# Guide to Networking Essentials, 6th Edition

*Chapter 4: Network Media*

# Objectives

- Define the primary cables used in wired networking
- Describe the characteristics of the major types of fiber-optic media
- Explain the technologies used for wireless networking

# Wired Networking

- Wired networking uses tangible physical media called cables
- Two broad categories of cables: copper wire and fiber optic
- The main differences between the two types:
  - Composition of signals (electricity or light)
  - Speed at which signals can be sent
  - Distance the signals can effectively travel

# Criteria for Choosing Network Media

- Bandwidth Rating – number of bits per second that can be transmitted across a medium
  - A factor determining bandwidth is how bit signals are represented on the medium (called **encoding**)
  - When possible, choose a cabling category that's compatible with the standard you want to implement now but will support the next level of speed your network is likely to need in the future
- Maximum Segment Length – maximum length of cable between two network devices
  - Each cable type can transport data only so far before its signals begin to weaken beyond what can be read by a receiving device (called **attenuation**)

# Criteria for Choosing Network Media

- Interference and Eavesdropping Susceptibility
  - Interference to electrical signals on copper media comes in the form of **electromagnetic interference (EMI)** and **radio frequency interference (RFI)**
  - Motors, transformers, fluorescent lights, and other sources of intense electrical activity can emit both EMI and RFI
  - RFI can also affect wireless networks if the frequencies are in the same range
  - Another interference found in copper wires is called **crosstalk**, which is interference one wire generates on another wire when both wires are in a bundle
  - Copper wire is susceptible to electronic eavesdropping
  - Fiber-optic media carries light signals and is not susceptible to interference or eavesdropping

# Criteria for Choosing Network Media

- Cable Grade
  - Building and fire codes include specific cabling requirements
  - Cables run between a false ceiling and the true ceiling (plenum) must be plenum-rated
  - UTP Cabling is marked as communication cable riser (CMR) or communication cable plenum (CMP)
  - CMR can only be used for building risers or in cable trays
  - CMP is suitable for use in plenum spaces
- Connection Hardware
  - Every type of cable has connectors that influence the kinds of hardware the cable can connect to
  - You must make sure the media you select can be supported by the network device

# Criteria for Choosing Network Media

- Ease of installation – the difficulty of installing the media
  - Factors to consider:
    - media's minimum bend radius, which limits the angle at which a cable can be bent to run around corners
    - Cost and time needed to terminate the medium
    - Physical environment – types of walls and ceilings, EMI or RFI
- Testability – A network that "works" might be crippled by excessive errors
  - It is important to certify whether the cable meets requirements for its category
- Total cost – includes cabling, connectors, termination panels, wall jacks, termination tools, testing equipment and time

# Coaxial Cable

- Often called “coax” for short
- Once was the predominant form of network cabling
- Inexpensive and easy to install
- Started to phase out in the early 1990s
- Still used primarily in connecting a cable modem to the wall outlet your cable TV/Internet provider installs

# Twisted-Pair Cable

- Comes in two types: unshielded and shielded
- Consists of one or more pairs of insulated strands of copper wires twisted around one another and housed in an outer jacket
- Twists are necessary to improve resistance to crosstalk between the individual wires and EMI from outside sources
  - The more twists per unit length, the better resistance to EMI and crosstalk
  - More expensive TP is twisted more than less expensive and provides a better pathway for higher bandwidth networks

# Unshielded Twisted-Pair Cable

- Most networks use Unshielded Twisted-Pair (UTP)
- Consists of four pairs of insulated wires
- Rated according to categories devised by the Telecommunications Industry Association (TIA) and Electronic Industries Alliance (EIA) and American National Standards Institutes (ANSI)
- Categories 1 – 6e are accepted in U.S.
- Two additional categories aren't yet TIA/EIA standards and might never be in U.S.
  - Europe has accepted Category 7 and 7a, which specify that each wire pair is shielded

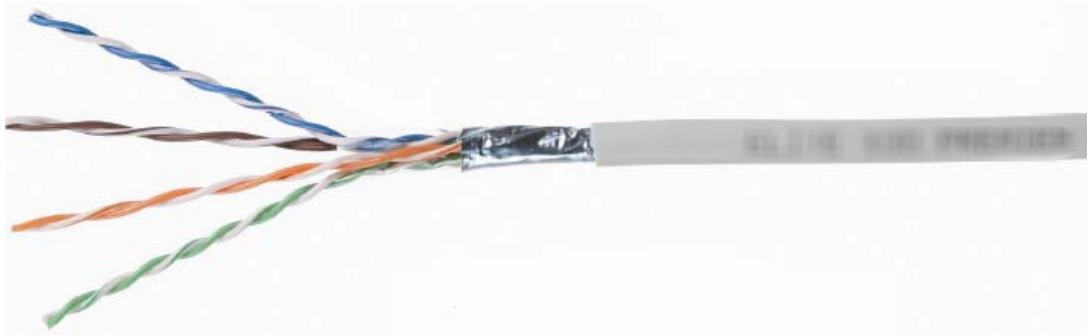
# Unshielded Twisted-Pair Cabling

| Characteristic | Value |
|---|---|
| Maximum cable length | 100 m (328 ft.) |
| Bandwidth | Up to 1000 Mbps |
| Bend radius | Minimum four times the cable diameter or 1 inch |
| Installation and maintenance | Easy to install, no need to reroute; the most flexible |
| Cost | Least expensive of all cabling options |
| Connector type | RJ-45 plug, RJ-45 jack, and patch panels |
| Security | Moderately susceptible to eavesdropping |
| Signaling rates | 100 MHz for Cat 5e; 250 MHz for Cat 6 |
| Interference rating | Susceptible to EMI and crosstalk |

- Categories 5e and 6 UTP Cabling Characteristics
  - These categories are the most popular types of UTP cabling in today's networks

# Shielded Twisted-Pair Cable

- Includes shielding to reduce crosstalk and interference
  - Has a wire braid inside the sheath material or a foil wrap
  - Best to use in electrically noisy environments or very high-bandwidth applications



# Twisted-Pair Cable Plant Components

- RJ-45 Connectors – STP and UTP uses registered jack 45 (RJ-45)
  - Most commonly used in patch cables, which are used to connect computers to hubs, switches, and RJ-45 wall jacks

# Twisted-Pair Cable Plant Components

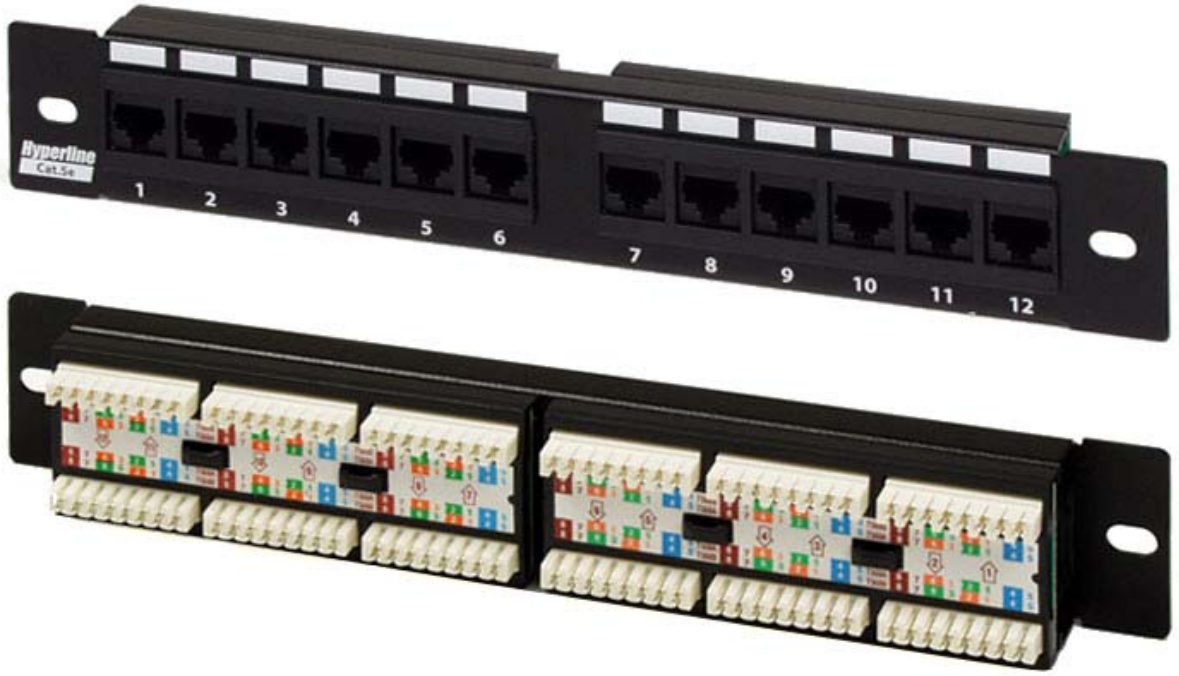
- Patch cable – short cable for connecting a computer to an RJ-45 wall jack or connecting a patch-panel port to a switch or hub
  - Can be made with inexpensive tools, two RJ-45 plugs and a length of TP cable

# Twisted-Pair Cable Plant Components

- RJ-45 jacks – what you plug an RJ-45 connector into when the computer is not near a switch or hub
  - Usually placed behind wall plates when cables are run inside walls

# Twisted-Pair Cable Plant Components

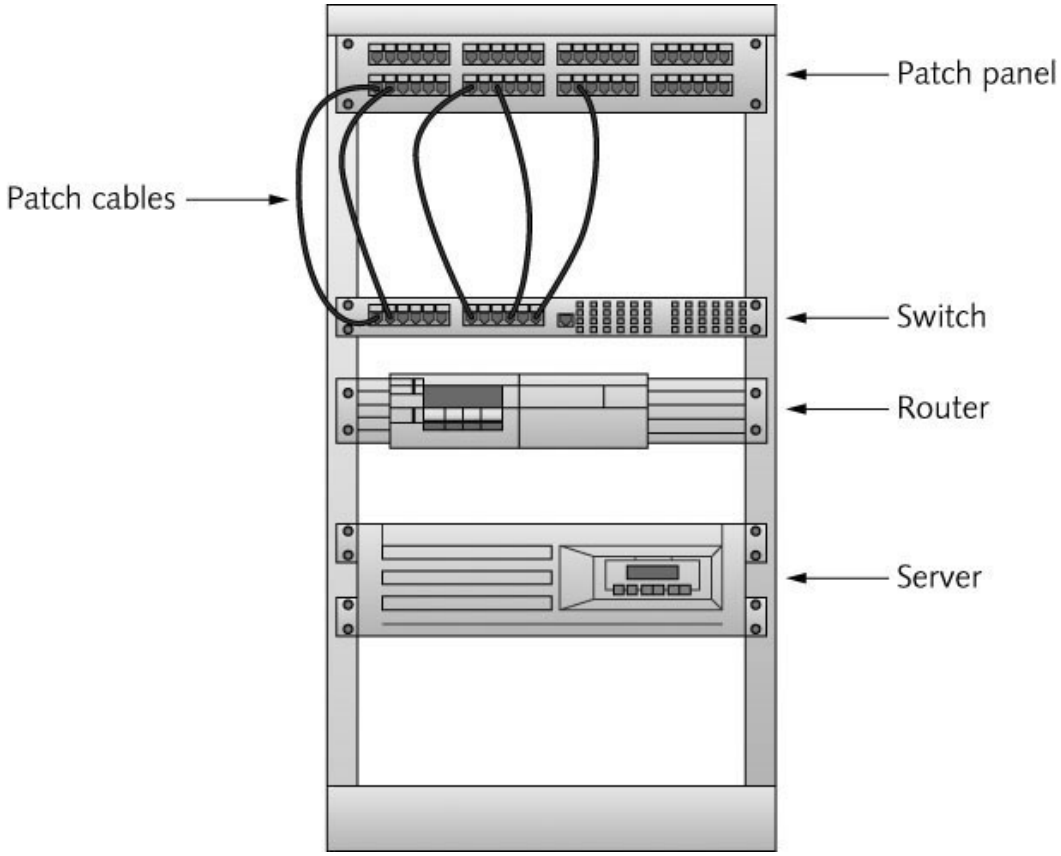
- Patch Panels – used to terminate long runs of cable from where the computers are to the wiring closet (where the switches and hubs are)



# Twisted-Pair Cable Plant Components

- Distribution racks – hold network equipment such as routers and switches, plus patch panels and rack-mounted servers

  (Also called 19” racks because the upright rails are 19” apart)

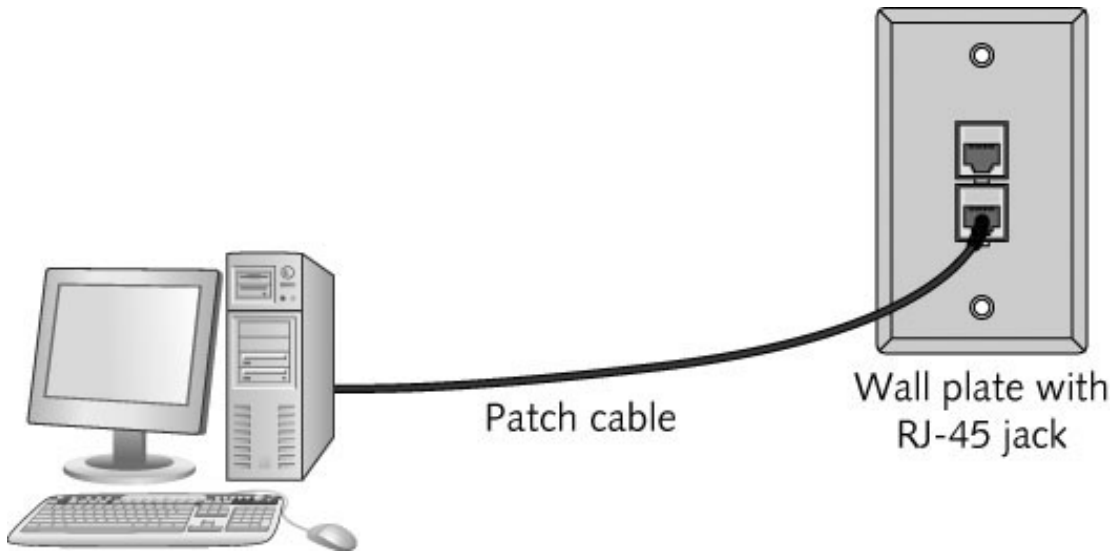


# Structured Cabling: Managing and Installing a UTP Cable Plant

- **Structured cabling** specifies how cabling should be organized, regardless of the media type or network architecture
- Large networks typically use most or all of these components:
  - Work area
  - Horizontal wiring
  - Telecommunication closets
  - Equipment rooms
  - Backbone or vertical wiring
  - Entrance facilities

# Structured Cabling: Managing and Installing a UTP Cable Plant

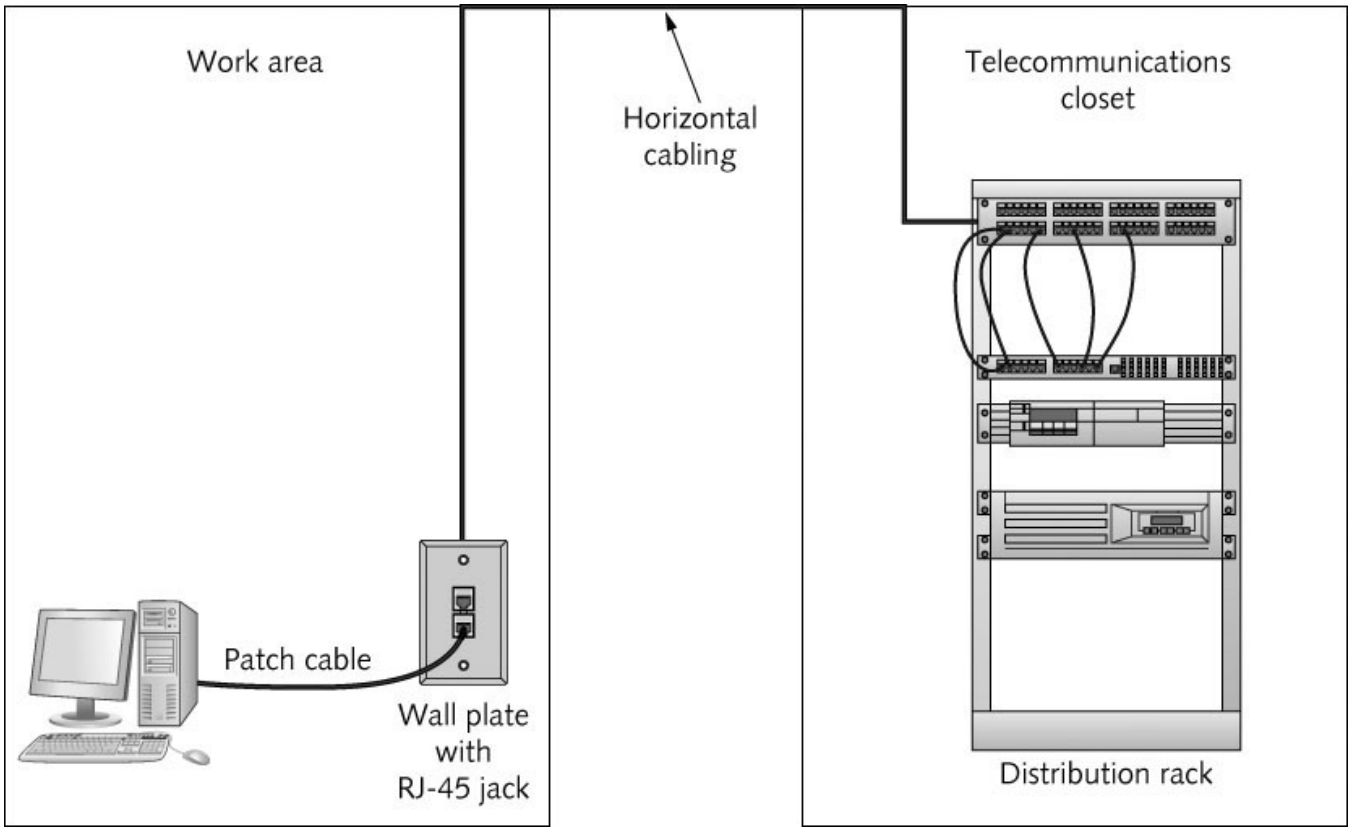
- Work Area – where workstations and other user devices are located
  - Faceplates and wall jacks are installed in the work area
  - Patch cables connect computers and printers to wall jacks



# Structured Cabling: Managing and Installing a UTP Cable Plant

- Horizontal wiring – runs from the work area's wall jack to the telecommunication closet and is usually terminated at a patch panel
  - Horizontal wiring from the wall jack to the patch panel should be no longer than 90 meters to allow for up to 10 meters for patch cables
- Telecommunications Closet
  - TC provides connectivity to computer equipment in the nearby work area
  - Typical equipment includes patch panels to terminate horizontal wiring runs, hubs, and switches
  - In smaller installations, network servers can be housed in the TC

# Structured Cabling: Managing and Installing a UTP Cable Plant

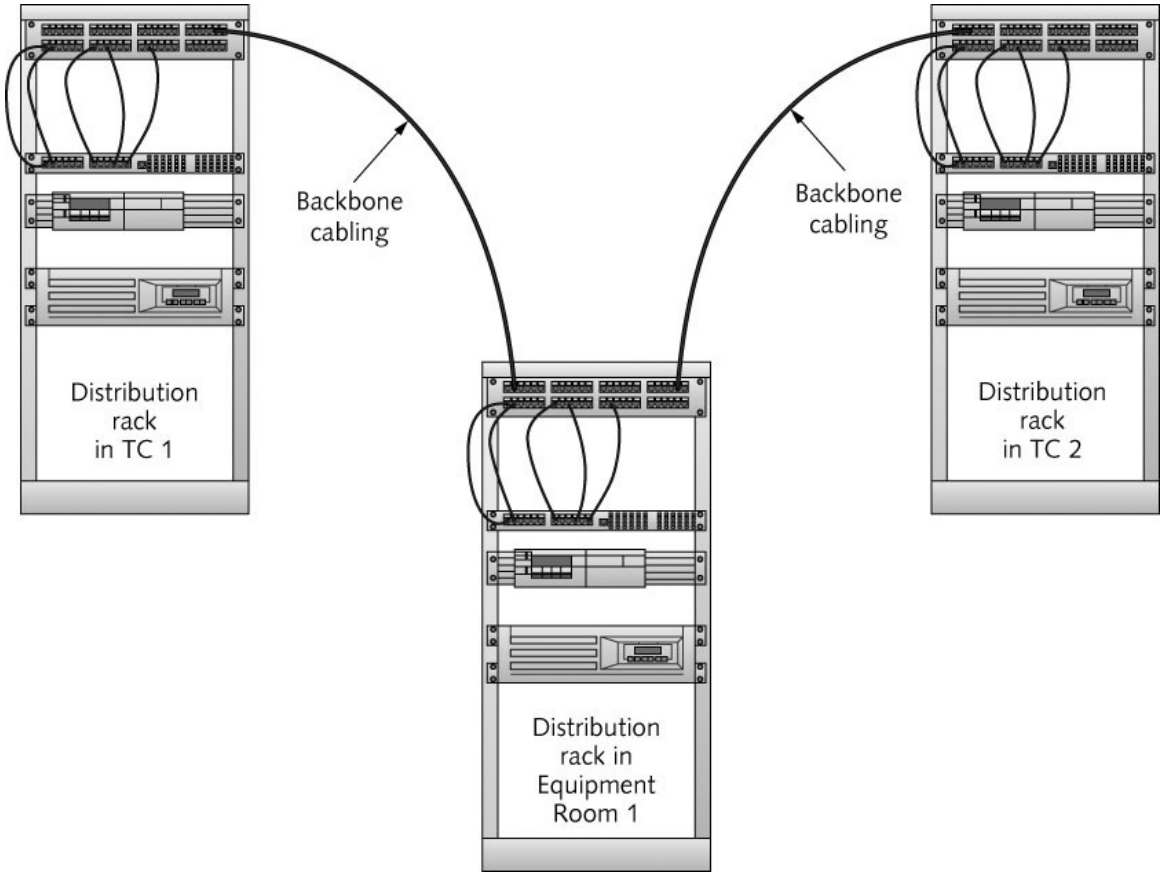



Work area, horizontal wiring, and telecommunications closet

# Structured Cabling: Managing and Installing a UTP Cable Plant

- Equipment Room – house servers, routers, switches, and other major network equipment and serve as a connection point for backbone cabling
  - Can be the main cross-connect for the entire network or it might serve as the connecting point for backbone cabling between buildings
- Backbone Cabling – interconnects TCs and equipment rooms
  - Runs between floors or wings of a building and between buildings
  - Frequently fiber-optic cable, but can also be UTP if the distance between TCs is less than 90 meters

# Structured Cabling: Managing and Installing a UTP Cable Plant




Backbone Cabling

# Structured Cabling: Managing and Installing a UTP Cable Plant

- Entrance Facility – the location of the cabling and equipment that connects a corporate network to a third-party telecommunications provider
  - Can also serve as an equipment room and the main cross-connect for all backbone cabling
  - Where a connection to a WAN is made
  - Demarcation point: point where corporate LAN equipment ends and a third-party provider's equipment and cabling begins

# Installing UTP Cabling

- Cable termination – putting RJ-45 plugs on the ends of cable or punching down wires into terminal blocks on a jack or patch panel
- Some tools needed:
  - Wire cutters
  - Crimping Tool
  - Cable Tester
  - Punchdown Tool
  - Cable Stripper
  - RJ-45 plugs/jacks

# Straight-Through Versus Crossover Cable

- When making or terminating a cable you must get the colored wires arranged in the correct order
  - Two standards of arrangement of wires: 568A and 568B
- Standard patch cables are called straight-through cables (same wiring standard on both ends)
- Crossover cables – use 568A standard on one side of the cable and 568B standard on the other side
  - This type of cable is often needed when you connect two devices of the same type to one another
    - Example: hub to hub, switch to switch, or PC to PC

# Medium Dependent Interface

- Network devices that connect by using RJ-45 plugs over twisted-pair cabling are classified as medium dependent interface (MDI) devices or MDI crossed (MDI-X) devices
- MDI devices transmit on pins 1 and 2 and receive on pins 3 and 6
  - PC NICs and routers are examples
- MDI-X devices receive on pins 1 and 2 and transmit on pins 3 and 6
  - Hubs and switches are examples
- When two switches (or any other like devices) need to be connected, you use a crossover cable so that transmit and receive wires get crossed

# Why Two Transmit and Two Receive Wires?

- One wire pair is used for transmit (labeled transmit+/transmit-) and one pair for receive (labeled receive+/receive-)
- The plus and minus symbols indicate that the wires carry a positive and negative signal
  - This **differential signal** mitigates the effect of crosstalk and noise on the cable

# Fiber-Optic Cable

- Bits are transmitted as pulses of light instead of electricity
- Immune to electrical interference
- Highly secure – electronic eavesdropping is eliminated
- Composition
  - A slender cylinder of glass fiber called the core is surrounded by a concentric layer of glass called the cladding
  - Fiber is then jacketed in a thin transparent plastic material called the buffer

# Fiber-Optic Cable

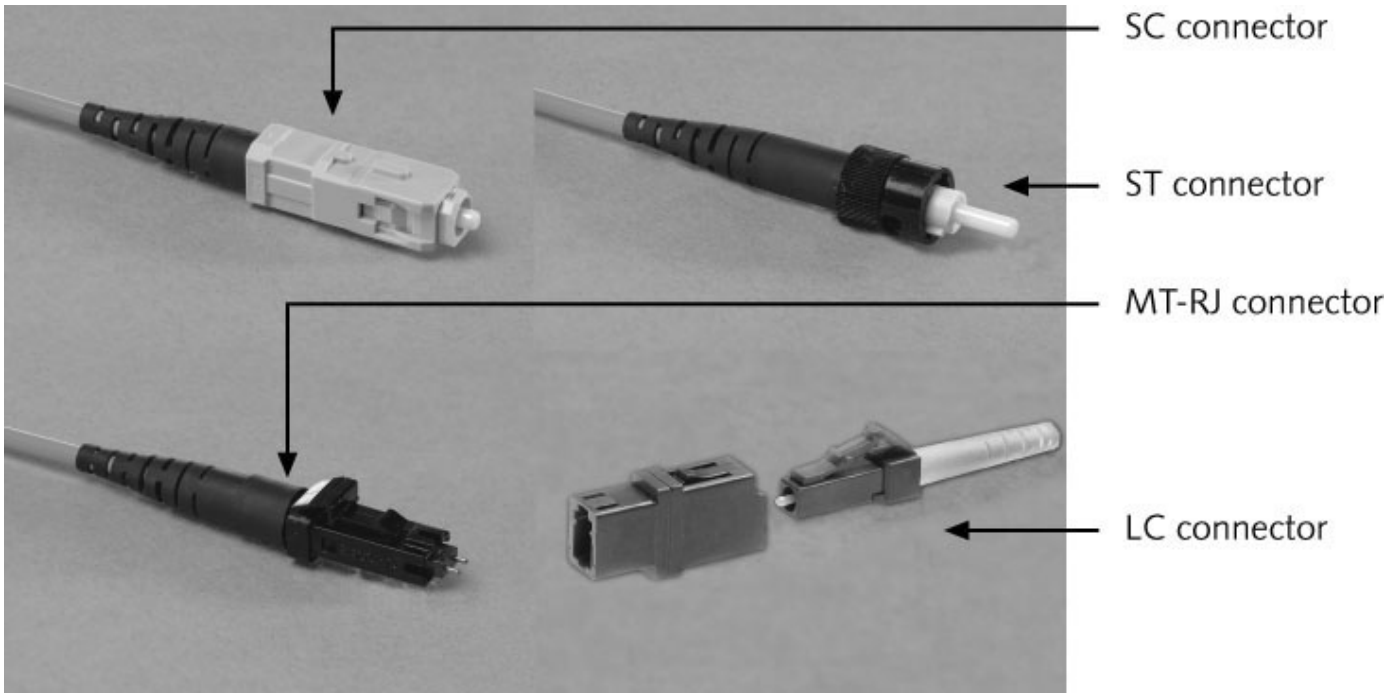
- Each fiber-optic strand carries data in only one direction
  - Network connections consist of two or more strands
- Like UTP patch cables, fiber-optic patch cables usually connect from a fiber-optic patch panel to a switch or router
- Fiber-optic cable used as backbone cabling often comes in bundles of 12 or more fiber strands
  - Even only using 2 in the backbone, running more is a good idea so that you are ready for any future expansion
- Some testing has shown that glass fibers can carry several terabits per second
  - It is speculated that fiber-optic cable will probably one day replace copper for all types of network connections

# Fiber-Optic Cable

| Characteristic | Value |
|---|---|
| Maximum cable length | 2 km (6562 ft.) to 100 km (62.14 miles) |
| Bandwidth | 10, 40, and 100 Gbps and higher |
| Bend radius | 30 degrees per foot |
| Installation and maintenance | Difficult to install and reroute; sensitive to strain and bending |
| Cost | Most expensive of all cabling options |
| Connector type | Several types (see bulleted list in the next section) |
| Security | Not susceptible to eavesdropping |
| Interference rating | None; least susceptible of all cable types |

Fiber-optic cable characteristics

# Fiber-Optic Connectors



# Fiber-Optic Installation

- Somewhat more difficult and time consuming than copper media installation
- Connectors and test equipment required for termination are still more expensive than copper
- There are many methods for terminating fiber-optic cables because of the many connectors and cable types available
  - Installation details are beyond the scope of this book

# Fiber-Optic Cable Types

- Single-mode fiber (SMF)
  - Includes a single, small-diameter fiber at the core (8 microns)
  - Costs more and generally works with laser-based emitters
  - Spans the longest distances
  - Used in higher-bandwidth applications
- Multimode fiber (MMF)
  - Uses a considerably larger diameter fiber at the core (50 and 62.5 microns)
  - Costs less than SMF
  - Works with lower-power light emitting diodes (LEDs)
  - Spans shorter distances

# Wireless Networking

- As wireless networking has become more affordable, demand has increased
- Many home users have turned to wireless networks
- Wireless networks are often used with wired networks to interconnect geographically dispersed LANs or groups of mobile users with wired servers and resources on a wired LAN (sometimes referred to as “hybrid networks”)
- Even in small networks with workstations connecting to a wireless AP or router, the AP or router usually connects to the Internet via a wired connection to a cable modem

# Wireless Benefits

- Creates temporary connections to existing wired networks.
- Establishes backup or contingency connectivity for existing wired networks
- Extends a network's span beyond the reach of wire-based or fiber-optic cabling, especially in older buildings where rewiring might be too expensive
- Allows businesses to provide customers with wireless networking easily, offering a service that gets customers in and keeps them there
- Enables users to roam around a corporate or college campus with their machines

# Types of Wireless Networks

- *Local area networks (LANs)* – usually provide connectivity for mobile users or across areas that couldn't otherwise be networked
- *Extended LANs* – usually used to increase a LAN's span beyond normal distance limitations
- *Internet service* – used to bring Internet access to homes and businesses
- *Mobile computing* – users communicate by using a wireless networking medium that enable them to move while remaining connected to a network

# Wireless LAN Components

- Network interface attaches to an antenna and an emitter rather than to a cable
- Transceiver/access point – a transmitter/receiver device that must be installed to translate between wired and wireless networks
  - Includes an antenna and a transmitter to send and receive wireless traffic but also connects to the wired side of the network
  - Shuttles traffic back and forth between a network's wired and wireless sides

# Wireless LAN Transmission

- Signals take the form of waves in the electromagnetic (EM) spectrum
- The frequency of the wave forms used for communication is measured in cycles per second, usually expressed as **hertz (Hz)**
- The principles governing wireless transmissions dictate that lower-frequency transmissions can carry less data more slowly over longer distances, and higher-frequency transmissions can carry more data faster over shorter distances

# Wireless LAN Transmission

- The following are the most commonly used frequencies for wireless data communication:
  - Radio – 10 KHz to 1 GHz
  - Microwave – 1 GHz to 500 GHz
  - Infrared – 500 GHz to 1 THz (terahertz)
- Wireless LANs make use of four primary technologies for transmitting and receiving data
  - Infrared
  - Laser
  - Narrowband (single-frequency) radio
  - Spread-spectrum radio

# Infrared LAN Technologies

- **Infrared (IR)** wireless networks use infrared light beams to send signals between pairs of devices
  - Work well for LAN applications because of their high bandwidth
  - Four main kinds of infrared LANs
    - Line-of-sight networks – require an unobstructed view between transmitter and receiver
    - Reflective wireless networks – broadcast signals from optical transceivers near devices to a central hub
    - Scatter infrared networks – bounce transmissions off walls and ceilings to deliver signals
    - Broadband optical telepoint networks – provide broadband services

# Laser-Based LAN Technologies

- Also require a clear line of sight between sender and receiver
- Aren’t as susceptible to interference from visible light sources as infrared

# Narrowband Radio LAN Technologies

- Use low-powered, two-way radio communication
- Receiver and transmitter must be tuned to the same frequency to handle incoming and outgoing data
- Requires no line of sight between sender and receiver as long as both parties stay within the broadcast range of these devices (typically 70 meters or 230 feet)
- Depending on the frequency, walls or other solid barriers can block signals
- Interference from other radio sources is also possible

# Spread-Spectrum LAN Technologies

- Uses multiple frequencies simultaneously, improving reliability and reducing susceptibility to interference
  - Also makes eavesdropping more difficult
- Two main kinds of spread-spectrum communications
  - Frequency hopping: switches data between multiple frequencies at regular intervals
  - Direct-sequence modulation: breaks data into fixed-size segments called chips and transmits the data on several different frequencies at the same time

# Wireless Extended LAN Technologies

- **Wireless bridges** – can connect networks up to three miles apart
  - Permit linking locations by using line-of-sight or broadcast transmissions
  - Eliminate the need for a third-party communications carrier
  - Longer-range wireless bridges are also available (up to 25 miles)

| Characteristic | Value |
|---|---|
| Frequency ranges | Unregulated: 902–928 MHz or 2.4 GHz, 5 GHz |
| Maximum distance | Limited to cell boundaries but often extends over several miles |
| Bandwidth | 1–2 Mbps for frequency hopping, 2–6 Mbps for direct-sequence modulation |
| Installation and maintenance | Depends on equipment; ranges from easy to difficult |
| Interference | Moderately resistant |
| Cost | Inexpensive to moderate |
| Security | Not very susceptible to eavesdropping |

# Microwave Networking Technologies

- Microwave systems deliver higher transmission rates than radio-based systems
  - Transmitters and receivers must share a common clear line of sight
- **Terrestrial microwave** systems use tight-beam, high frequency signals to link sender and receiver
  - By using relay towers, microwave systems can extend a signal across continental-scale distances
  - Many communications carriers use microwave towers to send traffic across sparsely populated areas
- **Satellite microwave systems** send and receive data from geosynchronous satellites that maintain fixed positions in the sky
  - Most organizations must lease frequencies from global communications carriers

# LAN Media Selection Criteria

- Three main media choices: UTP, fiber-optic, and wireless
- When having difficulty choosing between media types consider:
  - Bandwidth – Higher bandwidth means more expensive cable and higher installation costs
    - If you need 40 Gbps or more, then fiber-optic is really your only choice
  - Budget – A typical UTP cable installation cost $100 - $200 per cable run and fiber-optic might cost twice that much
    - Wireless have no physical installation costs but you need to install access points and verify connectivity

# LAN Media Selection Criteria

- Environmental considerations – How electrically noisy is the environment? How important is data security?
  - The more weight either factor has, the more likely fiber-optic or secured wireless is the right choice
- Span – What kind of distance must the network span?
  - Longer spans might require fiber-optic or wireless be used between buildings
  - Strategic placement of small switches or hubs gives UTP surprising reach
- Existing cable plant – For an upgrade, the existing cable plant must be considered
  - If some existing cable is to remain, is it compatible with the speeds and new equipment that are planned?

# Chapter Summary

- Wired networking media come in two primary categories: copper and fiber-optic
- Twisted-pair cabling comes in shielded or unshielded varieties
- Twisted-pair cabling components consist of connectors, patch cable, jacks, patch panels, and distribution racks
- A structured cabling plant consists of work areas, horizontal wiring, telecommunications closets, equipment rooms, backbone cabling, and entrance facilities

# Chapter Summary

- Fiber-optic uses pulses of light to represent bits and is immune to EMI, RFI, and electronic eavesdropping
- Wireless networks can be subdivided into LANs, extended LANs, and mobile computing
- Components of a wireless LAN are a NIC, an antenna, and a transceiver or access point
- Different technologies are used to transmit and receive data including: infrared, laser, narrowband radio, and spread-spectrum radio
- Networks combining fiber-optic, UTP, and wireless have become the norm