Network Infrastructure Concepts

CompTIA

Network Infrastructure Concepts

- Wired Networks
- Network Hardware Devices
- Wireless Networks
- Internet Connection Types
- Network Configuration Concepts
- Network Services

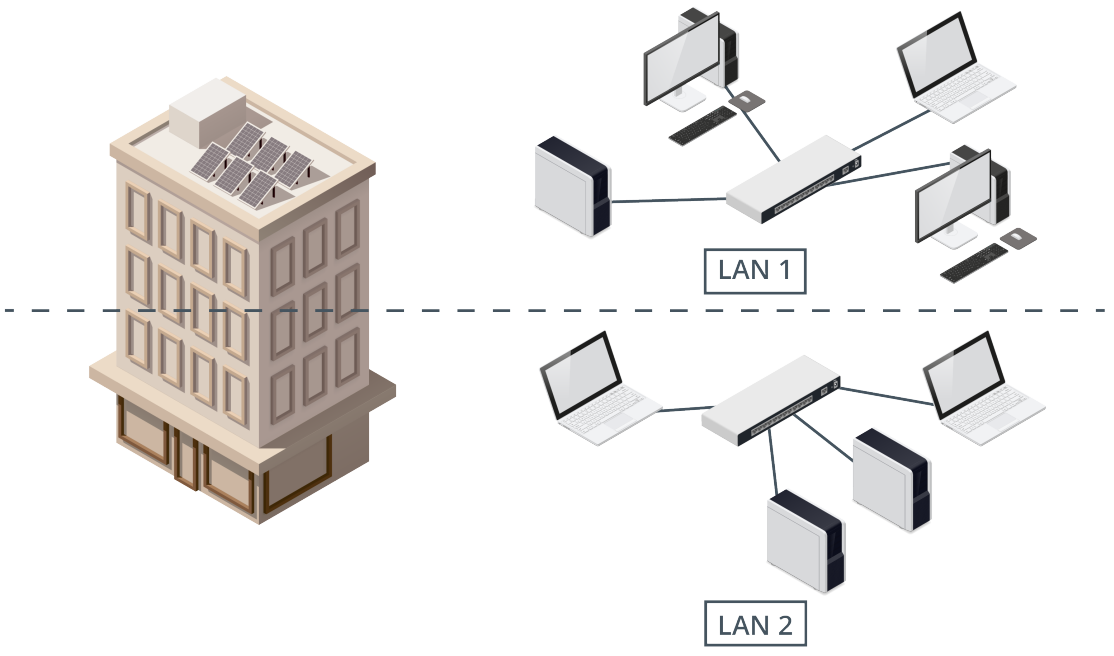
Network Types (Slide 1 of 4)

Network: In its most simple form, a network consists of two or more computers connected to each other by an appropriate transmission medium which allows them to share data.

- Purpose: provide services and resources to users
- Historically: files, folders, printers, email, databases
- Modern: web applications, social networking, VoIP, multimedia conferencing
- Types: LANs, WANs, MANs

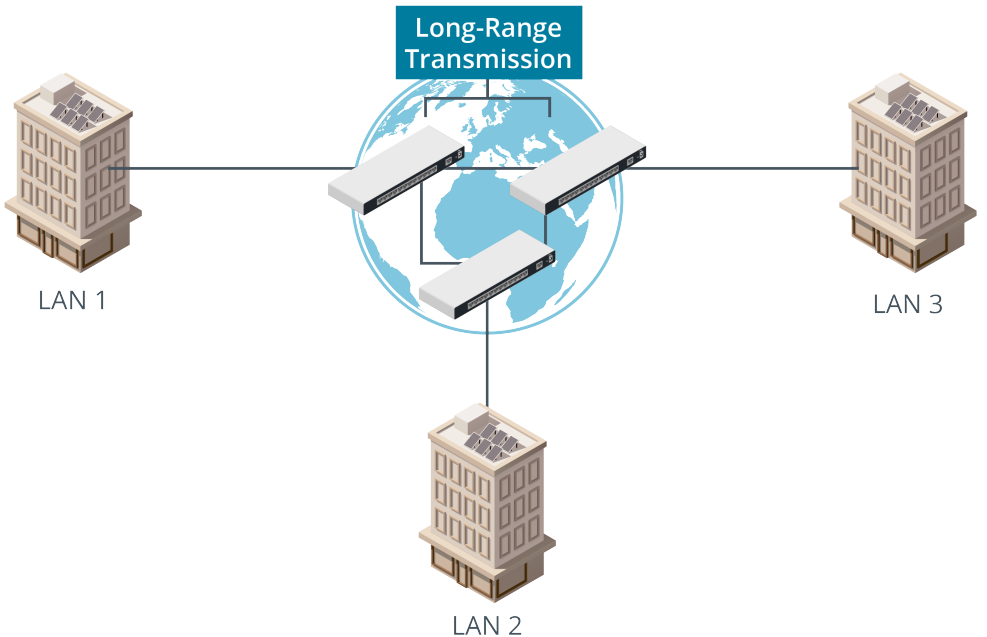
Network Types (Slide 2 of 4)

- LANs within a building



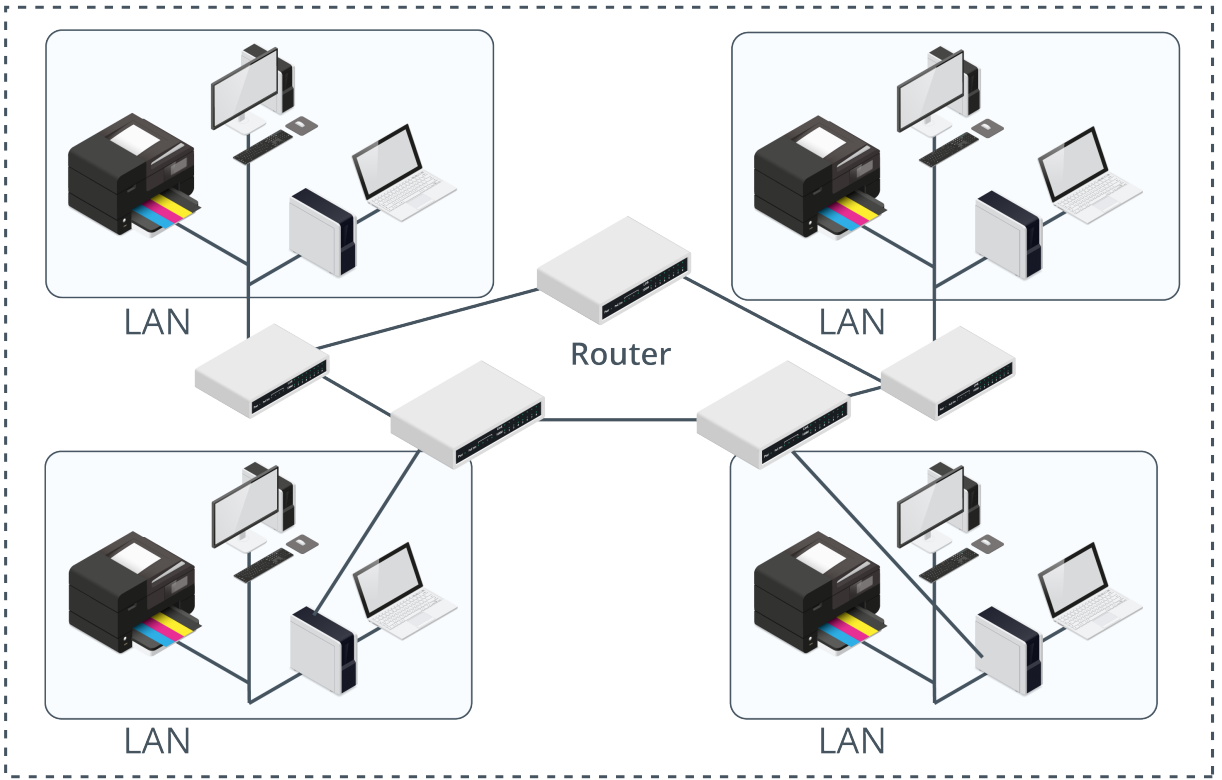
Network Types (Slide 3 of 4)

- A Wide Area Network (WAN)



Network Types (Slide 4 of 4)

- A Metropolitan Area Network (MAN)

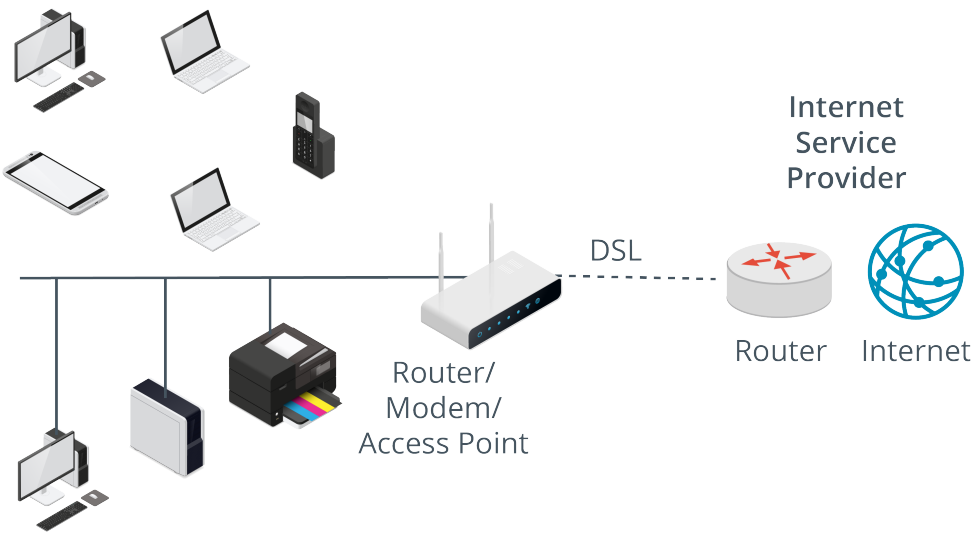


Ethernet Types and Standards

- Most cabled LANs build on Ethernet
  - Developed by DIX (Dec-Intel-Xerox) consortium
  - Maintained by IEEE (Electrical and Electronics Engineers) (called 802.3 standards)
- Types:
  - 10 Mbps (10BASE)
  - Fast Ethernet (100BASE)
  - Gigabit Ethernet (1000BASE)
  - 10G Ethernet (10GBASE)
- IEEE 802.11 standards (Wi-Fi) for WLANs are complementary to LAN standard
- Flexible, self-contained, scalable

Common Ethernet Network Implementations (Slide 1 of 3)

- SOHO: business network with server and clients, using single Internet appliance as access point, Ethernet switch, Internet modem, Internet router.

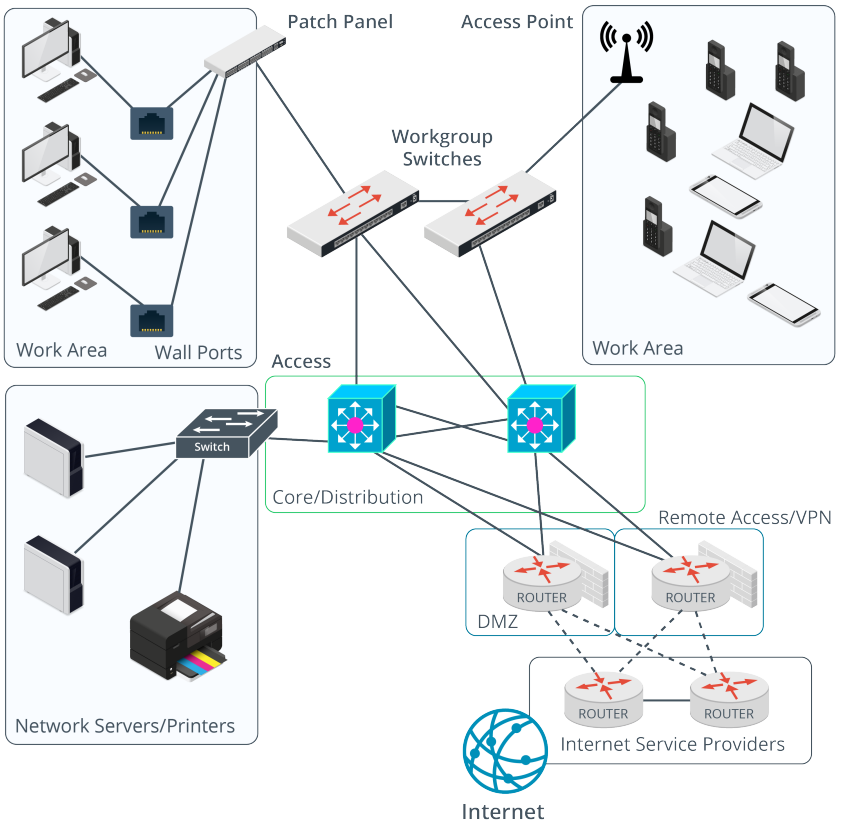


Common Ethernet Network Implementations (Slide 2 of 3)

- Enterprise network: usually dedicated single-function connectivity appliances.
  - Small and Medium (SME): tens of users; multiple switches, access points, routers.
  - Enterprise LAN: hundreds or thousands of servers and clients; multiple enterprise-class switches, access points, and routers.
  - Campus Area Network (CAN) = LAN spanning multiple nearby buildings.

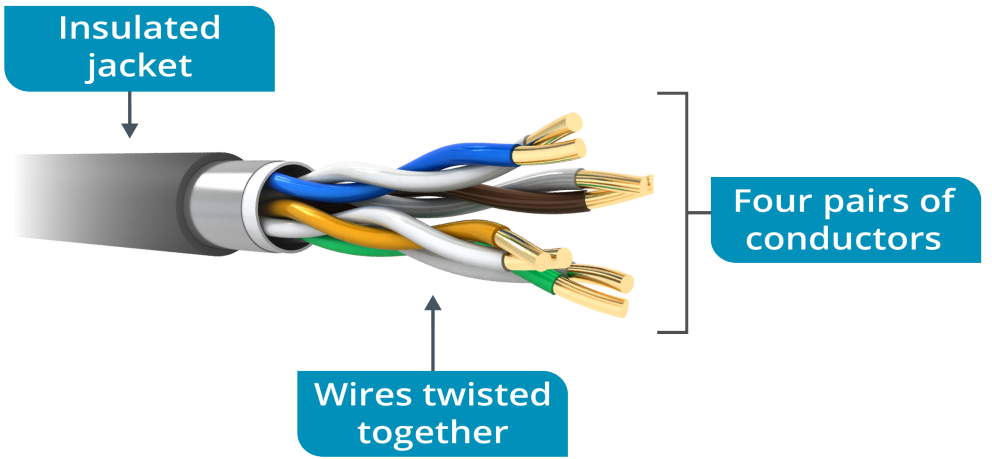
Common Ethernet Network Implementations (Slide 3 of 3)

- Positioning network components in an enterprise LAN



Twisted Pair Cabling and Connectors (Slide 1 of 4)

- Unshielded Twisted Pair (UTP)
  - Most widely used
  - Four copper conductor pairs
  - Insulating sheath
  - Twisted to reduce crosstalk and EMI
  - Paired wires carry equal/opposite signals
  - PVC jacket
  - Works well in low interference; has limited range, may exhibit attenuation (loss of force)



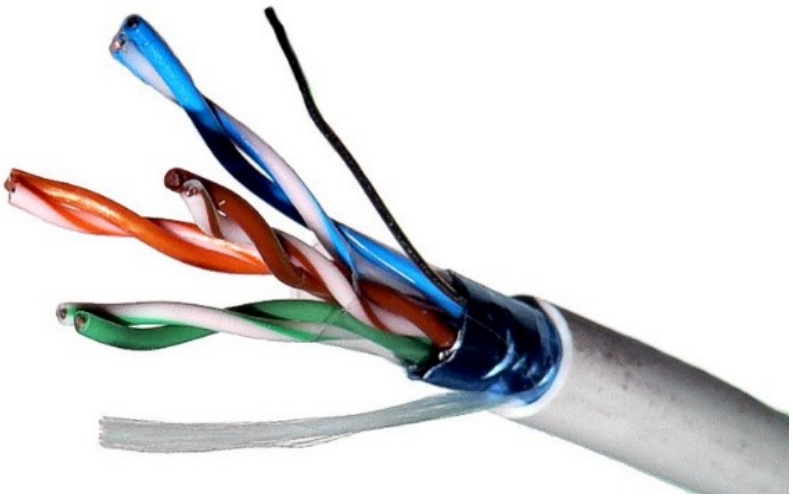
Twisted Pair Cabling and Connectors (Slide 2 of 4)

- Cat standards:

Cat	Frequency	Capacity	Max. Distance	Network Applications
5	100 MHz	100 Mpbs	100 m (328 ft)	100BASE-TX
5e (min standard)	100 MHz	1 Gbps	100 m (328 ft)	1000BASE-T
6	250 MHz	1 Gpbs	100 m (328 ft)	1000BASE-T
6	250 MHz	10 Gbps	50 m (180 ft)	10GBASE-T
6A	500 MHz	10 Gbps	100 m (328 ft)	10GBASE-T

Twisted Pair Cabling and Connectors (Slide 3 of 4)

- Shielded Twisted Pair (STP)
  - Originally used braided shield to reduce interference and crosstalk; can be bulky, difficult to install.
  - Modern STP uses screened cables; shield positioned around all pairs.
  - Shielded Cat 53/6/6A:
    - F/UTP (also ScTP) – all foil wrapped
    - U/FTP – individual foil wrapped
      - Reduce crosstalk interference
  - Modern STP solutions incorporate grounding in each element.



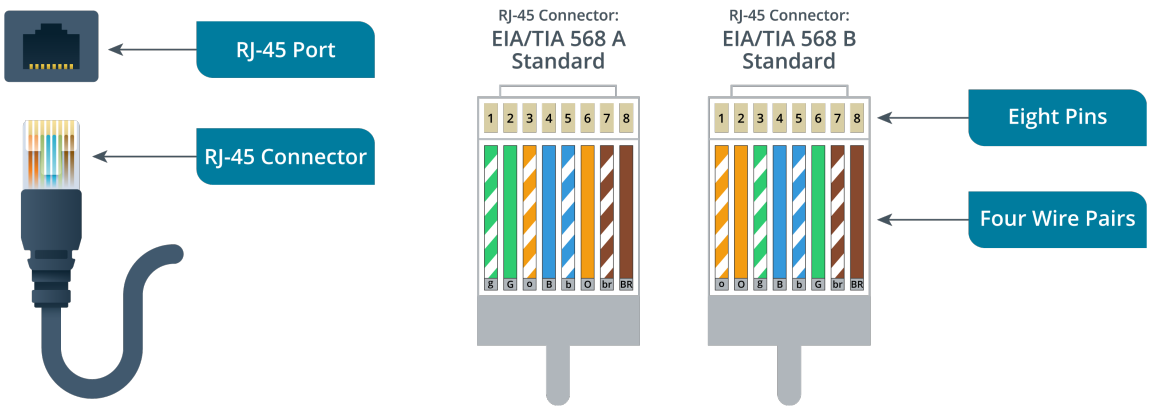
Twisted Pair Cabling and Connectors (Slide 4 of 4)

Plenum: An air handling space, including ducts and other parts of the HVAC system in a building.

- Plenum space:
  - Typically a false ceiling, may be raised floor.
  - May be used for communications wiring.
  - Can be conduit for fire.
- General purpose non-plenum cable uses PVC; marked CMG/MMG or CM/MP
- Plenum cable:
  - Must not emit smoke, must self-extinguish, meet other fire safety standards.
  - Uses treated PVC or FEP; can be less flexible, does not affect bandwidth.
  - Marked CMP/MMP.

Wiring Standards for Twisted Pair (Slide 1 of 2)

- Ethernet twisted pair terminated with RJ-45 connectors:
  - 8P8C (8-position/8-contact)
  - Color-coded (Blue, Orange, Green, Brown)
  - 1st conductor in pair has white/stripes
  - 2nd conductor in pair is solid color
- ANSI/TIA/EIA 568 termination standard for RJ-45:
  - T568A is shown
  - T568B:
    - Pin 1=Orange/White; Pin 2=Orange; Pin 3=Green/White; Pin 4=Green



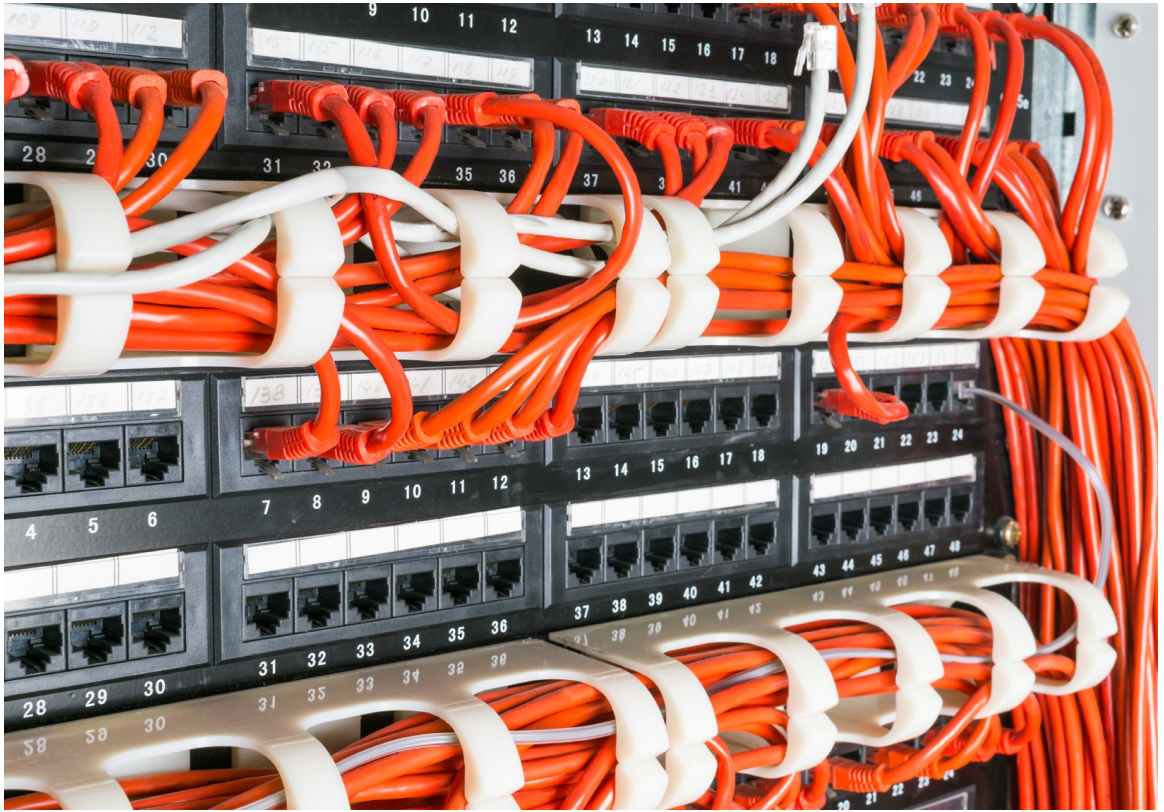
Wiring Standards for Twisted Pair (Slide 2 of 2)

- Normal (straight-through) cable has same termination at both ends.
- Crossover cable has T568A at one end, T568B at other.
  - Previously used for direct connections.
  - Now Gigabit Ethernet interfaces can automatically cross over with standard cable.
- Avoid mixing standards:
  - Both are common.
  - T568A mandated for US government and by TIA 570 residential cabling standard.

Patch Panels and Structured Cabling (Slide 1 of 2)

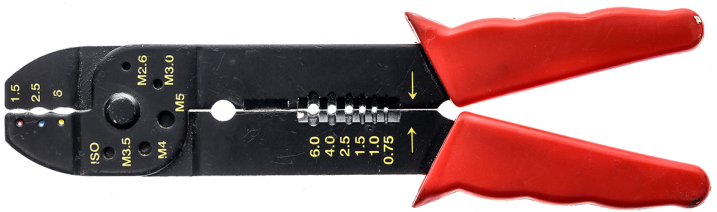
- Gigabit Ethernet: no more than 100 m of cable between switch and computer
- Solid cabling:
  - Single thick wire for permanent links to a patch panel, aka “drop cables”
  - Links RJ-45 port on wall plate with patch panel
  - Terminates in Insulation Displacement Connectors (IDC)
- Patch cord connects RJ-45 port on panel to port on switch
  - Stranded cable (thin wires; flexible, less efficient)
  - 5 m maximum length
- Second patch cord from computer to wall
- The use of patch cords, solid cabling and a patch panel together is known as a Structured cabling system (common in office environments)

Patch Panels and Structured Cabling (Slide 2 of 2)



Cable Installation and Testing Tools (Slide 1 of 7)

- Wire stripper/cutter: for cutting wire and stripping insulation and cable jackets.

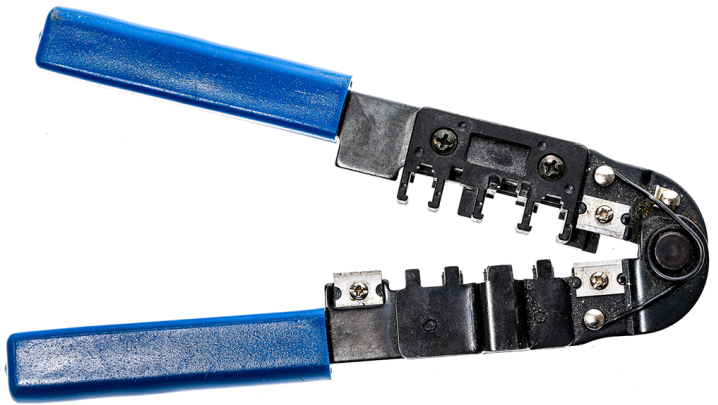


Cable Installation and Testing Tools (Slide 2 of 7)

- Punch-down tool: fixes conductors into an IDC.

Cable Installation and Testing Tools (Slide 3 of 7)

- Crimpers: fix a jack into a cable.



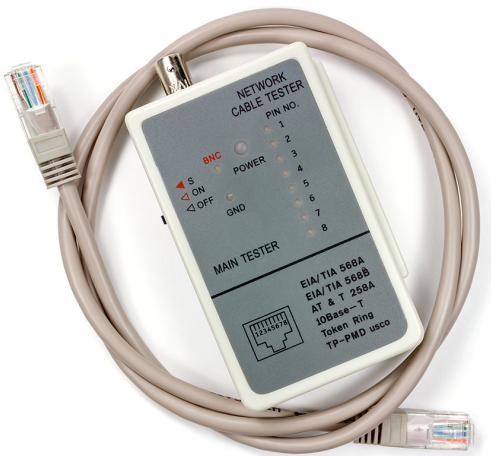
Cable Installation and Testing Tools (Slide 4 of 7)

- Cable testing:
  - Verify wiring installation and termination just after making connections, with access to cable runs.
  - Simpler than during user device setup.
  - Consider:
    - Patch cord between PC and wall.
    - Wall port and wall cabling.
    - Port on patch panel and patch cord to switch port.
  - Test with a known good cable.
  - Various troubleshooting devices.

Cable Installation and Testing Tools (Slide 5 of 7)

- Multimeter: basic cable testing tool; tests for copper wire continuity, existence of short, integrity of terminator.
- Wire map tester: identifies transpositions (wire crossovers) and reverse pairs.
- Advanced testers: show cable's physical/electrical properties.
- Certifiers: test and certify installation to a category.

Multimeter



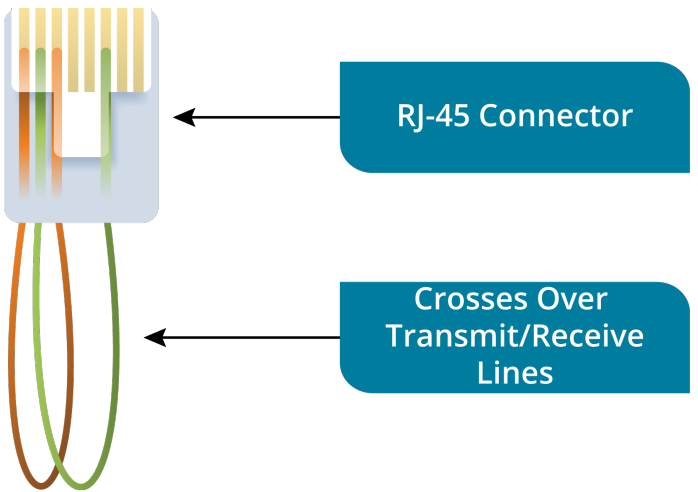
Cable tester

Cable Installation and Testing Tools (Slide 6 of 7)

- Tone generator and probe (aka “fox and hound” ; “tone and probe”): traces cable from end to end (follows signal through walls, vents. Bad labeling fix)
- Connect generator to wires, move locator over cable group until beep is loudest.

Cable Installation and Testing Tools (Slide 7 of 7)

- Loopback plug: tests a port
- Connects pin 1 to pin 3 and pin 2 to pin 6



Fiber Optic Cabling and Connectors (Slide 1 of 3)

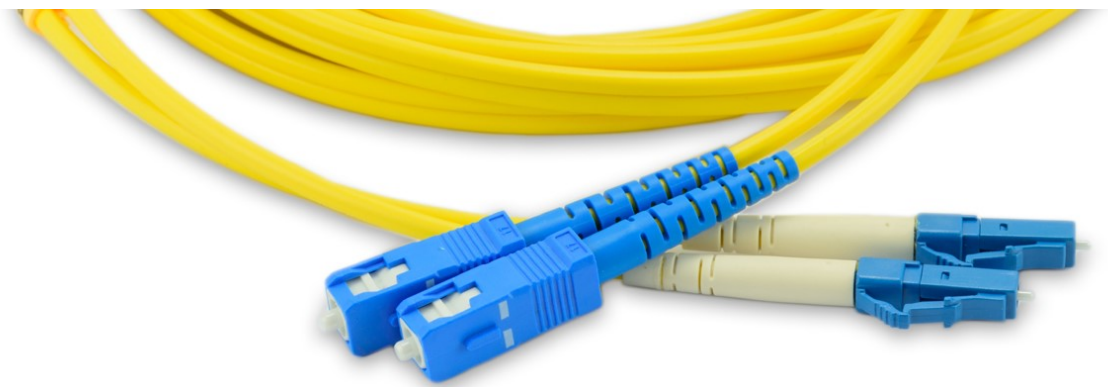
- Electrical signals on copper wire subject to interference/attenuation.
- Light signals on fiber optic cable resist interference, eavesdropping, attenuation.
- Supports higher bandwidth, longer cable runs.

Fiber Optic Cabling and Connectors (Slide 2 of 3)

- Single-Mode Fiber (SMF)
  - Small core, long wavelength, near-infrared signal generated by laser.
  - Data rates up to 10 Gbps or more; cable runs of many kilometers (suitable for WANs).
- Multi-Mode Fiber (MMF)
  - Larger core, shorter wavelength.
  - Less expensive optics, less expensive deployment.
  - Lower signaling speeds, shorter distances (suitable for LANs).

Fiber Optic Cabling and Connectors (Slide 3 of 3)

- Connector types:
  - Straight Tip (ST), Subscriber Connector (SC), Lucent/Local Connector (LC).
  - Patch cords can have same or mixed connectors.
  - Connectors damage easily; plug/unplug only when needed.



Coaxial Cabling and Connectors (Slide 1 of 4)

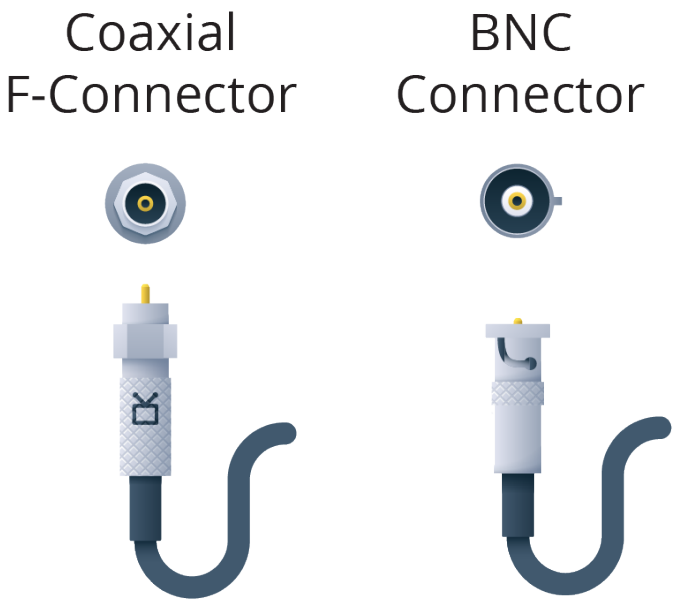
- Two conductors share the same axis to reduce interference.
- Signal conductor insulated; second wire mesh conductor acts as EMI shield and as ground.

Coaxial Cabling and Connectors (Slide 2 of 4)

- Radio Grade (RG) “standard”; developed by US military, categorizes cable by thickness and impedance (opposition to current flow).
  - RG-6: thicker core, better quality, often used as drop/patch cable in modern CATV and broadband.
  - RG-59: thinner core; drop cable for older CATV/cable modems; used in CCTV.
- Coax also available with tri- or quad-shielding.

Coaxial Cabling and Connectors (Slide 3 of 4)

- BNC connectors at cable ends in most cases.
- BNC couplers can connect cables .
- Impedance of connector must match cable type (50 or 75 ohm).
- Also screw-down F-connectors.



Coaxial Cabling and Connectors (Slide 4 of 4)

- 10BASE-5/Thicknet and 10BASE-2/Thinnet supported 10 Mbps, up to 500 m and 185 m, respectively.
- Coax now obsolete for LANs; in use for CCTV and drop cables for CATV and Internet.
- Hybrid Fiber Coax (HFC): Coax links fiber trunk in street to customer cable modem.
- Less attenuation that TP but bulkier, harder to install.

Activity

Discussing Wired Networks

30bird 12.1.1

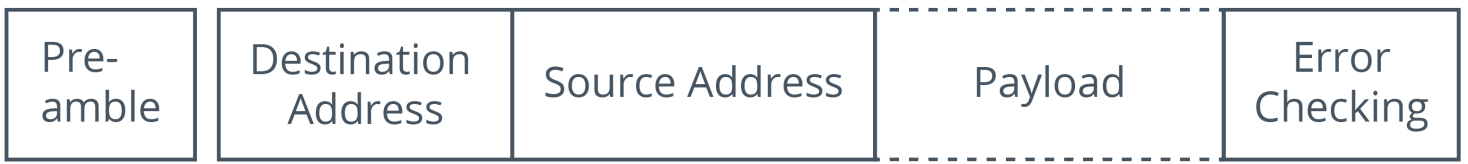
Network Interface Cards (Slide 1 of 2)

- Network Interface Card (NIC) port provides connection to network media.
- Data signals must come in regular units with consistent format.
- Each node must be able to address other nodes.
- Ethernet data link protocol provides addressing, framing functions.
- Several encoding mechanisms; NIC transceiver transmits and sends in agreed frame format.

Network Interface Cards (Slide 2 of 2)

- Construction of a frame:

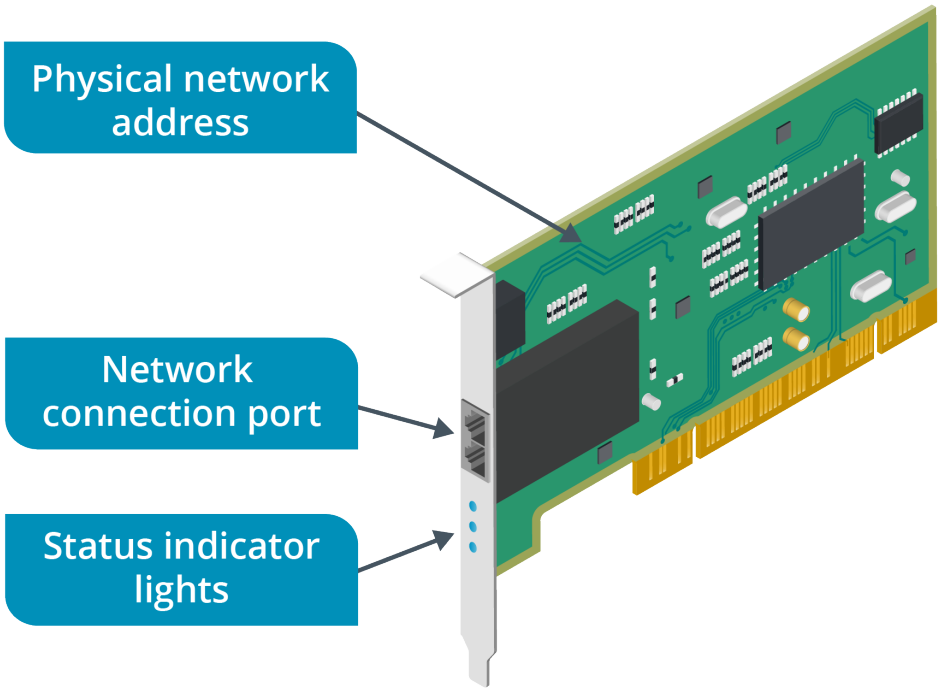
- “expect new frame soon” checksum value to compare
- V V



Ethernet NIC Features (Slide 1 of 4)

- Usually on board the motherboard.
- May be PCIe expansion board.
- All onboard cards support copper-based Ethernet with RJ-45 ports.
- Expansion cards may support:
  - Fiber optic.
  - Multiple port types.
  - Multiple ports of same type (can be bonded for higher-speed link).

Ethernet NIC Features (Slide 2 of 4)



Ethernet NIC Features (Slide 3 of 4)

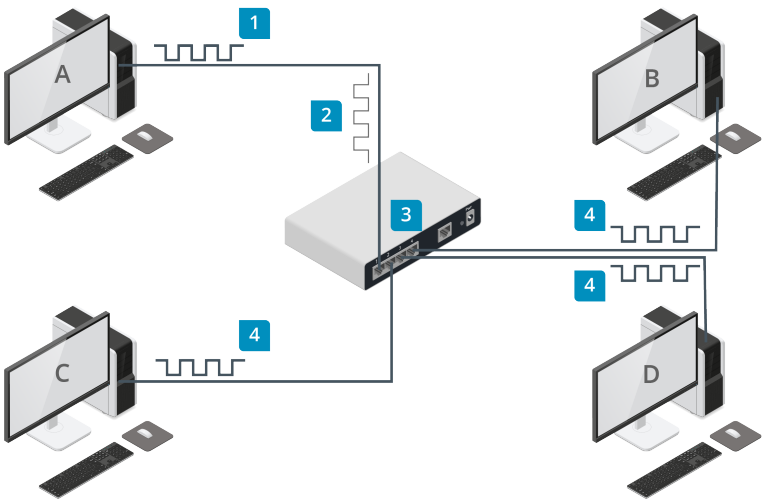
- MAC address: unique address for each Ethernet adapter port.
- Provides value for frame source and destination fields.
- 48 bits/6 bytes.
- Shown as 12 hex digits:
  - May have colon, hyphen, or no separator.
  - Examples: 00:60:8c:12:3a:bc or 00608c123abc.

Ethernet NIC Features (Slide 4 of 4)

- LED status lights show connection status (right above RJ-45 port):
  - Link light shows if network signal present.
  - Activity light flickers when packets received/sent.
  - Speed light possible on multi-speed adapters.
  - Dual-color LEDs combine functions.

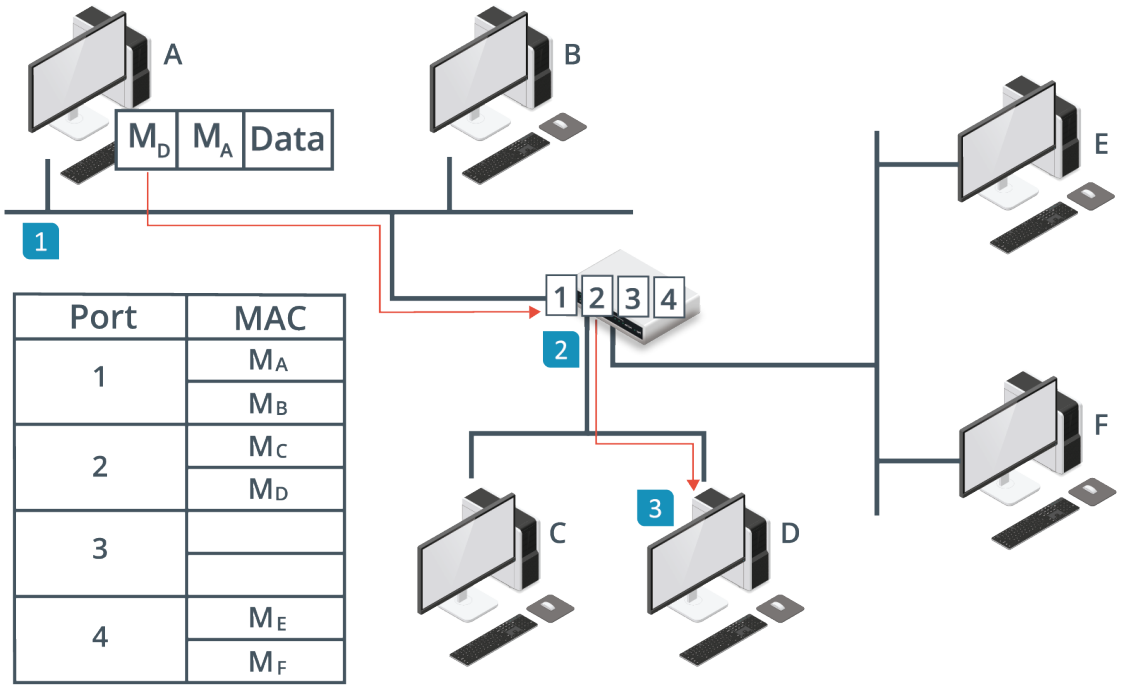
Legacy Networking Devices (Slide 1 of 2)

- Switch is appliance at core of modern networks.
- Legacy appliances include:
  - Hub: center of Ethernet star topology, works as multiport repeater for signals.
  - Repeater: retransmits signal to overcome distance limitations.
  - Bridge: divides network into segments (collision domains) to reduce contention and collision.



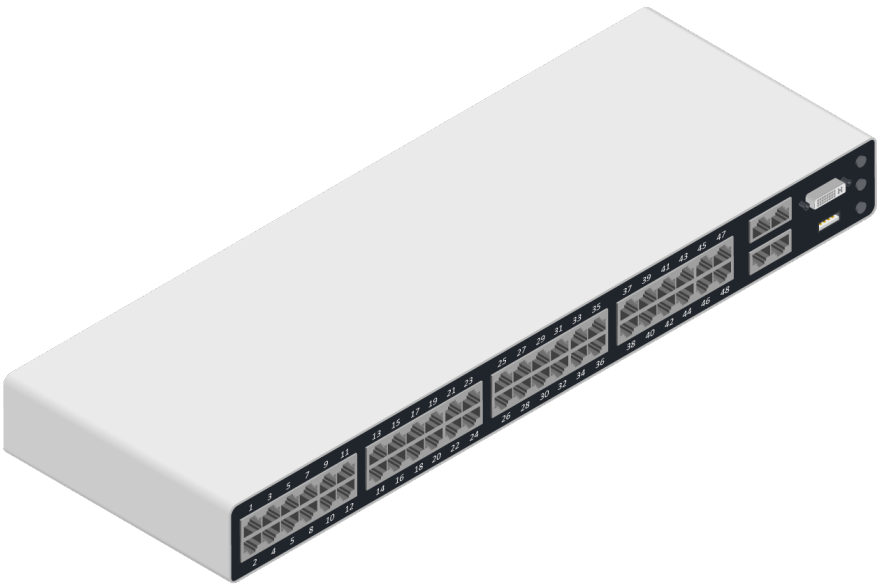
Legacy Networking Devices (Slide 2 of 2)

- Bridge operation:
- To D, from A



Switches (Slide 1 of 3)

- Ethernet switch in modern network acts like hub, repeater, and bridge.

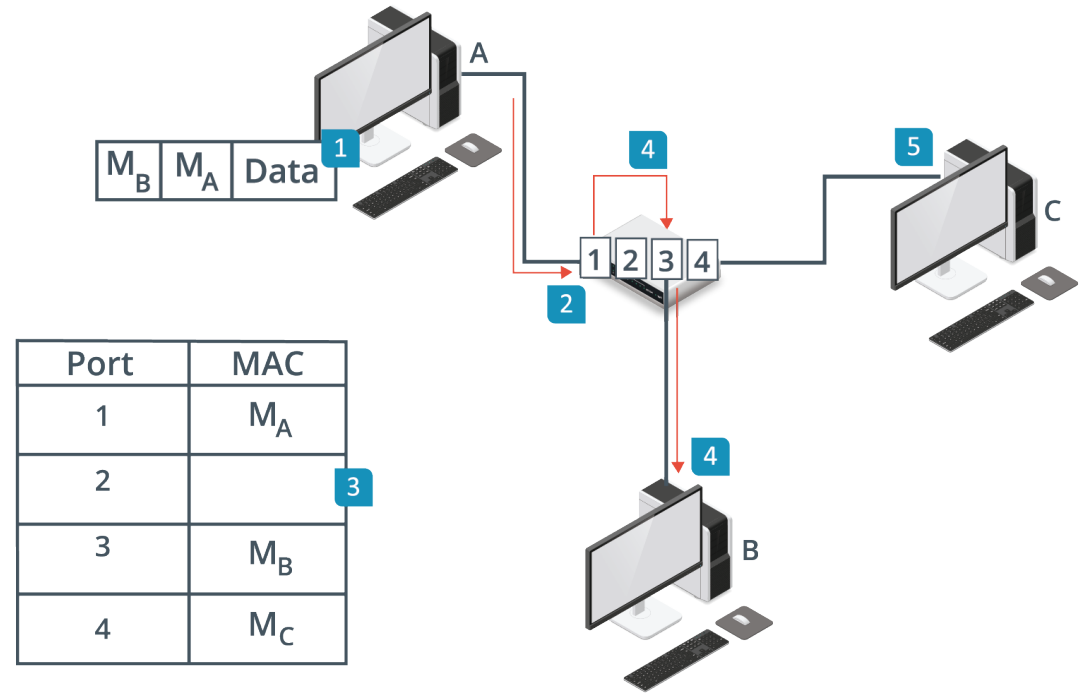


Switches (Slide 2 of 3)

- Microsegmentation:
  - Switches have up to 48 ports.
  - Multiple switches can connect into switched fabric with thousands of ports.
  - Each port is separate collision domain.
  - Establishes point-to-point link (virtual circuit) between any two nodes.
  - Collisions only occur if port is half-duplex (attached to a legacy card or node).
  - Collisions only affect that segment, not the whole network.

Switches (Slide 3 of 3)

- Switch operation:



Port	MAC
1	M_A
2	
3	M_B
4	M_C

Managed and Unmanaged Switches (Slide 1 of 3)

- Unmanaged switch:
  - Performs microsegmentation without configuration.
  - May be found in small networks (4 or 8 port switches).
  - Embedded in most ISP's Internet routers/modems.
- Managed switch (either web interface or command line):
  - For larger workgroups and corporate networks.
  - Unmanaged out of the box, but can be configured administratively.
  - Can provide thousands of access ports by linking switches.
  - Can divide into virtual LANs (VLANs).

Managed and Unmanaged Switches (Slide 2 of 3)

- Cisco Catalyst 9400 Series modular chassis

Managed and Unmanaged Switches (Slide 3 of 3)

- Interface configuration on a Cisco switch

```
FastEthernet1/0/1 is up, line protocol is up (connected)
  Hardware is Fast Ethernet, address is f41f.c253.7103 (bia f41f.c253.7103)
  MTU 1500 bytes, BW 100000 Kbit/sec, DLY 100 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Full-duplex, 100Mb/s, media type is 10/100BaseTX
  input flow-control is off, output flow-control is unsupported
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input 00:00:51, output 00:00:00, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     18 packets input, 1758 bytes, 0 no buffer
     Received 4 broadcasts (2 multicasts)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 watchdog, 2 multicast, 0 pause input
     0 input packets with dribble condition detected
     111 packets output, 13828 bytes, 0 underruns
     0 output errors, 0 collisions, 1 interface resets
     0 unknown protocol drops
```

Power Over Ethernet (PoE)

- Supplies power from a switch port over Cat 5 or better to a powered device.
- Two IEEE standards (both now in 802.3-2012):
  - 802.3af
  - 802.3at (PoE+)
- PoE-enabled switches called end-span/end-point PSE.
- Power injector can be used if switch does not support PoE.
- Switch detects if connected device is PoE-enabled.
- More efficient than powering each device through a wall socket.
- Network-management software can control devices, apply power schemes.

Ethernet Over Power (Slide 1 of 2)

- SOHO networks are unstructured, use a single router, incorporate smart appliances.
- Wireless is obvious solution; WLAN bandwidth may be adequate.
- There may be interference issues or appliances may not support Wi-Fi.
- Ethernet over Powerline uses building power circuits; overlays carrier signal to transfer Ethernet frames.
- Adapter plugs into electrical outlet; provides RJ-45 ports.
- No configuration needed, but security can be configured.
- Standards defined by IEEE 1901, managed by HomePlug Powerline Alliance.

Ethernet Over Power (Slide 2 of 2)

- Netgear Powerline AV200 adapters

Activity

Discussing Network Hardware Devices

Hub vs Switch vs Router:

https://www.youtube.com/watch?v=1z0ULvg_pW8

What is Wireless Networking?

- A range of connectivity products and devices.
- Personal area networking to Internet connectivity.
- Usually uses radio waves for transmission, tuned to specific frequency.

Wireless Frequencies and Channels (Slide 1 of 4)

- RF ranges from 3 KHz to 300 GHz
- Subdivided into bands (FM radio and TV are VHF band)
- Radio spectrum use regulated by governments
- Standardized by ITU (International Telecom Union)
- Frequency use requires a license
- Some unregulated frequencies

Wireless Frequencies and Channels (Slide 2 of 4)

- IEEE 802.11 standards = Wi-Fi
  - (Transfer rates for optimal installation; frequencies lack penetration; may be interference; data rate may drop with distance.)

Standard	Maximum Transfer Rate	Band
802.11a (1999)	54 Mbps	5 GHz
802.11b (1999)	11 Mbps	2.4 GHz
802.11g (2003)	54 Mbps	2.4 GHz
802.11n (2009)	288.8 Mbps/stream (Single Channel) 600 Mbps/stream (Bonded Channels)	2.4/5 GHz
802.11ac (2013)	1.7 Gbps (at time of writing)	5 GHz

Wireless Frequencies and Channels (Slide 3 of 4)

- Two most common frequency bands in 802.11:
  - 2.4 GHz:
    - Longer wavelength, longer range, propagates better through solids
    - Does not support many individual channels; is often congested
    - Increased risk of interference
    - Achievable data rates less than 5 GHz
  - 5 GHz:
    - Less effective at solid surface penetration
    - Lower range than 2.4 GHz
    - More individual channels; less congestion
    - Higher data rates

Wireless Frequencies and Channels (Slide 4 of 4)

- Range:
  - 2.4 GHz: maximum indoor range ~30-45 m (100–150 ft).
  - 5 GHz: maximum indoor range up to ~30 m.
  - Absolute range less important than number of clients to support and wall/ceiling construction.
- Channels:
  - 2.4 GHz: up to 14 channels, considerable overlap, co-channel interference.
    - Special codes distinguish pattern of each node.
    - Channel can become saturated.
  - 5 GHz: 23 non-overlapping channels:
    - More WANs in same area or access points closer together, higher client device density.

Wireless Network Standards (Slide 1 of 2)

- 802.11a/b/g considered legacy standards, limited to old equipment
  - 802.11b/g were more successful
  - Both worked at 2.4 GHz; 802.11b WLANs upgraded to 802.11G
  - 802.11a works at 5 GHz; incompatible

Wireless Network Standards (Slide 2 of 2)

Standard	Description
802.11n	• More bandwidth than legacy standards. • Multiplexes 2-4 antennas using MIMO. • AxB:C notation (transmit antennas, receive antennas, simultaneous streams). • Can use 2.4 GHz or 5 GHz band (preferred). • Can use channel bonding in 5 GHz band to deliver more bandwidth. • Nominal data rates 288.8 Mbps (single channel) and 600 Mbps (bonded channels).
802.11ac	• Continues development of 802.11n. • Works in 5 GHz range. • Can use 2.4GHz range for legacy standards in mixed mode. • Aims for throughput comparable to Gigabit Ethernet. • Supports channel bonding to 80 or 160 MHz channels; 8 special streams vs. 4; denser modulation. • Needs high-end equipment for sufficient antennas for 8 streams. • Theoretical data rate with 8 streams and 160 MHz channel bonding ~6.93 Gbps.

Access Points and Wireless Network Modes (Slide 1 of 3)

- Most Wi-Fi networks are Infrastructure mode
- Each client connects with an Access Point (AP)
- Forms Basic Service Set (BSS)
- MAC address of AP is BSSID
- Can group BSS's = ESS
- AP is bridge between wired/wireless network (Distribution System)
- AP connects to network like a host computer

Access Points and Wireless Network Modes (Slide 2 of 3)

- Access points can forward frames in a Wireless Distribution System (WDS):
  - Extends network without a cabled backbone.
  - Bridge mode and repeater mode.
  - Can be complex; can be compatibility issues with different vendors' devices.
- Range extender is simpler residential solution; can work with powerline adapter.

Access Points and Wireless Network Modes (Slide 3 of 3)

Configuration	Description
Ad-hoc and Wi-Fi Direct	• Stations configured to make direct peer-to-peer connections. • Older standards: ad-hoc mode. • Modern approach: Wi-Fi Direct.
Wireless Mesh Network (MSN)	• Part of 802.11s standard. • Nodes (Mesh Stations) can discover each other and make peer connections to form Mesh Basic Service Set. • Mesh stations perform path discovery and forwarding. • Routing protocol such as Hybrid Wireless Mesh Protocol (HWMP).
Personal Area Network (PAN)	• Using wireless connectivity to connect to devices with a few meters. • Printers, smartphones, headsets, etc.

Wireless Network Cards

- Each Wi-Fi network station needs network adapter compatible with 802.11 standard in use on network.
- Onboard adapters; expansion boards; USB-connected adapters.
- Link-layer MAC address like Ethernet cards.

Activity

Discussing Wireless Networks

30bird 11.2.1, 11.2.2, 11.2.6