely important to match the two manufacturers. Warranties are also available from some manufacturers for the entire cabling plant; i.e., for channels, backbone cabling, and campus cabling, including the fiberoptics. One of the problems with not coordinating cable and jack manufacturers happens over time—the connections at the jack become slightly loose and the network speed degrades until re-terminating the entire system becomes the best option. A 15-year warranty is preferred.

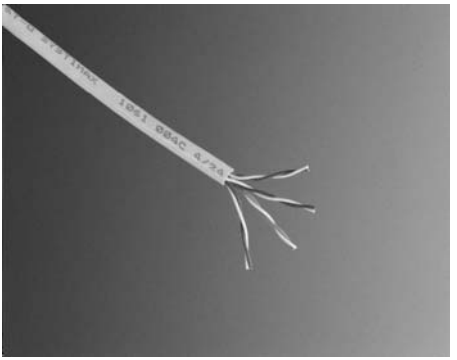

FIGURE 18.15 Lucent non-plenum CAT 5 power sum, four-pair cable. (*Copyright © 1999, Lucent Technologies, used by permission.*)

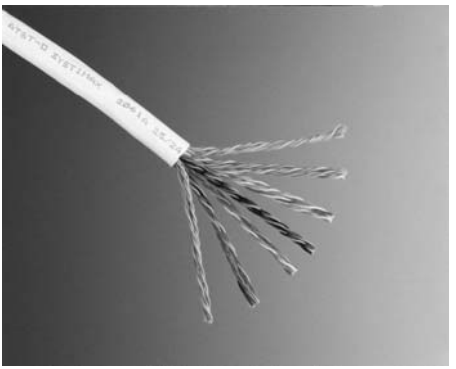

FIGURE 18.16 Lucent CAT 5 power sum, 25-pair cable. (*Copyright © 1999, Lucent Technologies, used by permission.*)

It is important to note the economic advantage of using a Category 6 solution. To implement Gigabit Ethernet on CAT 6, the network electronics will use two pairs of the cable to transmit 500 Mbps and two pairs to receive 500 Mbps. To implement Gigabit Ethernet on CAT 5e requires all four pairs to transmit and receive 250 Mbps. The network gear and the network interface cards (NICs) in the PC are much more expensive for the CAT 5e solution. The only difficulty is that the cabling is usually in the construction budget, and the electronics are in the IT budget.

Installing CAT 5 and better cable requires adherence to a few principles. The installer must not exceed the cable's minimum-bending radius (crush the cable) or exceed the cable's tensile strength, and he must properly terminate the cable. The most common office installation is to use CAT 5-rated J-hooks at 5-ft intervals above the drop ceiling. Cable trays may be used. Conduit may be used, but the permissible number of bends must be calculated. A limit of 180° (two 90° bends)

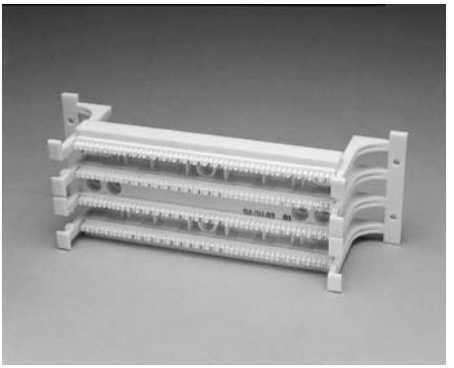

FIGURE 18.17 Lucent 110 wiring block. (*Copyright © 1999, Lucent Technologies, used by permission.*)

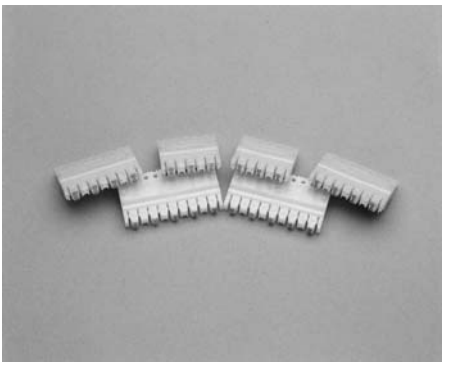

FIGURE 18.18 Lucent 110 connecting block. (*Copyright © 1999, Lucent Technologies, used by permission.*)

between pull boxes is preferred. The installer must not exceed the ratings of the J-hooks, cable tray, conduit, communications poles, and the furniture wire ways. (See Figs. 18.15–18.23.)

18.8 BUDGET

Costs may be derived from reference materials. R.S. Means publishes cost reference materials in a square foot format and in a unit cost format. Their costs are updated yearly based on construction projects. They include city and regional indexes for both materials and labor. For items which R.S. Means does not provide information, contact a distribution house like Anixter or Graybar. Black Box Corporation publishes prices in their catalog and they also provide useful system diagrams.

FIGURE 18.19 Lucent 110P field-terminated patch panel kit: includes wiring blocks, connecting blocks, horizontal jumper troughs, duct assemblies, hardware, label holders, and blank inserts. (*Copyright © 1999, Lucent Technologies, used by permission.*)

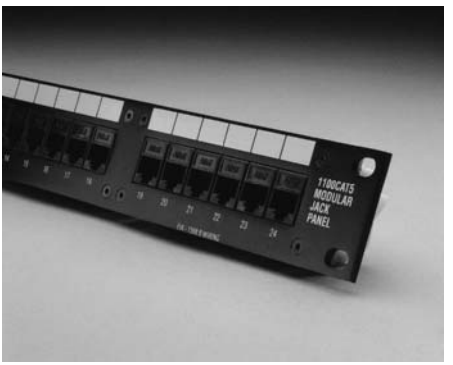

FIGURE 18.20 Lucent 1100 CAT 5 power sum, modular patch panel. (*Copyright © 1999, Lucent Technologies, used by permission.*)

The following is an outline of the items needed to budget a communications facility and also serves as a list of items to consider during planning.

1. Outside plant infrastructures:
   - **a.** Ductbanks: PVC encased in concrete is suggested. Include excavation, bed preparation, back fill, compaction, seeding, patching sidewalks and drives. Include innerduct in all fiberoptic ducts.
   - **b.** Manholes and handholes: Include excavation, bed preparation, backfill, compaction, seeding, patching sidewalks and drives. Include ground rods for copper cables and metal strength members where required.
   - **c.** Pole work.
   - **d.** Right of way costs.

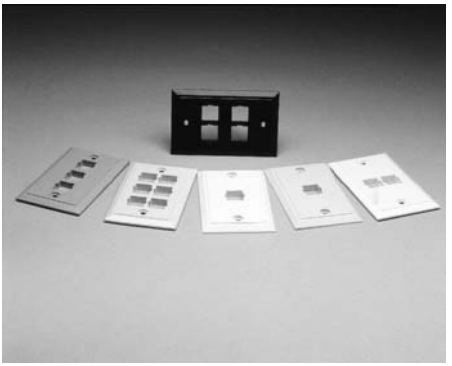

FIGURE 18.21 Lucent modular flush-mount faceplates. (*Copyright © 1999, Lucent Technologies, used by permission.*)

FIGURE 18.22 Lucent plenum CAT 5 GigaSPEED cable. (*Copyright © 1999, Lucent Technologies, used by permission.*)

2. Main communications room infrastructure:
- **a.** Square foot cost of base-rated room, fire-rated construction.
- **b.** Heating and air conditioning: Include humidification where needed. Include controls and monitoring. Anywhere from 2 to 5 tons of cooling is typical.
- **c.** Electric panel: 200-amp main breaker, 120/208 V, three-phase, four-wire, 42-pole is typical. Note that some installations require 240 V, in which case, a 120/240 V, single-phase panel is required. It may be necessary to provide two panels. Include transformers, shielded type, where required.
- **d.** Backup power. Some design will be required here. Any or none of the following may be required: generator, large floor-mounted UPS, rack-mounted UPSs, batteries for UPSs. Include systems monitoring.
- **e.** Lighting: fluorescent fixtures with 100% solid-state ballasts.
- **f.** Grounding: master ground bar with stand-off isolators; dedicated ground rod, bonding to steel, bonding to electrical service; grounding of cable tray, racks, and power backup system; grounding of PETs.

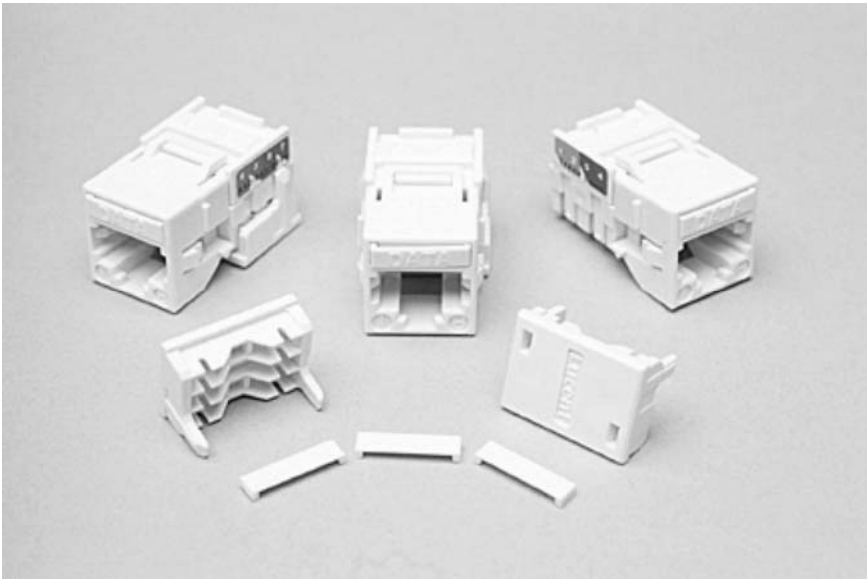

FIGURE 18.23 Lucent MGS2000 GigaSPEED modular information outlets. (*Copyright © 1999, Lucent Technologies, used by permission.*)

- **g.** Cable tray.
- **h.** Fire-rated plywood.
- **i.** Fire-stopping for tray penetrations and sleeves.
- **j.** Racks with cable managers and power strips.
- **k.** Smoke detectors.
- **l.** Emergency-power-off station, with circuiting where required by Code.
- **m.** Maintenance receptacles on each wall.
- **n.** Backup power wiring to racks and equipment, twist-lock receptacles or hard wired.
- **o.** Security, electric door locks with key bypass, card reader, magnetic door switch.

3. Building backbone, riser, or campus backbone infrastructure:
- **a.** Cable tray: Include partitions, innerduct protection for fibers, where required, and full length ground cable with connectors to each tray section and to each closet or room.
- **b.** Conduit, sleeves, and pull boxes. Include extra pull boxes since the communications industry uses a pull box for each 180° of conduit bend, as opposed to the power cable installers who use a pull box for each 360° of conduit bend.
- **c.** Fire-stopping for tray penetrations and sleeves.

4. Communications closet infrastructure:
- **a.** Square foot cost of base-rated room, fire-rated construction.
- **b.** Heating and air conditioning: Include humidification where needed. Include controls and monitoring. Anywhere from 2 to 5 tons of cooling is typical.
- **c.** Electric panel: 200-amp main breaker, 120/208 V, three-phase, four-wire, 42-pole is typical. Note that some installations require 240 V, in which case,

a 120/240 V, single-phase panel is required. It may be necessary to provide two panels. Include transformers, shielded type, where required.
- **d.** Backup power. Some design will be required here. Any or none of the following may be required: generator, large floor-mounted UPS, rack-mounted UPSs, batteries for UPSs. Include systems monitoring.
- **e.** Lighting: fluorescent fixtures with 100% solid-state ballasts.
- **f.** Grounding: ground bar with stand-off isolators, bonding to steel, bonding to electrical service; grounding of cable tray, racks, and power backup system.
- **g.** Cable tray.
- **h.** Fire-rated plywood.
- **i.** Fire-stopping for tray penetrations and sleeves.
- **j.** Racks with cable managers and power strips.
- **k.** Smoke detectors.
- **l.** Emergency-power-off station, with circuiting where required by Code.
- **m.** Maintenance receptacles on each wall.
- **n.** Backup power wiring to racks and equipment, twist-lock receptacles or hard wired.
- **o.** Security, electric door locks with key bypass, card reader, magnetic door switch.

5. Outside plant cable:
- **a.** Single-mode fiberoptic cable, non-LEC cable.
- **b.** Multimode fiberoptic cable, non-LEC cable.
- **c.** Copper cable, non-LEC cable.
- **d.** Terminations. Note that if gel-filled cables are used, extra terminations may be necessary to meet fire codes which require that gel-filled cables must terminate within 50 ft of entering a building.
- **e.** Fiber testing, OTDR.
- **f.** Copper testing, electronic cable tester.

6. Main communications room cable and equipment:
- **a.** Fiberoptic entrance facility.
- **b.** Protected-entrance terminals, PETs.
- **c.** Punch-down blocks.
- **d.** Cross connects.
- **e.** PBX, own, lease, or none.
- **f.** PBX rectifier system, batteries.
- **g.** Special equipment, channel banks, smart jacks, ISDN punch-down blocks, modems.
- **h.** Patch panels and wire managers.
- **i.** Fiberoptic splice trays.
- **j.** Fiberoptic patch panels.
- **k.** Any special arrangements for LEC and CLEC equipment.
- **l.** Network gear, switches, hubs, bridges, routers, gateways, servers, media converters, wireless gear.
- **m.** Special cable with connectors and panels and patches, coax, T1, T1C, telco cable.
- **n.** Patch cords designed for the system.
- **o.** Fiber testing, OTDR.
- **p.** Copper testing, electronic cable tester.
- **q.** Equipment testing.
- **r.** Backup power systems, if not provided with infrastructure.

7. Building backbone or riser cable:

   a. High-pair count copper voice cable, plenum-rated as required; riser- and fire-rated as required.
   b. Fiberoptic cable: single-mode, multimode, or hybrid; plenum rated as required.
   c. Special cables, T1, T1C, coax; plenum rated as required.
   d. Terminations.
   e. Fiber testing, OTDR.
   f. Copper testing, electronic cable tester.
8. Communications closet cable and equipment:
   a. Fiberoptic splice trays.
   b. Fiberoptic patch panels.
   c. Punch-down blocks.
   d. Patch panels and wire managers.
   e. Patch cables designed for the system.
   f. Cross connects.
   g. Distributed system PBX cabinet.
   h. Backup power systems, if not provided with infrastructure.
   i. Network gear, switches, hubs, bridges, routers, gateways, servers, media converters, wireless gear.
   j. Special cable with connectors and panels and patches, coax, T1, T1C, telco cable.
   k. Fiber testing, OTDR.
   l. Copper testing, electronic cable tester.
   m. Equipment testing.
9. Horizontal cabling:
   a. Horizontal voice and data cable, CAT 5, CAT 5e, or CAT 6. An average of 175 ft per run is a rough estimate for office building use. Use plenum-rated cable.
   b. J-hooks, use one every 5 ft, based on a review of the plans.
   c. Cable tray in halls, as required.
   d. System furniture outlets and jacks.
   e. Wall outlets and jacks.
   f. Wall phone outlets and jacks.
   g. ADA outlets.
   h. Communications poles.
   i. Network interface cards (NICs) in PCs.
   j. Patch cables at PC.
   k. Modems.
   l. Printers.
   m. Fiber testing, OTDR.
   n. Copper testing, electronic cable tester.
   o. Equipment testing.
   p. Standard 15-year warranty testing.

Note that for a CAT 5e and CAT 6 solution, patch panels, horizontal cabling, jacks, PC patch cables, and closet patch cables must be approved as a system. The horizontal cabling effects the cost and design of the network. Note that a CAT 6 solution is presently considered to be less expensive than a CAT 5 or CAT 5e solution for running gigabit speeds. The cost of the network equipment to compensate for signal degradation is higher than the cost of CAT 6 cabling.

18.9 LINKS

A list of web sites is provided. The sites include glossaries, catalogs, product information, application information, manuals, wiring diagrams, service providers, and code organizations. Product information changes so rapidly that reviewing current information on the Web is essential.

3Com	www.3com.com
3M	www.3M.com
Aironet Wireless Communications	www.aironet.com
Alcatel	www.alcatel.com
AltaVista Homepage	www.altavista.com
Altigen Homepage	www.altigen.com
Amp	www.amp.com
ANSI	www.ansi.org
ASTM	www.astm.org
Bell Atlantic	www.bell-atl.com
BICSI	www.bicsi.org
Black Box	www.blackbox.com
B-Line	www.bline.com
BOCA International	www.bocai.org
Cable Design Technologies, CDT	www.cdtc.com
Clec.com	www.clec.com
Code of Federal Regulations	www.access.gpo.gov/nara/cfr
Corning Optical Fiber	www.corningfiber.com
Design and Consulting	www.nevling.com
Electronic Industries Alliance	www.eia.org
Ericsson	www.ericsson.com
Factory Mutual	www.fmglobal.com
Fluke	www.fluke.com
Global Engineering Documents	www.global.ihs.com
IBM	www.ibm.com
IEEE	www.ieee.org
IEEE Computer Society	www.computer.org
Lucent	www.lucent.com
Lucent Octel	www.octel.com
McGraw-Hill	www.mcgraw-hill.com
MCI World USA Home Page	www.wcom.com
Microtest	www.microtest.com
Mohawk/CDT	www.mohawk-cdt.com
National Fire Protection Agency	www.nfpa.org
National Resource for Global Standards	www.nssn.org
Newton Instrument	www.newtoninst.com
Nortel Networks: Home	www.nortelnetworks.com
PC Magazine Online	www.zdnet.com/pcmag/
R.S. Means	www.rsmeans.com
Siemens Business Communications	www.siemenscom.com
Square D	www.squared.com
The Siemon Company	www.siemon.com
Telecommunications Industries Association	www.tiaonline.org
Thomas Register of American Manufactures	www.thomasregister.com
Toshiba	www.toshiba.com
UL's Home Page	www.ul.com
Underground Utility Line Protection Law	www.paonecall.org