CH5 Network Cabling

Transmission Basics

- Networking media is the physical or atmospheric paths that signals follow
- What indicates network efficiency?
  - Bandwidth
    - maximum amount of data that can be transmitted during a set period of time
    - Analogy: the bandwidth of a three lane highway is the number of cars that can pass a checkpoint during heavy traffic and traveling at the speed limit
  - Throughput
    - also known as payload rate or effective data rate
    - how much data is transmitted during a set period of time
    - Analogy: throughput measures the actual traffic on a three-lane freeway that passes in one minute
  - Bit rate
    - the measurement term for bandwidth and throughput. It's bits transmitted per second. Ex: 1000 bits per second
- Side Note
  - data storage quantities are in BYTES
  - data transmission quantities (throughput) is in BITS per second
- Transmission Flaws
  - Factors that degrade network performance
    - Noise
      - degrades/distorts the signal on a network
      - measured in decibles dB
      - sources:
        - EMI: Electromagnetic interference. Caused by sources of electrical activity like fluorescent lights or microwaves. It can also be caused by radio frequency interference.
        - Crosstalk: when the signal from one wire infringes on the signal traveling over an adjacent wire
          - Types of crosstalk
            - Alien crosstalk: between two cables

        - NEXT (near end crosstalk): between wire pairs near the source of a signal
        - FEXT (far end crosstalk): measured at the far end of the cable from the signal source
    - One way to fix noise effecting the network signal is to ensure that the strength of the signal exceeds the strength of the noise.
- Attenuation
    - loss of signal strength the farther it gets from the source
    - to correct this signals are boosted en route with a repeater which regenerates the digital signal without the noise
- Latency
    - delay in data being transmitted to the destination host
    - length of cable and connectivity devices can effect latency
    - measure latency by calculating a packet's RTT (round trip time). This is how long it takes for a packet to be sent back and forth. Typically its milliseconds.
    - latency can cause packets to arrive out of order, this is called jitter
    - if there is too much latency then the node may assume there is no more data coming and will return a transmission error to the sender

- Import NIC settings that effect Network efficiency
    - full-duplex / duplex
        - signals can travel in both directions simultaneously
        - Analogy: talking on the phone because both parties can speak at the same time
    - half-duplex
        - signals can travel in both directions but only one at a time
        - Analogy: using a walkie talkie
    - simplex
        - signals travel in only direction
        - one-way or unidirectional communication
        - ex: broadcast radio or garage door openers
    - multiplexing
        - a form of transmission that allows multiple signals to travel simultaneously over one medium
        - a multiplexer (a device that can combine many signals on a channel) is required at the transmitting end of the channel. The receiving end must have a demultiplexer to separate the combined signals
        - three types of multiplexing used on copper lines

- TDM (time division multiplexing)
  - divides the channel into time slots. Each slot is reserved for a designated node regardless of whether the node has data to transmit
  - inefficient if some nodes rarely send data
- STDM (statistical time division multiplexing)
  - divides the channel into time slots and assigns the slots based on priority and need
  - uses all slots, maximizes bandwidth
- FDM (frequency division multiplexing)
  - assigns different frequencies to create multiple frequency bands so that multiple signals can transmit on the line at the same time
  - after being modulated into different frequencies the signal is then multiplexed to simultaneously travel over a single channel and demultiplexed at the end

- three types of multiplexing used with fiber-optic cable
  - WDM (wavelength division multiplexing)
    - compatible with any fiber-optic cable
    - carries multiple light signals simultaneously by dividing a light beam into different wavelengths/colors on a single fiber
    - works like a prism dividing white light into different colors
  - DWDM (dense wavelength division multiplexing / dense WDM)
    - used on high-bandwidth or long-distance WAN links
    - increases number of channels provided by normal WDM to 80-320 channels
  - CWDM (coarse wavelength division multiplexing / coarse WDM)
    - spaces frequency bands wider apart which leads to cheaper transceiver equipment
    - supports 4, 8, 16, or 18 channels per fiber

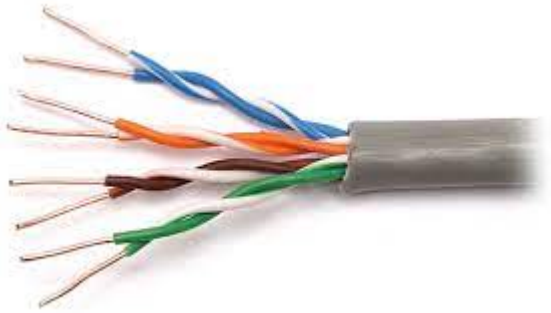
Copper Cable

- Coaxial cable:
  - foundation for Ethernet
  - replaced by twisted-paid cable and fiber
  - RG (radio guide) rating because it can be used by radio frequencies in broadband transmission

        - measures materials used for shielding and conducting cores; they influence transmission
    - cable specifications
        - RG-59: 75 ohms (impedance), 20 or 22 AWG core, braided copper
        - RG-6: 75 ohms (impedance), 18 AWG core, solid copper
    - connector types
        - F-connectors
            -

            - the pin in the center of the connector is the conducting core of the cable
            - must contain a solid metal core
            - connects to the cable by being screwed on
        - BNC connector
            -

            - crimped or twisted on to a coaxial cable
            - Bayonet Neill-Concelman
            - the male BNC connector has its own conducting pin
            - used with RG-59 coaxial cables
- Twisted-Pair Cable
    - color-coded pairs of insulated copper wires
    - copper wires are twisted in pairs and insulated with a plastic sheath
    -



- in Ethernet networks the twisted pair cable contains four pairs
  - Fast Ethernet networks have one pair send data, another pair receives data, and the other two pairs are not used for data transmission
  - Gigabit Ethernet use all four pairs for both sending and receiving data
- the higher the twist ratio (how many times the wire is twisted in a foot) is the less crosstalk there is but it does increase the risk of attenuation
- Twisted-pair cabling standards
  - Cat 3
    - 10Mbps throughput
    - 16MHz bandwidth
  - Cat 5
    - 100 Mbps throughput
    - 100MHz bandwidth
  - Cat 5e
    - enhanced category 5
    - 1000 Mbps (1Gbps) throughput
    - 350MHz bandwidth
    - high-quality copper
    - higher twist ratio
    - reduces crosstalk
  - Cat 6
    - 10Gbps throughput
    - 250MHz bandwidth
    - plastic core prevents crosstalk between twisted pairs in the cable
    - foil insulation, fire resistant plastic sheath
  - Cat 6a
    - Augmented category 6
    - 10Gbps throughput
    - 500MHz bandwidth

        - backward compatible with cat 5, 5e, and 6 so lower-level cabling can be replaced without equipment changes
        - transmits data at multigigabit per second
    - Types of Twisted-pair cabling
        - STP(shielded twisted pair)
            - pairs are individually insulated and encased in a metallic substance like foil for shielding
                - acts as a barrier against electromagnetic forces
                - contains the electrical energy of the signals inside
        - UTP(unshielded twisted pair)
            - one or more insulated wire pairs encased in a plastic sheath
            - no shielding
            - less expensive, more susceptible to noise
- Straight-through cable
    - patch cable
    - allows signals to pass from one end to the other
    - most common type of networking cable
    - make one by terminating the RJ-45 plugs at both ends of the cable identically
    - used to connect two unlike devices
        - ex: a switch transmitting on the wire a router received on
    - in the past if two like devices use this they cannot communicate because both devices will transmit on the same wire and receive on the same wire
    - modern devices have an autosense function that can detect the way the wires are terminated in a plug and will adapt the transmit and receive signaling accordingly
- Crossover cable
    - for like devices
    - the transmit and receive wires are reversed
- Rollover Cable
    - reverses all the wires without regard to how they are paired
    - the cable terminations are a mirror image of each other
- PoE
    - Power over Ethernet
    - the method for supplying electrical power over twisted-pair Ethernet connections
    - power is carried over the network connections
        - useful for nodes that are located far from traditional power receptacles or that need a constant power source
        - 15.4 watts for standard PoE devices

        - 25.5 watts for PoE+ devices
    - devices used
        - PSE(power sourcing equipment)
            - device that supplies power
        - PDs(powered devices)
            - receive power from the PSE
    - requires Cat 5 or better cable
- ★Ethernet standards for Twisted-pair cable
    - a cable's category determines the fastest network speed it can support
    - Physical Layer characteristic
        - a function of this layer is to provide signaling between two nodes as they negotiate a common language to communicate with
    - 100Base-T
        - Fast Ethernet
        - 100Mbps max transmission speed
        - 100m max distance per segment
        - Cat 5 or better needed
        - 2 pairs of wires used for transmission
    - 1000Base-T
        - Gigabit Ethernet
        - 1000Mbps max transmission speed
        - 100m max distance per segment
        - Cat 5 or better, Cat 5e preferred
        - 4 pairs of wires used for transmission
    - 10GBase-T
        - 10,000Mbps max transmission speed
        - 100m max distance per segment
        - Cat 6a or Cat 7, Cat 7 preferred
        - 4 pairs of wires used for transmission

Fiber-Optic Cable

- Sometimes called fiber
- has one or several glass or plastic fibers at the core
- data is transmitted through central fibers by a pulsing light that is sent from of these:
    - laser: high data throughput

    - LED(light emitting diode): cool burning, used for shorter fiber-optic connections
- cladding is the layer of glass/plastic that covers the fibers
    - less dense than the inner core so it reflects light back to the core in patterns that vary depending on the transmission mode
- light reflection allows bending in the cable
- each strand of glass in transmits in one direction only (simplex) so two strands are needed for full-duplex communication
- fiber-optic is the most expensive transmission medium
- benefits of fiber-optic cable over copper
    - high throughput
        - 100 gigabits
    - high resistance to noise
    - strong security
    - less attenuation
    - segment lengths can be up to 40,000 meters
        - the length is limited due to the degradation of the light signal after a certain distance -- optical loss
- SMF (Single Mode Fiber)
    - accommodates the highest bandwidths and longest distances of all transmission media due to the laser-generated light reflecting very little on the core as it travels
    - high cost makes it so it's almost always used for long connections
    - the Internet backbone uses this fiber
    - Connectors
        - are classified by the size and shape of the ferrule (tip of a connector that makes contact in the jack or other connector)
        - reduces back reflection, when the light signal turns back into the fiber that is transmitting the signal
            - measured as optical loss in dB (decibels)
            - used on SMF ferrules to reduce back reflection:
                - UPC (Ultra Polished Connector): a rounded surface on the tips allows the internal fibers to meet. Adapters are blue.
                - APC(Angle Polished Connector): the same rounded surface as UPC but the ends are at an angle to each other by 8 degrees. Adapters are green.
                -

Table 5-5 Characteristics of fiber connectors

Photo	Connector	Polish	Ferrule characteristics	Full-duplex?
	LC	UPC, APC	1.25 mm	Yes
	ST	UPC	2.5 mm	No
	SC	UPC, APC	2.5 mm	Can be
	MTRJ	N/A	2 fibers	Yes

- MMF(multimode fiber)
  - larger than SMF
  - pulses of light travel at different angles
  - greater attenuation than SMF
  - less expensive than SMF, used for shorter connections
  - Connectors are classified by the number of fibers
- FDP (fiber distribution panel)
  - where the transition between SMF and MMF cabling occurs

Tools needed to terminate fiber-optic cable

1. Fiber stripper to strip off the outer layers of the cable
2. fiber cleaver to cut a clean slice through the fiber strands

Media Converter

- hardware that allows networks/segments using different media to connect and exchange signals

Fiber Transceivers

- a modular interface that is plugged into a switch socket to connect with the motherboard
- hardware that can be changed out without disrupting operations is called hot-swappable

Types of transceivers

- GBIC (gigabit interface converter)
- has RJ-45 ports for copper cables or SC ports for fiber-optic connections
- SFP(small form-factor pluggable)
- same function as GBIC
- more compact, more ports per linear inch

- used for 1Gbps connections
- XFP(10 Gigabit small form-factor pluggable)
- supports up to 10Gbps
- larger than SFP
- lower power consumption than SFP+
- SFP+
- max transmission is 16Gbps
- same module size as SFP
- QSFP(quad small form-factor pluggable)
- max transmission 40Gbps
- four channels in a single transceiver
- QSFP+
- same tech as QSFP
- transmission rate of 112Gbps
- CFP(centum form-factor pluggable)
- 100Gbps connections
- BiDi Transceiver
- fiber cable carries data in both directions

Ethernet Standards for Fiber-Optic cable**

- 1000Base-LX
  - more common
  - uses long wavelengths 1300nanometers
  - used for long backbones connecting buildings in a MAN or connecting ISP with its telecommunications carrier
- 1000Base-SX
  - less expensive than LX
  - shorter wavelengths at 850 nanometers
  - segment length depends on the diameter of the fiber and the measure of the highest frequency of signal a multimode fiber can support over a specific distance (Modal Bandwidth)
  - better for shorter networks

Common Fiber Cable Problems

- fiber types not being paired correctly. They have different sized diameters and it will effect transmission
- SMF, MMF, and POF have different wavelengths and if a transmission is sent on the wrong cable type it won't be using the correct wavelength
- if connectors get dirty even slightly they won't be able to transmit. Fiber jacks must be covered when not in use.

Troubleshooting Tools

- Testing a cable connectivity and network port
  - a loopback adapter attaches to a port/cable connector and crosses the transmit line with the receive line to create a closed loop. The host believes it's connected to a network and hears its own data transmission.
- TX/RX reverse
  - when the TX (transmission) and RX(receive) wires are crossed and case NEXT (near end crosstalk)
- Toner and probe kit
  - Tone generator (toner): electronic device that issues a signal on a wire
  - Tone locator (probe): a device that emits a tone when it senses electrical activity on a wire
  - Place the tone generator at one of the wire using a connector. Then swipe the prove over each of the terminations and once you hear the tone you will know the location of the wire's termination
  - Never use on a wire that's connected to a device's port or network adapter. The toner transmits electricity over the wire and can damage the device or network adapter
- Multimeter
  - measures electric circuit: resistance, voltage, impedance
  - Used for:
    - verify if a cable is conducting electricity by measuring the voltage
    - check for noise on a wire
    - test for short/open circuits on a wire
      - short circuit is unwanted connection
      - Open circuit is missing a connection like a broken wire
- Cable Continuity Tester
  - checking if a cable is carrying a signal to its destination
  - can verify if wires in a UTP or STP cable are paired correctly
  - a tester for a fiber-optic cable can issue light pulses on the fiber to determine if they are reaching the end of the fiber
- Cable Performance Tester
  - line tester, certifier, network tester
  - tests continuity and faults
  - measures the distance to a connectivity device, termination point, or damage in the cable
  - measures attenuation

- measures NEXT (near end crosstalk) and alien cross talk
- measures termination resistance and impedance
- issues pass/fail ratings for Cat 3, 5, 5e, 6, 6a, and 7 standards
- stores and prints results
- a TDR(time domain reflectometer) can issue a signal on a cable and then measure the way the signal comes back to the TDR. This can detect bad connectors, crimps, bends, short circuits, cable mismatches, bad wiring, or other defects
- a OTDRs (optical time domain reflectometers) transmits light-based signals of different wavelengths over the fiber. This allows it to measure the length of the fiber, find the location of splices, breaks, bends, and mismatched connectors, and measures the attenuation over the cable

OPM(Optical Power Meter)

- a light meter
- measures the amount of light power transmitted on a fiber-optic line