Network Cabling

Objectives

- Explain basic data transmission concepts, including throughput, bandwidth, multiplexing, and common transmission flaws
- Identify and describe the physical characteristics and official standards of coaxial cable, twisted-pair, and fiber-optic cable, and their related connectors
- Compare the benefits and limitations of various networking media
- Select and use the appropriate tool to troubleshoot common cable problems

Transmission Basics

- Transmission techniques in use on today's network are complex and varied
- This section covers:
  - Measurements that indicate network efficiency
  - Obstacles to good network performance

Throughput and Bandwidth (1 of 2)

- *Bandwidth*
  - *The amount of data that could be theoretically transmitted during a given period of time*
- *Throughput*
  - *Measure of how much data is actually transmitted during given time period*
- *Both are commonly expressed as bits transmitted per second, called bit rate*

Throughput and Bandwidth (2 of 2)

Quantity	Prefix	Abbreviation
1 bit per second	n/a	1 bps = 1 bit per second
1000 bits per second	kilo	1 Kbps = 1 kilobit per second
1,000,000 bits per second	mega	1Mbps = 1 megabit per second
1,000,000,000 bits per second	giga	1 Gbps = 1 gigabit per second
1,000,000,000,000 bits per second	tera	1 Tbps = 1 terabit per second

Transmission Flaws (1 of 4)

- Noise:
  - Any undesirable influence degrading or distorting signal
  - Measured in dB (decibels)
- Types of noise
  - EMI (electromagnetic interference):
    - Caused by motors, power lines, televisions, copiers, fluorescent lights, etc.
    - One type of EMI is RFI (radio frequency interference)
  - Cross-talk:
    - Signal on one wire infringes on adjacent wire signal
      - Alien cross-talk occurs between two cables
      - Near end cross-talk (NEXT) occurs near source
      - Far end cross-talk (FEXT) occurs at the far end

Transmission Flaws (2 of 4)

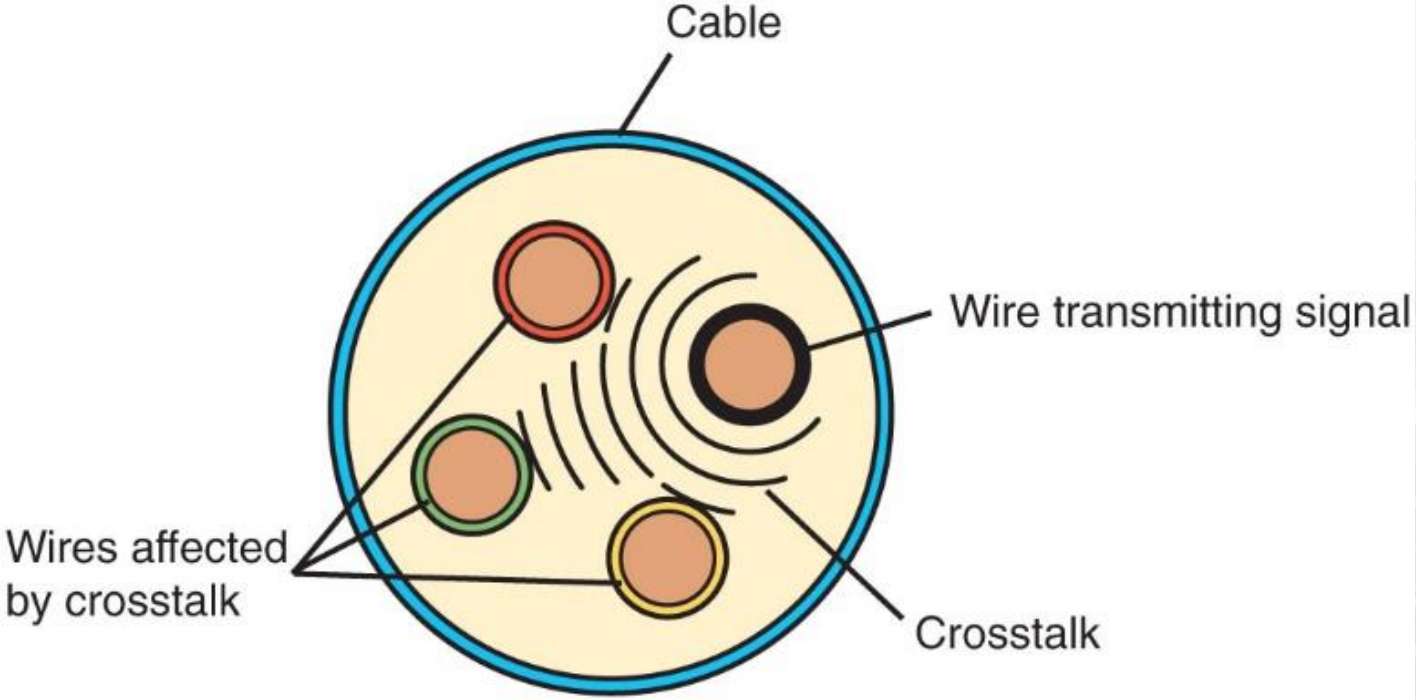


Figure 5-1 Crosstalk between wires in a cable

Transmission Flaws (3 of 4)

- Attenuation
  - Loss of signal's strength as it travels away from source
- Signals can be boosted:
  - Repeater—Regenerates a digital signal in its original form
    - Without noise previously accumulated

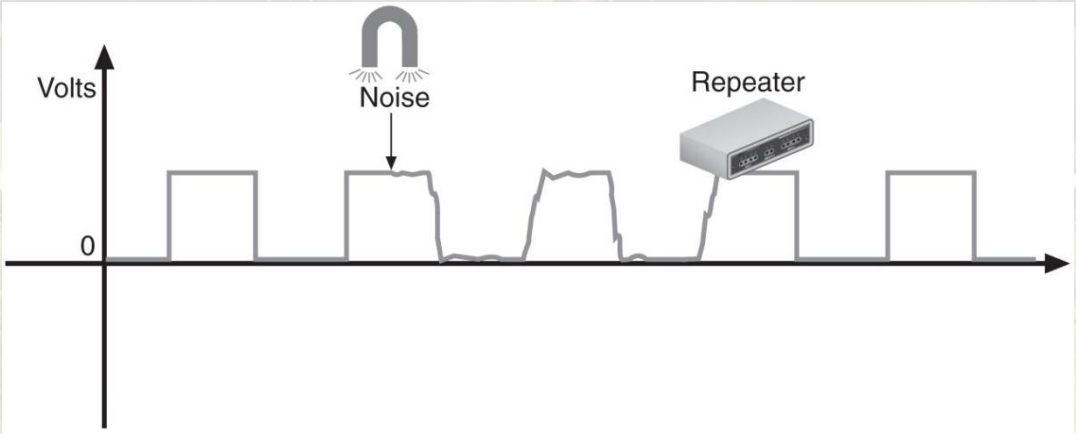


Figure 5-2 A digital signal distorted by noise and then repeated

Transmission Flaws (4 of 4)

- Latency:
  - Delay between signal transmission and receipt
  - May cause network transmission errors
- Latency causes:
  - Cable length
  - Intervening connectivity device
- Round trip time (RTT):
  - Time for packet to go from sender to receiver, then back from receiver to sender
- If packets experience varying amounts of delay:
  - They can arrive out of order
  - A problem commonly called jitter or PDV (packet delay variation)

Duplex, Half-Duplex, and Simplex (1 of 2)

- NIC settings include the direction in which signals travel over the media and the number of signals that can traverse the media at any given time
  - These two settings are combined to create different methods of communication
- Full-duplex—Also called duplex
  - Signals travel in both directions over a medium simultaneously
- Half-duplex
  - Signals may travel in both directions but only in one direction at a time
- Simplex
  - Signals may travel in only one direction and is sometimes called one-way or unidirectional, communication

Duplex, Half-Duplex, and Simplex (2 of 2)

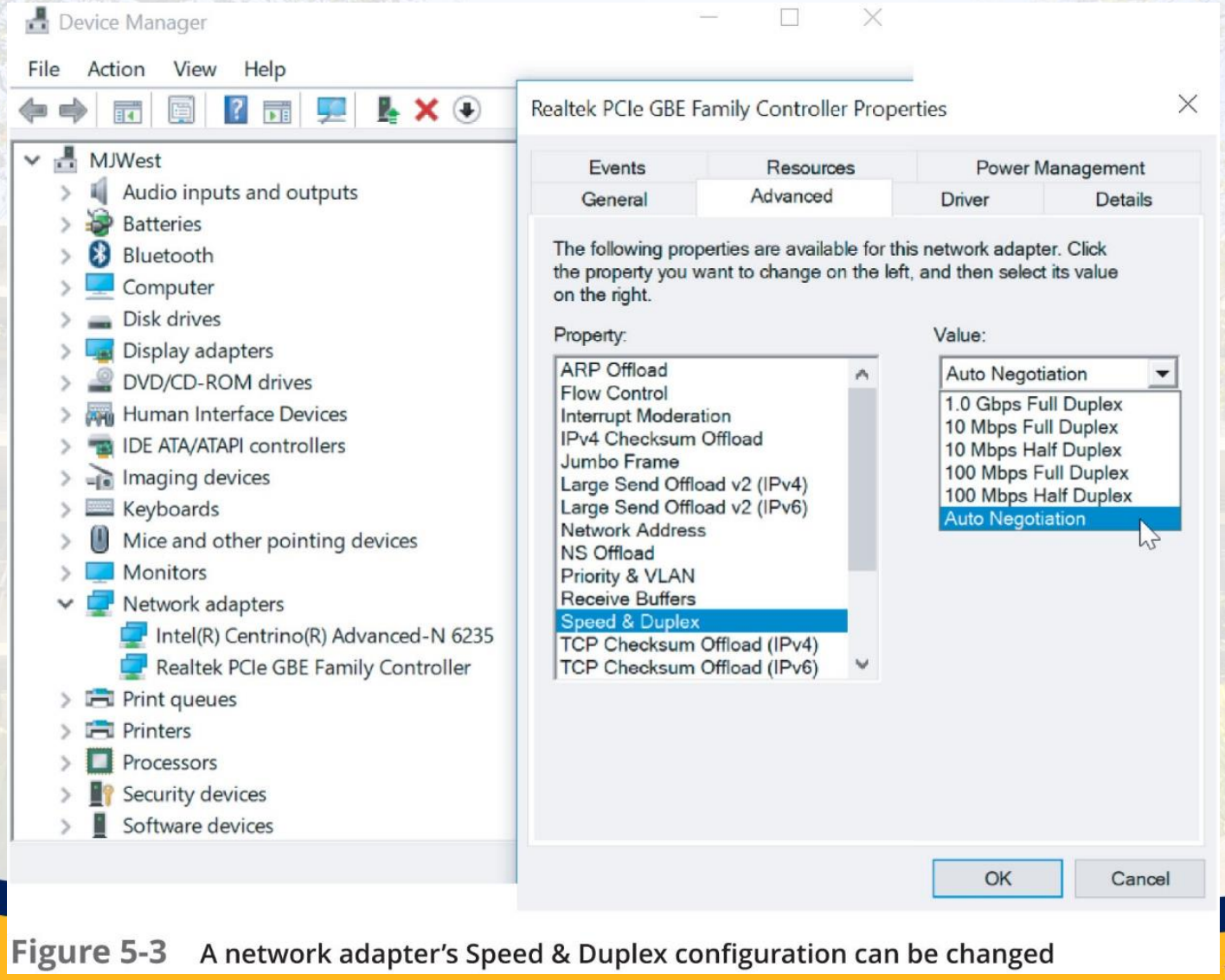


Figure 5-3 A network adapter's Speed & Duplex configuration can be changed

Multiplexing (1 of 4)

- Multiplexing
  - A form of transmission that allows multiple signals to travel simultaneously over one medium
- Subchannels
  - Logical multiple smaller channels
- Multiplexer (mux):
  - Combines many channel signals
  - Required at the transmitting end of the channel
- Demultiplexer (demux)
  - Separates the combined signals

Multiplexing (2 of 4)

- Three types of multiplexing are used on copper lines
- TDM (time division multiplexing)
  - Divides channel into multiple time intervals
- STDM (statistical time division multiplexing):
  - Transmitter assigns slots to nodes
    - According to priority and need
  - Maximizes available bandwidth on a network
- FDM (frequency division multiplexing)
  - Assigns different frequency band for each communications subchannel

Multiplexing (3 of 4)

- Three types of multiplexing are used on fiber-optic cable
- WDM (wavelength division multiplexing)
  - Carries multiple light signals simultaneously by dividing a light beam into different wavelengths or colors
- DWDM (dense wavelength division multiplexing):
  - Extraordinary capacity
  - Typically used on high-bandwidth or long-distance WAN links
- CWDM (Coarse wavelength division multiplexing):
  - Channels are spaced more widely apart across entire frequency band
  - Effective distance is more limited because the signal is not amplified

Multiplexing (4 of 4)

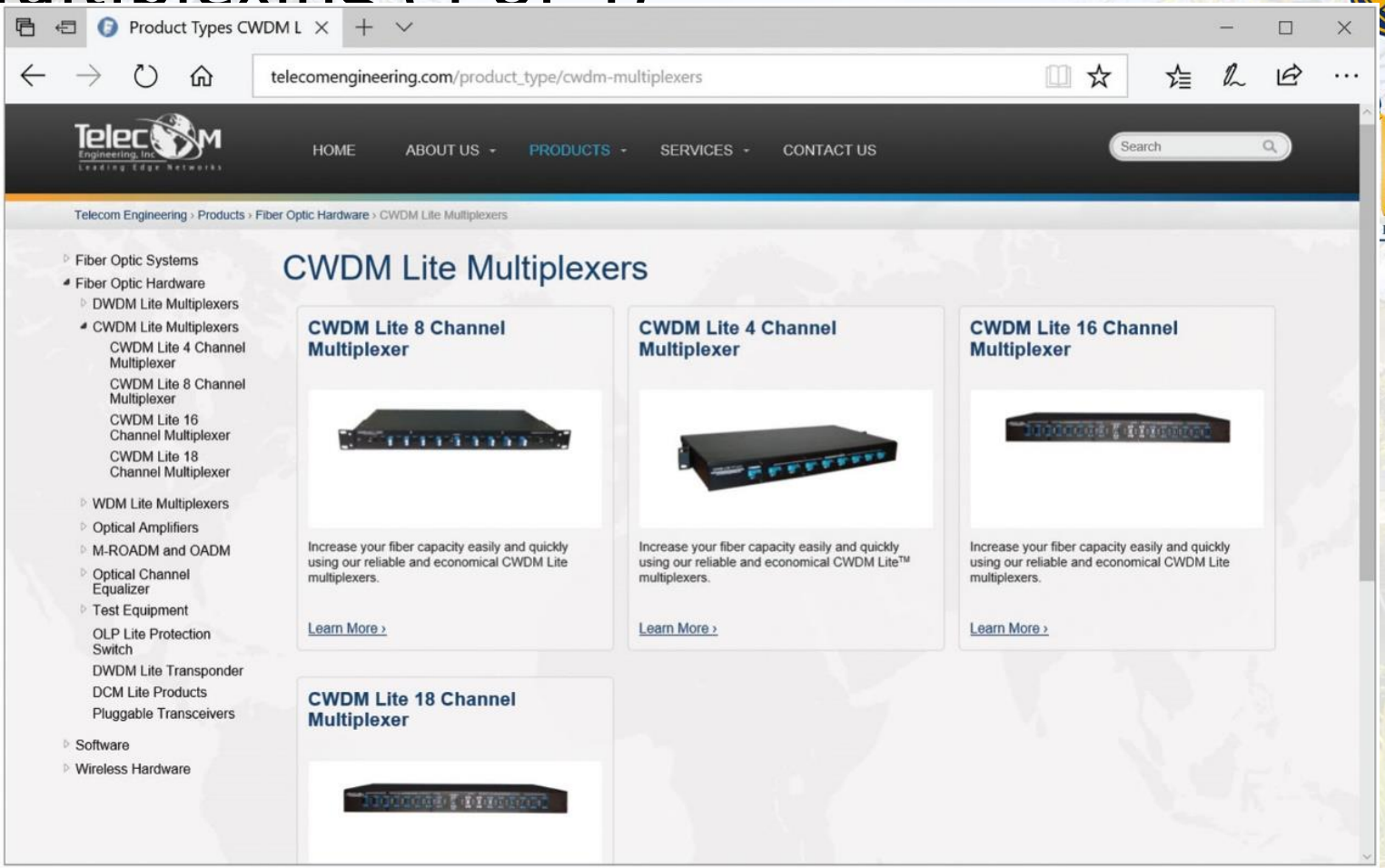


Figure 5-4 CWDM multiplexers come in 4-channel, 8-channel, 16-channel, and 18-channel varieties

Source: Telecom Engineering, Inc.

Copper Cable

- Coaxial cable is considered a “legacy” cable

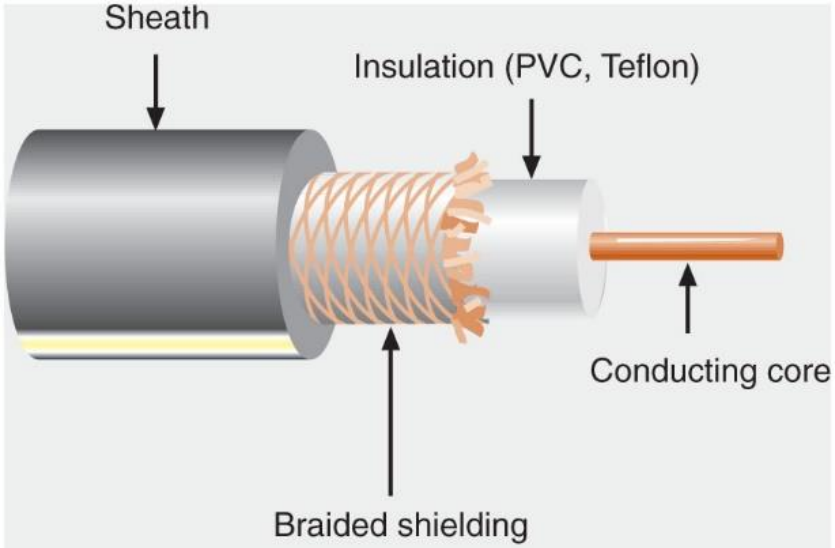


Figure 5-5 Coaxial cable

Twisted-Pair Cable (1 of 3)

- Color-coded insulated copper wire pairs:
  - 0.4–0.8 mm diameter
  - Encased in a plastic sheath
  - Every two wires are twisted together

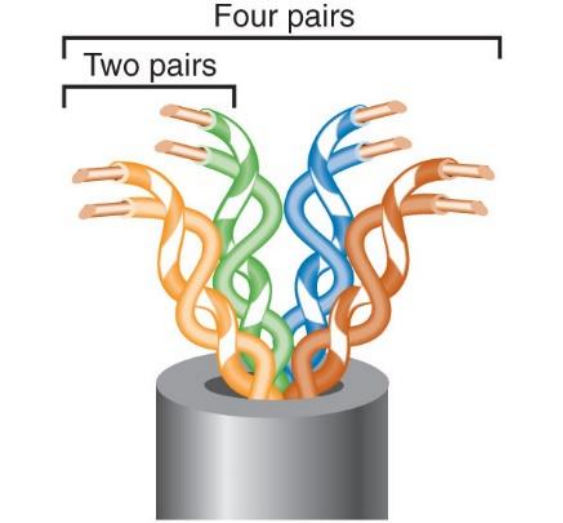


Figure 5-8 Twisted-pair cable

Twisted-Pair Cable (2 of 3)

- Twisted-pair cabling in Ethernet networks contains four wire pairs:
  - Fast Ethernet uses one pair to send data and one pair to receive data
  - Networks using Gigabit Ethernet use all four pairs for both sending and receiving
- Wiring standard specification
  - TIA/EIA 568
- Most common twisted pair types:
  - Category (cat) 3, 5, 5e, 6, 6a, and 7
  - CAT 5e or higher used in modern LANs
- Two categories:
  - Shielded twisted pair (STP)
  - Unshielded twisted pair (UTP)

Twisted-Pair Cable (3 of 3)

Figure 5-9 This data cable is Cat 5e

STP (Shielded Twisted Pair)

- Individually insulated
- Surrounded by metallic substance shielding (foil):
  - Barrier to external electromagnetic forces
  - Contains electrical energy of signals inside
  - Must be grounded

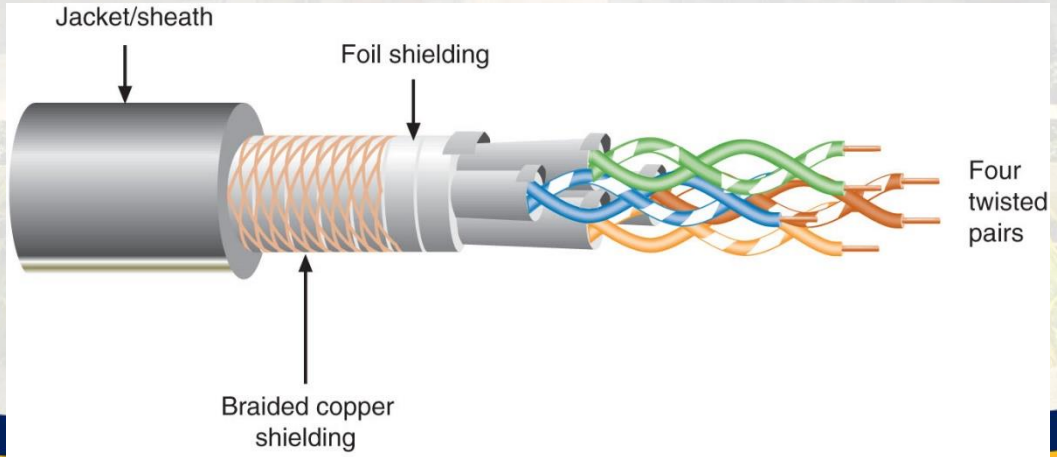


Figure 5-10 STP cable

UTP (Unshielded Twisted Pair)

- One or more insulated wire pairs encased in plastic sheath:
  - No additional shielding
  - Less expensive, less noise resistance

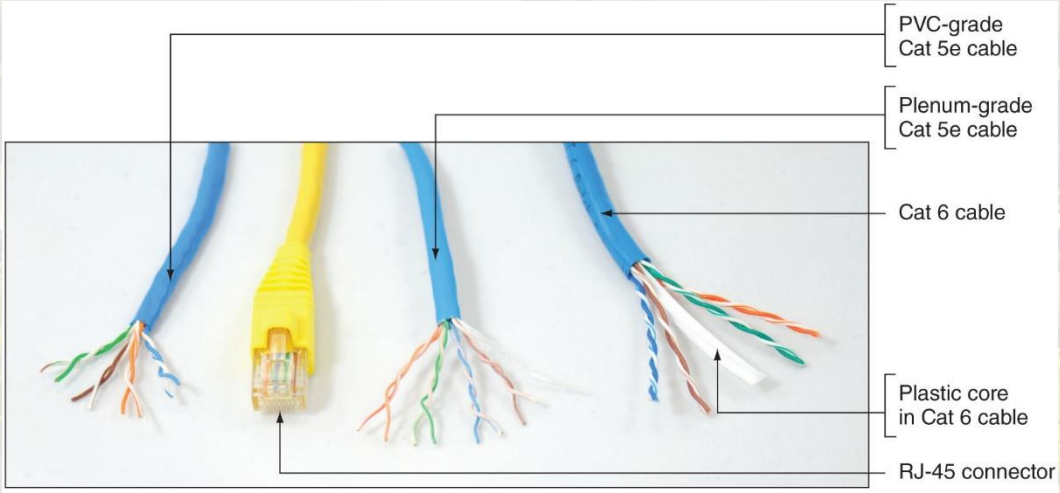


Figure 5-11 Various UTP cables and RJ-45 connector

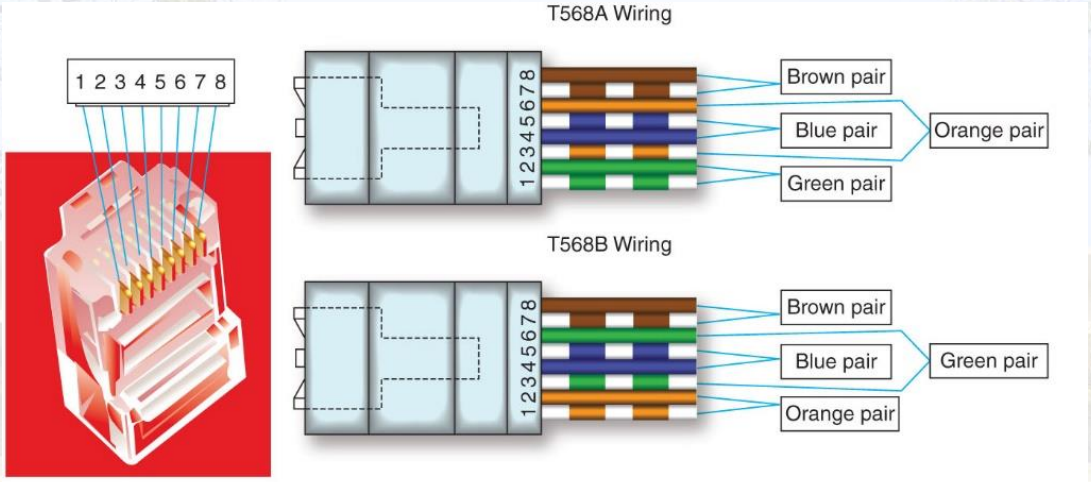
Comparing STP and UTP

- Throughput
  - STP and UTP can transmit the same rates
- Cost
  - STP and UTP vary in cost
  - STP is more expensive than UTP
- Connector
  - STP and UTP use Registered Jack 45
- Noise immunity
  - STP is more noise resistant
- Size and scalability
  - Maximum segment length for both: 100 meters on Ethernet networks that support data rates from 1 Mbps and 10 Gbps

Cable Pinouts (1 of 4)

- Proper cable termination is a requirement for two nodes on a network to communicate
  - Poor terminations can lead to loss or noise in a signal
- TIA/EIA specifies two methods of inserting wires into RJ-45 plugs:
  - TIA/EIA 568A
  - TIA/EIA 568B
- No functional difference between the two standards
  - Just make sure you use the same standard on every RJ-45 plug and jack

Cable Pinouts (2 of 4)



Pin #	T568A Color	T568B Color	Fast Ethernet function	Gigabit Ethernet function
1	White/green	White/orange	Tx+	Bidirectional+
2	Green	Orange	Tx−	Bidirectional−
3	White/orange	White/green	Rx+	Bidirectional+
4	Blue	Blue	*Unused*	Bidirectional+
5	White/blue	White/blue	*Unused*	Bidirectional−
6	Orange	Green	Rx−	Bidirectional−
7	White/brown	White/brown	*Unused*	Bidirectional+
8	Brown	Brown	*Unused*	Bidirectional−

Figure 5-13 T568A and T568B standard terminations for Fast Ethernet and Gigabit Ethernet

Cable Pinouts (3 of 4)

- Straight-through cable (also called patch cable)
  - Terminate RJ-45 plugs at both ends identically
- Crossover cable
  - Transmit and receive wires on one end reversed
- Rollover cable (also called console cable):
  - All wires are reversed
  - Terminations are a mirror image of each other
  - Used to connect a computer to the console port of a router
    - When making configuration changes to the device

Cable Pinouts (4 of 4)

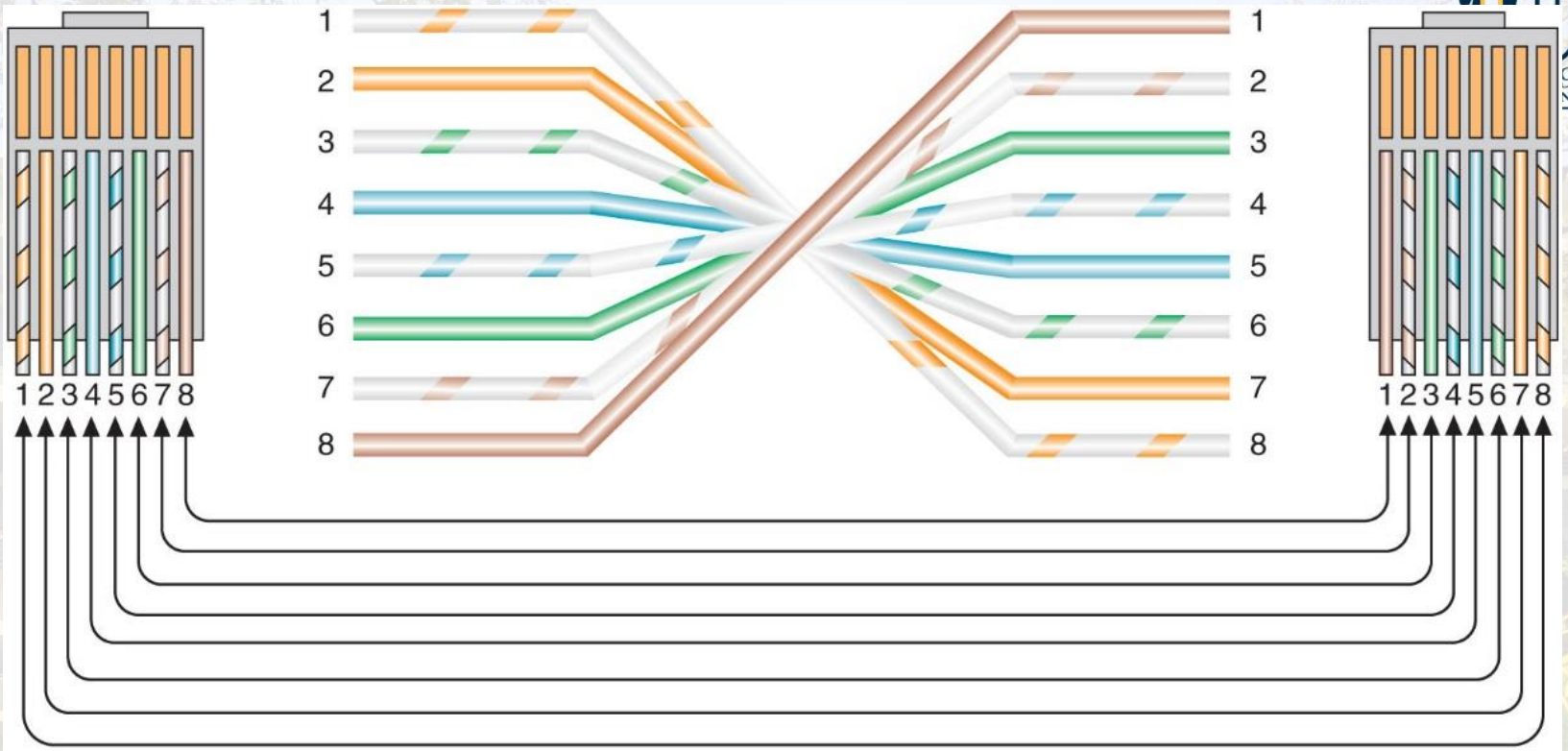


Figure 5-17 RJ-45 terminations on a rollover cable

PoE (Power over Ethernet) (1 of 4)

- PoE—IEEE 802.3af standard which specifies a method for supplying electrical power over twisted-pair Ethernet connections
- Amount of power provided:
  - 15.4 watts for standard PoE devices
  - 25.5 watts for newer PoE+ devices (802.3at standard)
- PoE standard specifies two types of devices:
  - PSE (power sourcing equipment)
  - PD (powered devices)

PoE (Power over Ethernet) (2 of 4)

- PoE requires Cat 5 or better copper cable
- The IEEE standard requires that a PSE device first determine whether a node is PoE-capable before attempting to supply it with power
- On networks that demand PoE but don't have PoE-capable equipment, you can add PoE adapters

PoE (Power over Ethernet) (3 of 4)

Source: D-Link North America

Figure 5-28 Power and data separately enter this PoE injector through ports shown on the right, and exit together through the port shown on the left

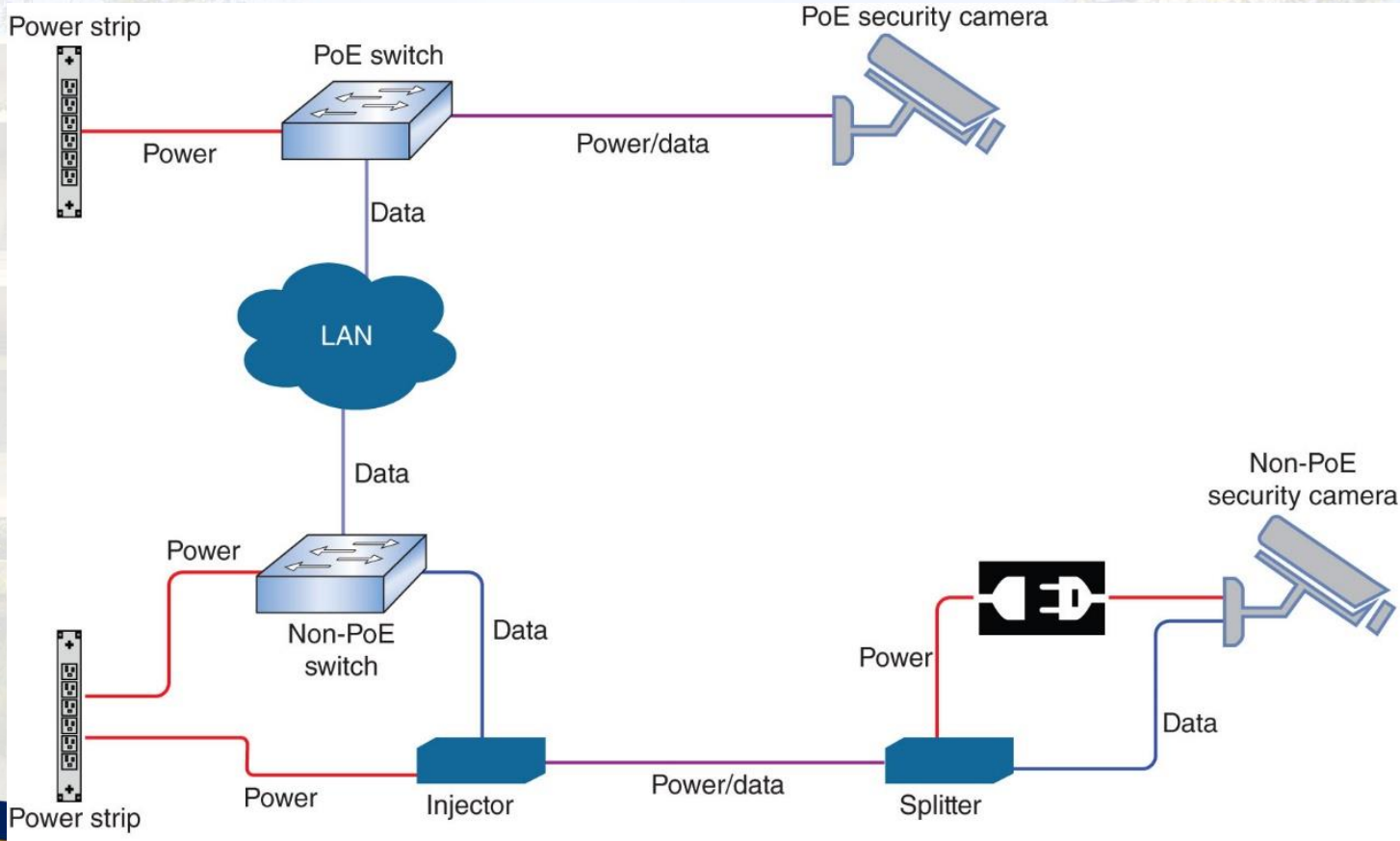


Figure 5-27 PoE adapters can add PoE functionality to non-PoE devices on a network

PoE (Power over Ethernet) (4 of 4)

Source: D-Link North America

Figure 5-28 Power and data separately enter this PoE injector through ports shown on the right, and exit together through the port shown on the left

Ethernet Standards for Twisted-Pair Cable (1 of 2)

- A cable's category (Cat 5e or Cat 6) determines the fastest network speed it can support
  - A Layer 1 characteristic
- A device's NIC is also rated for maximum network speeds
- Most LANs today use devices and NICs that can support Fast Ethernet and Gigabit Ethernet
  - Devices can auto-negotiate for the fastest standard they have in common

Ethernet Standards for Twisted-Pair Cable (2 of 2)

- Table 5-4 Ethernet standards used with twisted-pair cabling

Standard	Maximum transmission speed (Mbps)	Maximum distance per segment (m)	Physical media	Pairs of wires used for transmission
100Base-T Fast Ethernet	100	100	Cat 5 or better	2 pair
1000Base-T Gigabit Ethernet	1000	100	Cat 5 or better (Cat 5e is preferred)	4 pair
10GBase-T 10-Gigabit Ethernet	10,000	100	Cat 6a or Cat 7 (Cat 7 is preferred)	4 pair

Fiber-Optic Cable (1 of 4)

- Fiber-optic cable (fiber)
  - Contains one or more glass or plastic fibers at its center (core)
- Data transmission
  - Pulsing light sent from laser or light-emitting diode (LED) through central fibers
- Cladding:
  - Layer of glass or plastic surrounding fibers
  - Different density from glass or plastic in strands
  - Reflects light back to core
  - Allows fiber to bend

Fiber-Optic Cable (2 of 4)

- Plastic buffer outside cladding:
  - Protects cladding and core
  - Opaque to absorb escaping light
  - Surrounded by Kevlar (polymeric fiber) strands
- Plastic sheath covers Kevlar strands

Figure 5-29 A fiber-optic cable

Source: Optical Cable Corporation

Fiber-Optic Cable (3 of 4)

- Benefits over copper cabling:
  - Extremely high throughput
  - Very high noise resistance
  - Excellent security
  - Able to carry signals for longer distances
- Drawbacks:
  - More expensive than twisted pair cable
  - Requires special equipment to splice

Fiber-Optic Cable (4 of 4)

- Throughput
  - Proven reliable in transmitting data at rates that can reach 100 gigabits per second per channel
- Cost
  - Most expensive transmission medium
- Noise immunity
  - Unaffected by EMI
- Size and scalability:
  - Segment lengths vary from 2 to 40,000 meters
  - Depends on the light's wavelength and type of cable

SMF (Single Mode Fiber) (1 of 2)

- Consists of narrow core (8–10 microns in diameter):
  - Laser-generated light travels over one path
    - Little reflection
  - Light does not disperse as signal travels
- Can carry signals many miles:
  - Before repeating is required
- Rarely used for shorter connections:
  - Due to cost
  - The Internet backbone depends on SMF

SMF (Single Mode Fiber) (2 of 2)

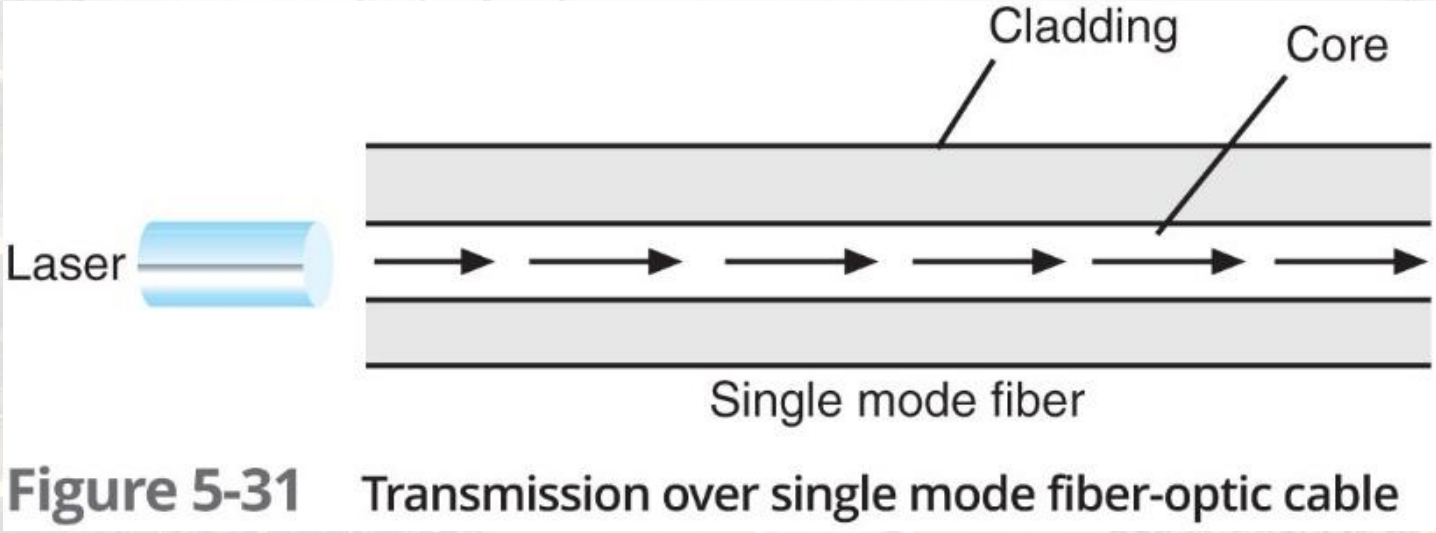


Figure 5-31 Transmission over single mode fiber-optic cable

MMF (Multimode Fiber) (1 of 2)

- Contains a core with a larger diameter than single mode fiber
  - Common sizes: 50 or 62.5 microns
- Laser or LED generated light pulses travel at different angles
- Greater attenuation than single-mode fiber
- Common uses:
  - Cables connecting routers, switches, and servers on the backbone of a network
  - Cables to connect a desktop workstation to the network
- Transition between SMF and MMF might occur at an FDP (fiber distribution panel)

MMF (Multimode Fiber) (2 of 2)

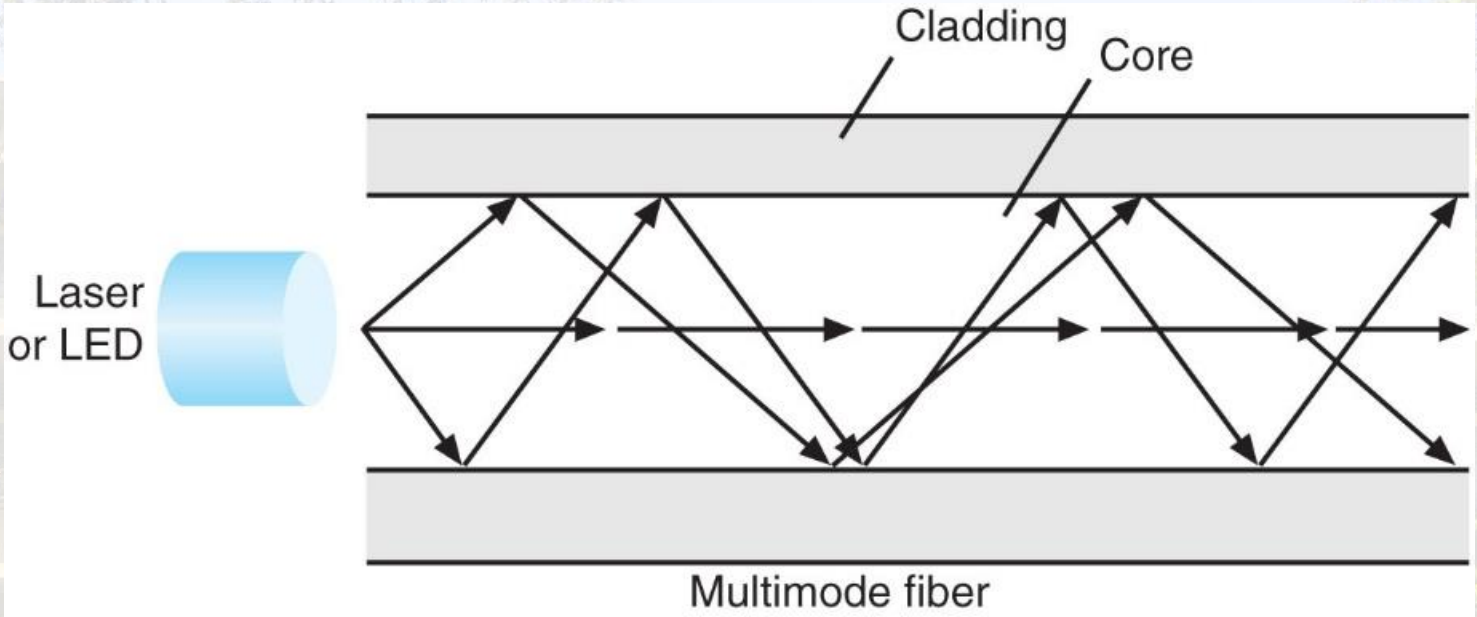


Figure 5-32 Transmission over multimode fiber-optic cable

Fiber Connectors (1 of 3)

- MMF connectors
  - Classified by the number of fibers
- SMF connectors
  - Classified by size and shape of the ferrule
- Ferrule—The extended tip of a connector that makes contact with the receptacle in the jack

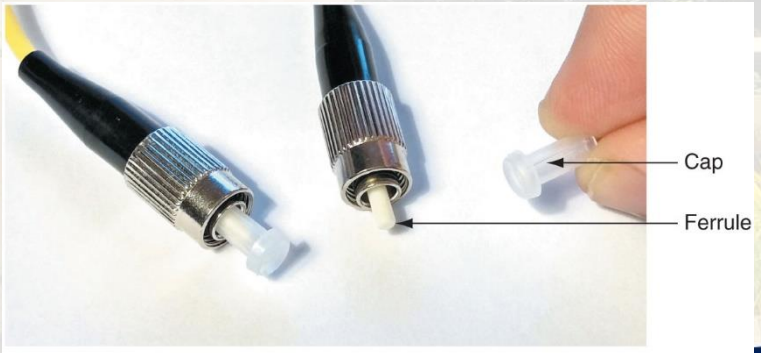


Figure 5-33 A cap protects the ferrule when the connector is not in use

Fiber Connectors (2 of 3)

- Shapes and polishes used by SMF ferrules to reduce back reflection:
  - Ultra Polished Connector (UPC)
  - Angle Polished Connector (APC)

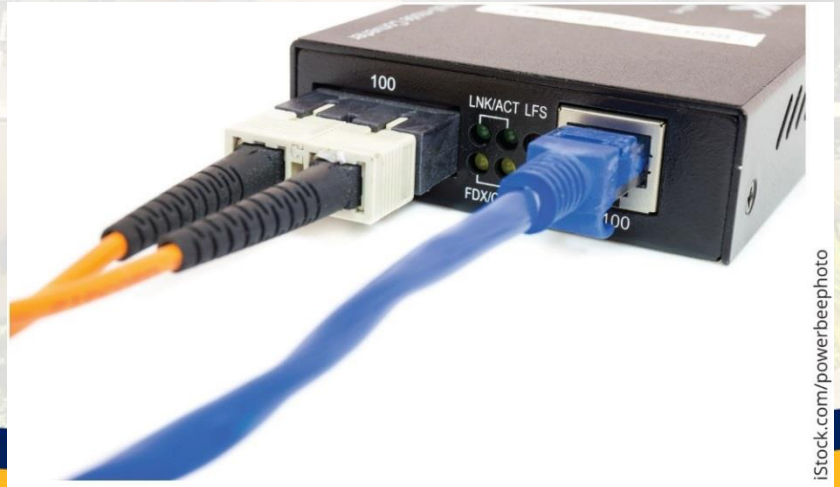
Figure 5-34 Two current types of mechanical connections in fiber-optic connectors

Fiber Connectors (3 of 3)

- SMF connectors are typically available with a 1.25-mm ferrule or a 2.5-mm ferrule:
  - Most common 1.25-mm connector is the LC (local connector)
  - Two 2.5-mm connectors are the SC (standard connector) and ST (straight tip)
- Most common MMF connector is the MTRJ
- Existing fiber networks might use ST or SC connectors
  - LC and MT-RJ are used on the very latest fiber-optic technology

Media Converters

- Media converter:
  - Hardware that enables networks or segments running on different media to interconnect and exchange signals
  - Completes the physical connection and converts electrical signals from copper cable to light wave signals
    - Can also be used to convert networks using MMF with networks using SMF



iStock.com/powerbeephoto

Figure 5-35 Copper wire-to-fiber media converter

Fiber Transceivers (1 of 4)

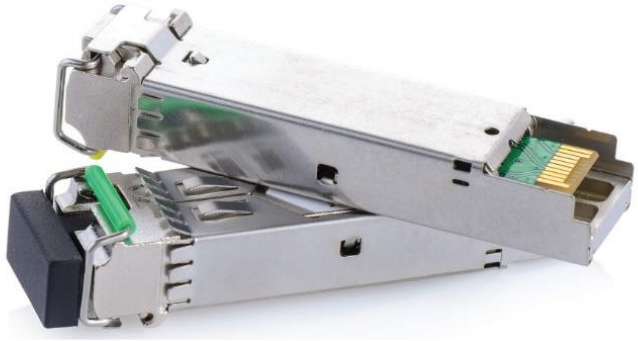
- Some switches allow you to change and upgrade its interfaces
  - They contain sockets where one of many types of modular interfaces, called transceivers, can be plugged in
- GBIC—A standard type of modular interface designed for Gigabit Ethernet connections
  - May contain RJ-45 or fiber-optic cable ports

Figure 5-37 GBIC (Gigabit interface converter) with dual SC ports

Fiber Transceivers (2 of 4)

- Newer transceivers that have made the GBIC obsolete:
  - SFP (small form-factor pluggable)
  - XFP (10 Gigabit small form-factor pluggable)
  - SFP+
  - QSFP (quad small form-factor pluggable)
  - QSFP+
  - CFP (centum form-factor pluggable)
- To avoid a transceiver mismatch
  - Devices must be paired based on supported speeds and protocols

Fiber Transceivers (3 of 4)



iStock.com/sommail

Figure 5-38 These SFPs slide into a switch to add fiber-optic connectivity

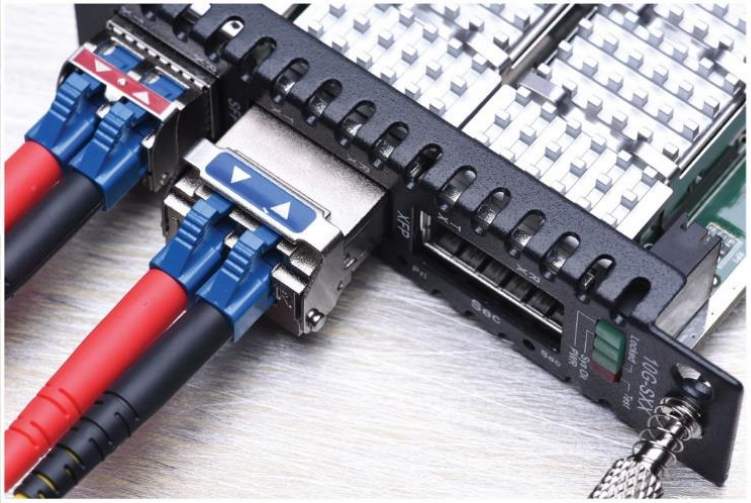


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Figure 5-39 This media converter supports both SFP+ and XFP

Fiber Transceivers (4 of 4)

- BiDi transceivers:
  - Allows bidirectional transmission on both ports
  - Means fiber cable carries data in both directions
- Installing a transceiver:
  - Slide the transceiver into a socket on the back of the connectivity device
  - Most SFPs come with a tab or latch system and keyed so that they will slide into the socket when aligned properly

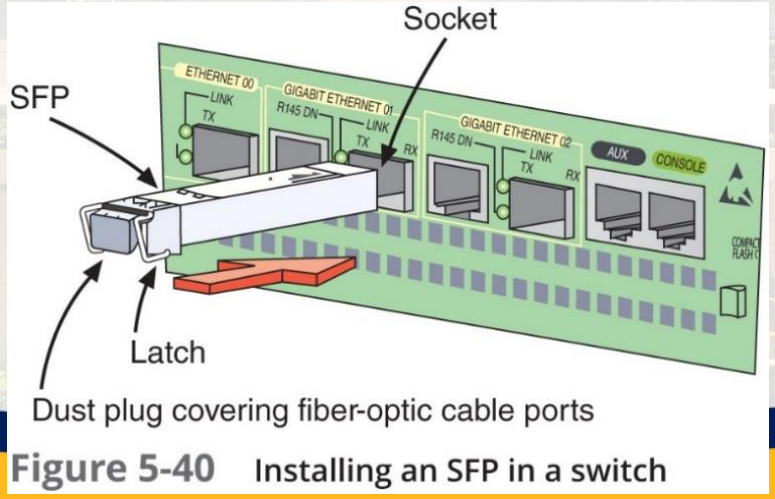

Figure 5-40 Installing an SFP in a switch

Ethernet Standards for Fiber-Optic Cable (1 of 2)

- Table 5-6 Ethernet standards using fiber-optic cable

Standard		Maximum transmission speed (Mbps)	Maximum distance per segment (m)	Physical media
Gigabit Ethernet	1000Base-LX	1000	550 for MMF, 5000 for S M F	MMF or S MF
blank	1000Base-SX	1000	Up to 550, depending on modal bandwidth and fiber core diameter	MMF
10-Gigabit Ethernet	10GBase-SR and 10GBase-LW	10,000	Up to 300, depending on modal bandwidth and fiber core diameter	MMF
blank	10GBase-LR and 10GBase-LW	10,000	10,000	SMF
blank	10GBase-ER and 10GBase-EW	10,000	40,000	SMF

Ethernet Standards for Fiber-Optic Cable (2 of 2)

- Table 5-7 1000Base-SX Segment lengths

Multimode fiber diameter	Maximum segment length
50 microns	550 m
62.5 microns	275 m

Common Fiber Cable Problems

- Fiber type mismatch:
  - More of a fiber core mismatch
  - Even same-mode cables can be mismatched if the cores have different widths
- Wavelength mismatch
  - SMF, MMF, and POF (Plastic Optical Fiber) use different wavelengths
- Dirty connectors
  - Signal loss and other errors can start to cause problems

Troubleshooting Tools

- Start troubleshooting a network connection problem by checking the network connection LED status indicator lights:
  - Steady light indicates connectivity
  - Blinking light indicates activity
  - Red or amber light might indicate a problem
- If a cabling issue is suspected
  - Know which tools are designed to analyze and isolate problems

Toner and Probe Kit (1 of 3)

- Tone generator (toner):
  - Small electronic device
  - Issues signal on wire pair
- Tone locator (probe)
  - Emits tone when electrical activity detected
- Probe kit or toner probe
  - Generator and locator combination
- Testing requires trial and error
- Used to determine where wired pair terminates
- Not used to determine cable characteristics

Toner and Probe Kit (2 of 3)

Figure 5-43 A toner and probe kit by Fluke Corporation

Toner and Probe Kit (3 of 3)

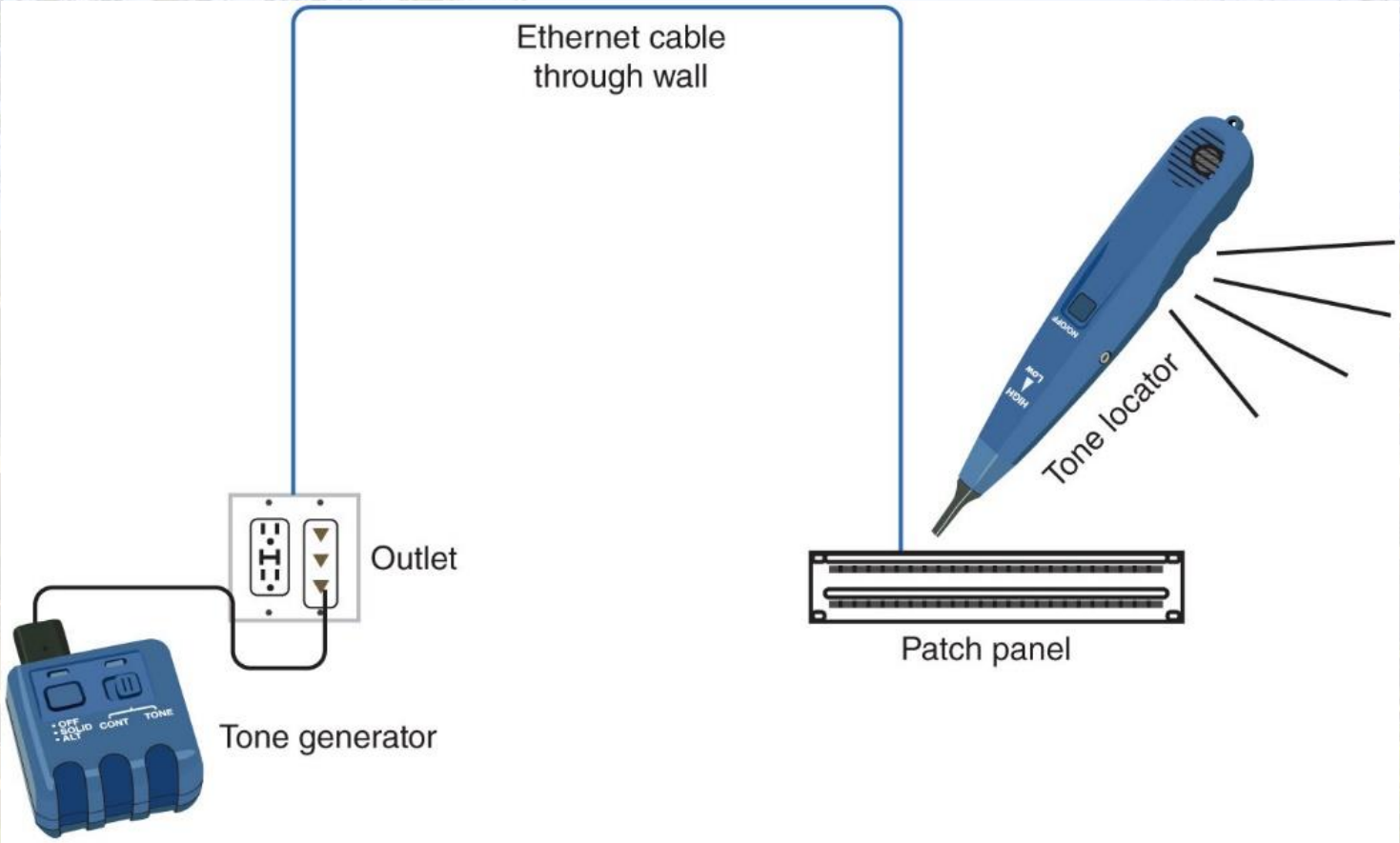

Figure 5-44 A toner and probe kit locates the termination of a wire

Multimeter (1 of 2)

- Multimeter
  - Measures electric circuit characteristics
    - Resistance, voltage, and impedance
- Use a multimeter to do the following:
  - Measure voltage to verify cable is conducting electricity
  - Check for the presence of noise
  - Test for short or open circuits in the wire:
    - Short circuit is an unwanted connection
    - Open circuit is one where needed connections are missing

Multimeter (2 of 2)

Figure 5-45 A multimeter

Cable Continuity Tester (1 of 3)

- Cable continuity testers (cable testers)
  - Tests whether cable carries signal to destination
- Copper-based cable tester
  - Consists of two parts:
    - Base unit generates voltage
    - Remote unit detects voltage
- Series of lights, audible tone
  - Used to signal pass/fail

Cable Continuity Tester (2 of 3)

- Some continuity testers verify UTP, STP wires paired correctly
  - Not shorted, exposed, crossed
- Fiber optic continuity tester:
  - Issues light pulses on fiber
  - Determines whether pulses reach other end
- Offer convenience: Portable, lightweight, and low cost

Cable Continuity Tester (3 of 3)

Figure 5-46 Use a cable tester pair to determine the type of cable and if the cable is good

Cable Performance Tester (1 of 2)

- Cable performance tester, line tester, or certifier
  - Performs similarly to continuity testers but can be used to:
    - Measure distance to a connectivity device, termination point, or cable fault
    - Measure attenuation
    - Measure NEXT (near end cross-talk)
    - Measure termination resistance and impedance
    - Issue pass/fail ratings for Cat 3–7 standards
    - Store and print results or save to a computer database
    - Graphically depict attenuation and cross-talk

Cable Performance Tester (2 of 2)

- TDR (time domain reflectometer):
  - Issue signal, measures signal bounce back
  - Indicates distance between nodes
  - Indicates whether terminators properly installed, functional
- OTDRs (optical time domain reflectometers):
  - Measure fiber length
  - Determine faulty splice locations, breaks, connectors, bends, and measure attenuation over cable
  - Measure attenuation over the cable
  - Can be expensive

OPM (Optical Power Meter) (1 of 2)

- OPM (optical power meter):
  - Also called a light meter
  - Measures the amount of light power transmitted on a fiber-optic line
  - Must be calibrated precisely, following highly accurate optical power standards
  - Surrounding room temperature, connection type, and the skill of the technician all affect the final test results

OPM (Optical Power Meter) (2 of 2)

Courtesy of Fluke Networks

Figure 5-47 (a) On the left, the DTX-1800 device by Fluke Networks is a high-end cable performance tester designed to certify structured cabling (b) The optical power meter on the right is a more budget-friendly device that measures light power transmitted on a fiber-optic line

Chapter Summary (1 of 4)

- Bandwidth is the amount of data that could theoretically be transmitted during a given period of time
- Noise can degrade or distort a signal
- Duplex signals are free to travel in both directions over a medium simultaneously
- Today's networks might use RG-59 coaxial cable for short connections
- Twisted-pair cable consists of color-coded pairs of insulated copper wires that are twisted in pairs:
  - STP cable's shielding acts as a barrier to external electromagnetic forces
  - UTP cable is both less expensive and less resistant to noise than STP
  - STP and UTP both use RJ-45 modular connectors and data jacks

Chapter Summary (2 of 4)

- A crossover cable has the transmit and receive wires reversed
- A router's console port is used with a console cable, or rollover cable
- A crimper pushes on the pins inside an RJ-45 connector so they pierce the wire's insulation
- Data is transmitted through the central fibers of fiber-optic cable via pulsing light sent from a laser or an LED source
- Laser-generated light travels over a single path in SMF cables
- MMF contains a core with a larger diameter than SMF over which many pulses of light generated by a laser or LED light source travel at different angles
- Older fiber networks might use ST or SC connectors

Chapter Summary (3 of 4)

- A media converter is hardware that enables networks or segments running on different media to interconnect and exchange signals
- Cabling problems unique to fiber include fiber type mismatch, wavelength mismatch, and dirty connectors
- Start troubleshooting a network connection problem by checking the network connection LED status indicator lights
- A tone generator issues a signal on a wire that can be detected by a tone locator
- A multimeter can measure many characteristics of an electric circuit, including its resistance, voltage, and impedance

Chapter Summary (4 of 4)

- A cable continuity tester is battery operated and has two parts: The base unit that connects to one end of the cable and generates a voltage, and the remote unit that connects to the other end of the cable and detects the voltage
- A sophisticated cable performance tester will include TDR (time domain reflector) that issues a signal on a cable and then measures the way the signal bounces back
  - Detecting the type and locations of cable defects
- An OPM (optical power meter) measures the amount of light power transmitted on a fiber-optic line