Computer Systems

Lecture : Networks

Principles of Networking

- Networks are systems that are formed by links.
- People use different types of networks every day:
  - Mail delivery system
  - Telephone system
  - Public transportation system
  - Corporate computer network
  - The Internet

- Computers can be linked by networks to share data and resources.
- A network can be as simple as two computers connected by a single cable or as complex as hundreds of computers connected to devices that control the flow of information.

Computer Networks

- A computer data network is a collection of hosts connected by networking devices such as computers, printers, scanners, smartphones, and file and print servers.
- Resources shared across networks include different types of services, storage devices, and applications.
- Network devices link together using a variety of connections:
  - Copper cabling
  - Fiber-optic cabling
  - Wireless connection
- Benefits from networking include:
  - Fewer peripherals needed
  - Increased communication capabilities
  - Avoid file duplication and corruption
  - Lower cost licensing
  - Centralised administration
  - Conservation of resources

Types of Networks

- **LAN (Local Area Network):** A group of interconnected computers under one administrative control group that governs the security and access control policies that are in force on the network.
- **WLAN (Wireless Local Area Network):** A group of wireless devices that connect to access points within a specified area. Access points are typically connected to the network using copper cabling.
- **PAN (Personal Area Network):** Network that connects devices, such as mice, keyboards, printers, smartphones, and tablets within the range of an individual person. PANs are most often connected with Bluetooth technology.

Types of Networks

- **MAN (Metropolitan Area Network):** Network that spans across a large campus or a city. Consisting of various buildings interconnected through wireless or fiber optic backbones.
- **WAN (Wide Area Network):** Connections of multiple smaller networks such as LANs that are in geographically separated locations. The most common example of a WAN is the Internet.

Types of Networks

- **Peer-to-peer networks**: Devices which are connected directly to each other without any additional networking devices between them and no centralised network administration. Each device has equivalent capabilities and responsibilities.
- **Client/server networks**: In a client/server model, the client requests information or services from the server. The server provides the requested information or service to the client.

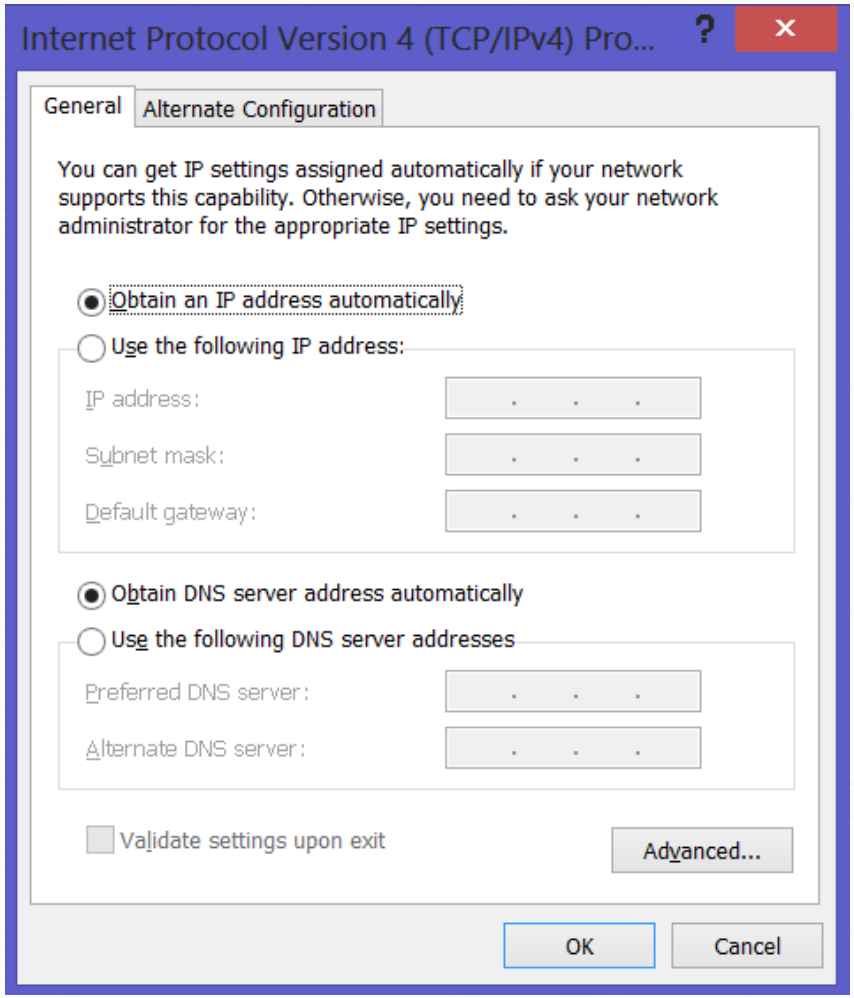
Bandwidth and Latency

- **Bandwidth** is the amount of data that can be transmitted within a fixed time period.
- Bandwidth is measured in bits per second and is usually denoted by the following:
  - bps - bits per second
  - Kbps - kilobits per second
  - Mbps - megabits per second
  - Gbps - gigabits per second
- **Latency** is the amount of time it takes data to travel from source to destination.
- Data is transmitted in one of three modes:
  - **Simplex** (Unidirectional transmission) is a single, one-way transmission.
  - **Half-duplex** allows data to flow in one direction at a time.
  - **Full-duplex** allows data to flow in both directions at the same time.

IP Addressing

- An IPv4 address is a unique number used to identify a network device and is represented as a 32bit binary number, divided into four **octets** (groups of eight bits):
  - Example: 10111110.01100100.00000101.00110110
- An IP address is also represented in a **dotted decimal** format.
  - Example: 190.100.5.54
- When a host is configured with an IP address, it is entered as a dotted decimal number, such as 192.168.1.5. This IP address must be unique on a network.
- IP Classes
  - Class A: Large networks, implemented by large companies and some countries — Range 1-127
  - Class B: Medium-sized networks, implemented by universities — Range 128-191
  - Class C: Small networks, implemented by ISP for customer subscriptions — Range 192-223
  - Class D: Special use for multicasting — Range 224-239
  - Class E: Used for experimental testing — Range 240-254
- IPv6 address - 128 bits or 32 hexadecimal values.
  - Example : 2001:0db8:85a3:0000:0000:8a2e:0370:7334

Dynamic Host Configuration Protocol (DHCP)



- DHCP automatically provides computers with an IP address.
- The DHCP server can assign these to hosts:
  - IP address
  - Subnet mask
  - Default gateway
  - Domain Name System (DNS) server address

Internet Protocols

- A **protocol** is a set of rules. Internet protocols govern communication within and between computers on a network.
- Many protocols consist of a **suite** (or group) of protocols stacked in layers.
  - Devices and computers connected to the Internet use a protocol suite called **TCP/IP** to communicate with each other.
- The main functions of protocols:
  - Identifying errors
  - Compressing data
  - Deciding how data is to be sent
  - Addressing data
  - Deciding how to announce sent and received data
- The information is transmitted mostly via two protocols, TCP and UDP.

TCP and UDP Protocols and Ports

- A **port** is a numeric identifier used to keep track of specific conversations. Every message that a host sends contains both a source and destination port.

Common Network Protocols and Ports

Protocol	Port	Description
TCP/IP	NA	A suite of protocols used to transport data on the Internet
NetBEUI/ NetBIOS	137, 139, 150	A small, fast protocol designed for a workgroup network that requires no connection to the Internet
HTTP	80	A communication protocol that establishes a request/response connection on the Internet
HTTPS	443	Uses authentication and encryption to secure data as it travels between the client and Web server
FTP	20/21	Provides services for file transfer and manipulation
SSH	22	Securely connects to a remote network device
Telnet	23	Connects to a remote network device
POP3	110	Downloads email messages from an email server
IMAP	143	Downloads email messages from an email server
SMTP	25	Sends mail in a TCP/IP network

Physical Network Components

- Network devices:
  - Computers
  - Hubs
  - Switches
  - Routers
  - Wireless access points
- Network media:
  - Twisted-pair copper cabling
  - Fiber-optic cabling
  - Coaxial cabling
  - Radio waves

Network Devices

- **Hub**
  - Extend the range of a signal by receiving then regenerating it and sending it out all other ports.
  - Any data packet coming from one port is sent to all other ports. It is then up to the receiving computer to decide if the packet is for it.
  - Allow for **collisions** on the network segment and are often not a good solution.

- **Bridges**
  - Bridges are typically used to separate parts of a network that do not need to communicate regularly, but still need to be connected.
  - A bridge looks at the destination of the packet before sending. If the destination address is not on the other side of the bridge it will not transmit the data.
  - A bridge only has one incoming and one outgoing port.

Network Devices

- **Switches**
  - A switch has multiple ports.
  - When a packet comes through a switch it is read to determine which computer to send the data to.
  - Refers to a table of MAC addresses to determine which port to use to forward the frame.
  - This leads to increased efficiency in that packets are not going to computers that do not require them.
  - Most large networks use switches rather than hubs to connect computers within the same subnet.

- **Routers**
  - Devices that connect entire networks to each other. They use IP addresses to forward packets to other networks.
  - A router can be a computer with special network software installed or can be a device built by network equipment manufacturers.
  - Routers contain tables of IP addresses along with optimal routes to other networks.

Network Devices

- **Wireless Access Points (WAP)**
  - Provide network access to wireless devices such as laptops and PDAs.
  - Use radio waves to communicate with radios in computers, PDAs, and other wireless access points.
  - Have limited range of coverage.
- **Multipurpose Devices**
  - There are network devices that perform more than one function.
  - It is more convenient to purchase and configure one device that serves all of your needs than to purchase a separate device for each function. This is especially true for the home user.
  - In your home, you would purchase a multipurpose device instead of a switch, a router, and a wireless access point.

Network Devices

Network-attached storage (NAS)

- Consists of one or more hard drives, an Ethernet connection, and an embedded operating system

- The NAS device connects to the network, allowing users on the network to access and share files, stream media, and back up data to a central location

Power over Ethernet (PoE)

- PoE switch transfers small amounts of DC current over Ethernet cable, along with data, to power PoE devices such as Wi-Fi access points.

Network Devices

- **VoIP phones** - carry telephone calls over the data networks and Internet.
- **Hardware firewalls** - use various techniques for determining what is permitted or denied access to a network segment.
- **Internet appliance** – web TV, game consoles, Blu-ray players etc.
- **Purchasing Authentic Networking Devices** - Computer and network problems can be related to counterfeit components.

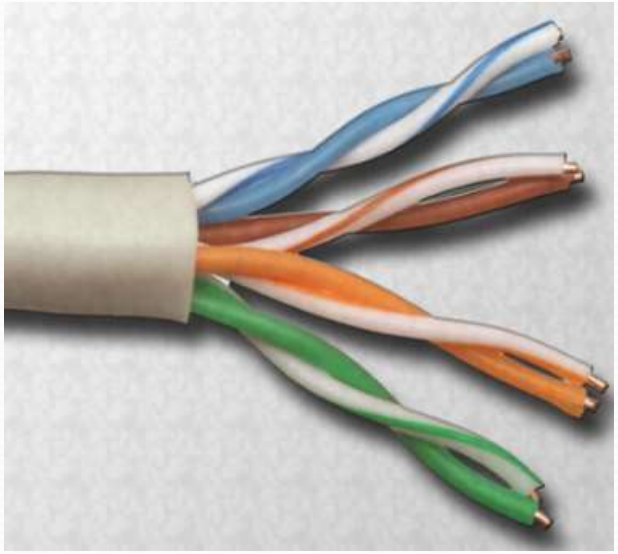
Coaxial Cable

- A copper-cored network cable surrounded by a heavy shielding

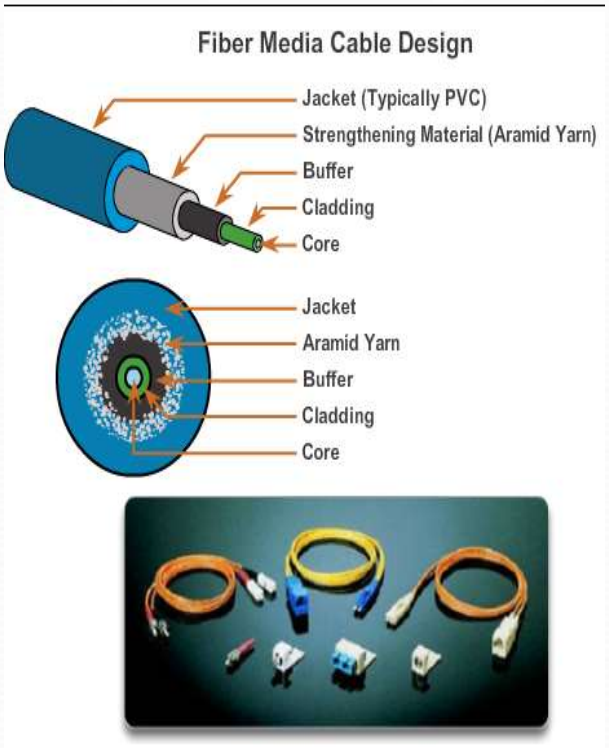
- Types of coaxial cable:
  - **Thicknet or 10Base5** - Coaxial cable that was used in networks and operated at 10 megabits per second with a maximum length of 500 m
  - **Thinnet or 10Base2** - Coaxial cable that was used in networks and operated at 10 megabits per second with a maximum length of 185 m
  - **RG-59** - Most commonly used for cable television in the US
  - **RG-6** - Higher quality cable than RG-59 with more bandwidth and less susceptibility to interference

Twisted-Pair Cabling

- A pair of twisted wires forms a circuit that transmits data.
- The twisted wires provide protection against crosstalk (electrical noise) because of the cancellation effect.
- Pairs of copper wires are encased in color-coded plastic insulation and twisted together.
- An outer jacket of poly-vinyl chloride (PVC) protects the bundles of twisted pairs.
- There are two types of this cable:
  - **Unshielded twisted-pair (UTP)**
    - (Cat 3, Cat 5, 5e ,Cat 6 and Cat 7)
    - Has two or four pairs of wires
    - Has a range of 328 ft (100 meters)
  - **Shielded twisted-pair (STP)**
    - Each pair is wrapped in metallic foil to better shield the wires from electrical noise. Four pairs of wires are then wrapped in an overall metallic braid or foil.

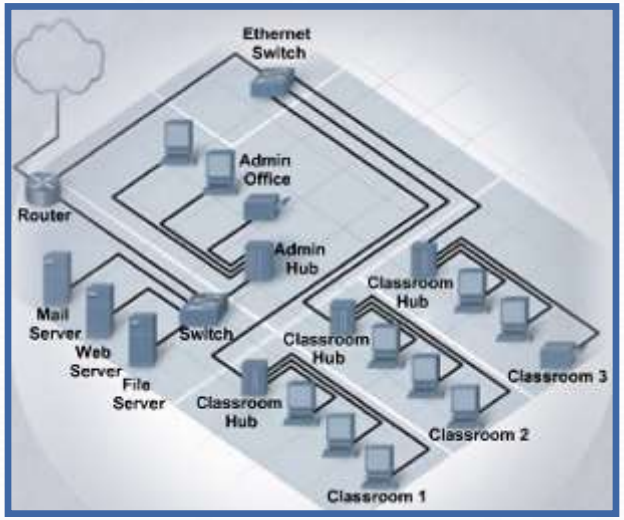


Fiber-Optic Cable

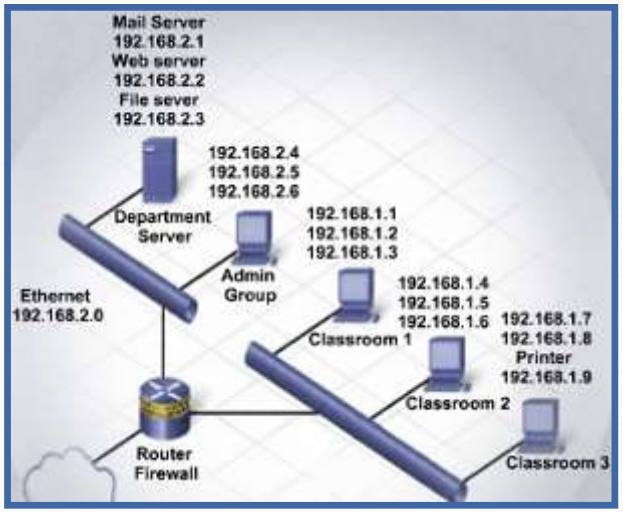


- A glass or plastic strand that transmits information using light and is made up of one or more optical fibers enclosed together in a sheath or jacket.
- Not affected by electromagnetic or radio frequency interference.
- Signals are clearer, can go farther, and have greater bandwidth than with copper cable.
- Usually more expensive than copper cabling and the connectors are more costly and harder to assemble.
- Two types of glass fiber-optic cable:
  - **Multimode** - Cable has a thicker core than single-mode cable, easier to make, can use simpler light sources (LEDs), and works well over distances of a few hundred meters or less.
  - **Single-mode -** Cable has a very thin core, harder to make, uses lasers as a light source, and can transmit signals dozens of kilometers with ease.

Two Types of LAN Topologies



Physical topology is the physical layout of the components on the network.



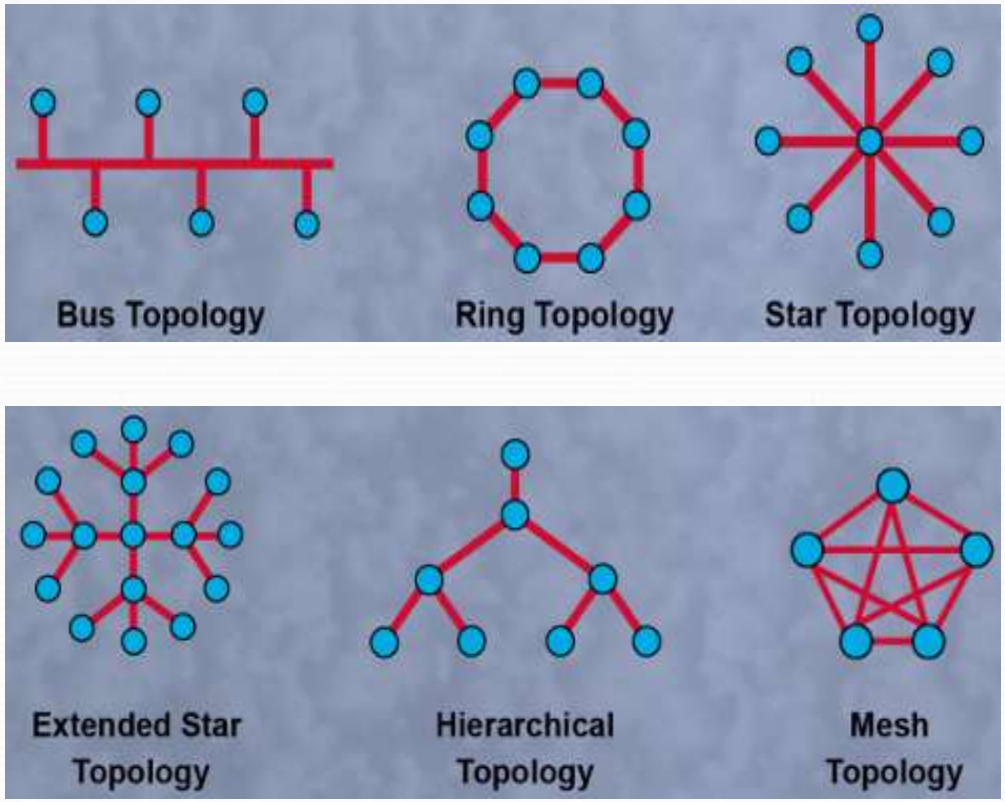
Logical topology determines how the hosts access the medium to communicate across the network.

Logical Topologies

- The two most common types of logical topologies are **broadcast and token passing**.
  - **Broadcast topology**- A host broadcasts a message to all hosts on the same network segment. There is no order that hosts must follow to transmit data. Messages are sent on a First In, First Out (FIFO). Ethernet is based on this topology.
  - **Token passing** controls network access by passing an electronic token sequentially to each host. When a host receives the token, it can send data on the network. If the host has no data to send, it passes the token to the next host and the process repeats itself.

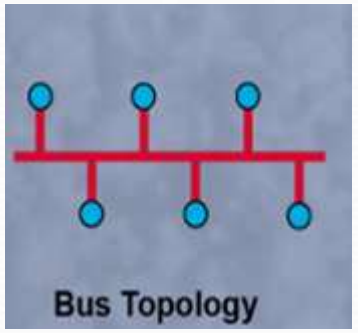
Determine a Network Topology

- A physical topology defines the way in which computers, printers, and other devices are connected to a network.

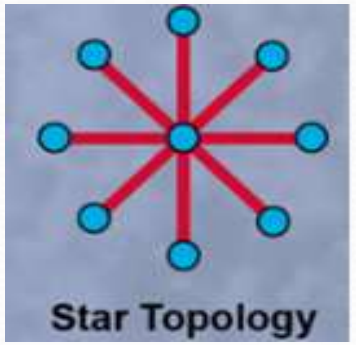


LAN Physical Topologies

- **Bus**
  - Each computer connects to a common cable The ends of the cable have a **terminator** installed to prevent signal reflections and network errors.
  - Only one computer can transmit data at a time or frames will collide and be destroyed.

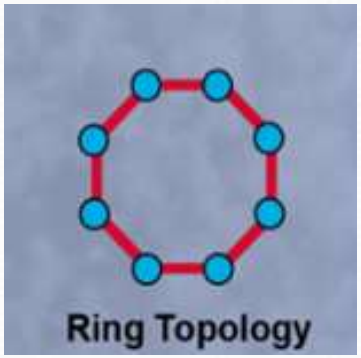


- **Star**
  - Has a central connection point : a hub, switch, or router.
  - Easy to troubleshoot, since each host is connected to the central device with its own wire.

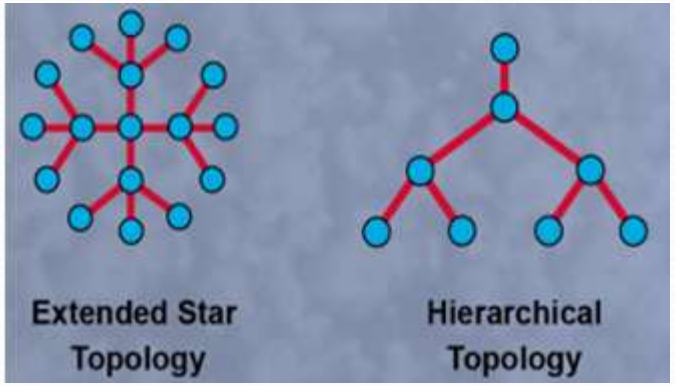


LAN Physical Topologies

- **Ring**
  - Hosts are connected in a physical ring or circle.
  - A special frame, a **token**, travels around the ring, stopping at each host to allow data transmission.
  - There are two types of ring topologies:
    - Single-ring and Dual-ring



- **Hierarchical or Extended Star Topology**
  - A star network with an additional networking device connected to the main networking device to increase the size of the network.
  - Used for larger networks.



LAN Physical Topologies

- **Mesh Topology**
  - Connects all devices to each other.
  - Used in WANs that interconnect LANs. The Internet is an example of a mesh topology.

- **Hybrid**
  - A hybrid topology is a combination of two or more basic network topologies, such as a star-bus, or star-ring topology. The advantage of a hybrid topology is that it can be implemented for a number of different network environments.

Ethernet Technologies

- **10BASE-T**
  - An Ethernet technology that uses a star topology.
  - The **ten (10)** represents a speed of 10 Mbps, the **BASE** represents baseband transmission and the **T** represents twisted-pair cabling.

Ethernet Standards

Ethernet Standards	Media	Transfer Rates
10BASE-T	Category 3	Transfers data at a rate of 10 Mb/s.
100BASE-TX	Category 5	At 100 Mb/s, transfer rates of 100BASE-TX are ten times that of 10BASE-T.
1000BASE-T	Category 5e, 6	The 1000BASE-T architecture supports data transfer rates of 1 Gb/s.
10GBASE-T	Category 6a, 7	The 10GBASE-T architecture supports data transfer rates of 10 Gb/s.

Wireless Ethernet Standards

IEEE 802.11 is the standard that specifies connectivity for wireless networks.

Wi-Fi (wireless fidelity), refers to the 802.11 family

- **802.11a** - Devices conforming to the 802.11a standard allow WLANs to achieve data rates as high as 54 Mbps. IEEE 802.11a devices operate in the 5 GHz radio frequency range and within a maximum range of 150 feet (45.7 m).
- **802.11b** operates in the 2.4 GHz frequency range with a maximum theoretical data rate of 11 Mbps. These devices operate within a maximum range of 300 feet (91 m).
- **802.11g** provides the same theoretical maximum speed as 802.11a, which is 54 Mbps, but operates in the same 2.4 GHz spectrum as 802.11b. Unlike 802.11a, 802.11g is backward-compatible with 802.11b. 802.11g also has a maximum range of 300 feet (91 m).
- **802.11n** is a newer wireless standard that has a theoretical bandwidth of 540 Mbps and operates in either the 2.4 GHz or 5 GHz frequency range with a maximum range of 984 feet (250 m).

- These protocols specify the frequencies, speeds, and other capabilities of the different Wi-Fi standards.

Wireless Ethernet Standards

	Bandwidth	Frequency	Range	Interoperability
802.11a	Up to 54 Mbps	5 GHz band	100 feet (30 meters)	Not interoperable with 802.11b, 802.11g, or 802.11n
802.11b	Up to 11 Mbps	2.4 GHz band	100 feet (30 meters)	Interoperable with 802.11g
802.11g	Up to 54 Mbps	2.4 GHz band	100 feet (30 meters)	Interoperable with 802.11b
802.11n	Up to 540 Mbps	2.4 GHz band	164 feet (50 meters)	Interoperable with 802.11b and 802.11g
802.15.1 Bluetooth	Up to 2 Mbps	2.4 GHz band or 5 GHz band	30 feet (10 meters)	Not interoperable with any other 802.11

Selecting a NIC

- Most network interfaces for desktop computers are either integrated into the motherboard or are an expansion card that fits into an expansion slot.
- Most laptop network interfaces are either integrated into the motherboard or fit into a PC Card or ExpressBus expansion slot.
- USB network adapters plug into a USB port and can be used with both desktops and laptops.

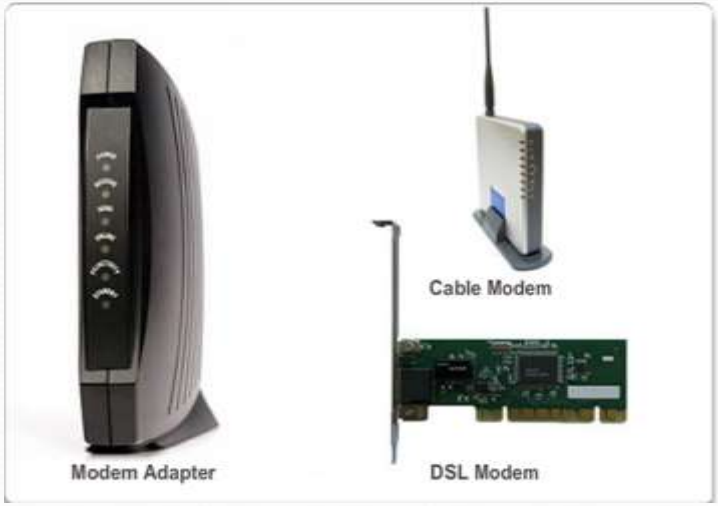
Configure the NIC

- Every NIC must be configured with the following information:
  - Protocols
  - IP address
  - MAC address

- Alternate IP configuration in Windows simplifies moving between a network that requires using DHCP and a network that uses static IP settings. Windows uses the alternate IP configuration assigned to the NIC if no access to DHCP

Modem

- A **modem** is an electronic device that transfers data between one computer and another using analog signals over a telephone line.
  - A transmitting modem converts digital data to analog signals, called **mo**dulation.
  - The receiving modem reconverts the analog signals back to digital data, called **dem**odulation.
- An **internal** modem plugs into an expansion slot on the motherboard and a software driver is installed.
- **External** modems connect to a computer through the serial and USB ports and also require a software driver.

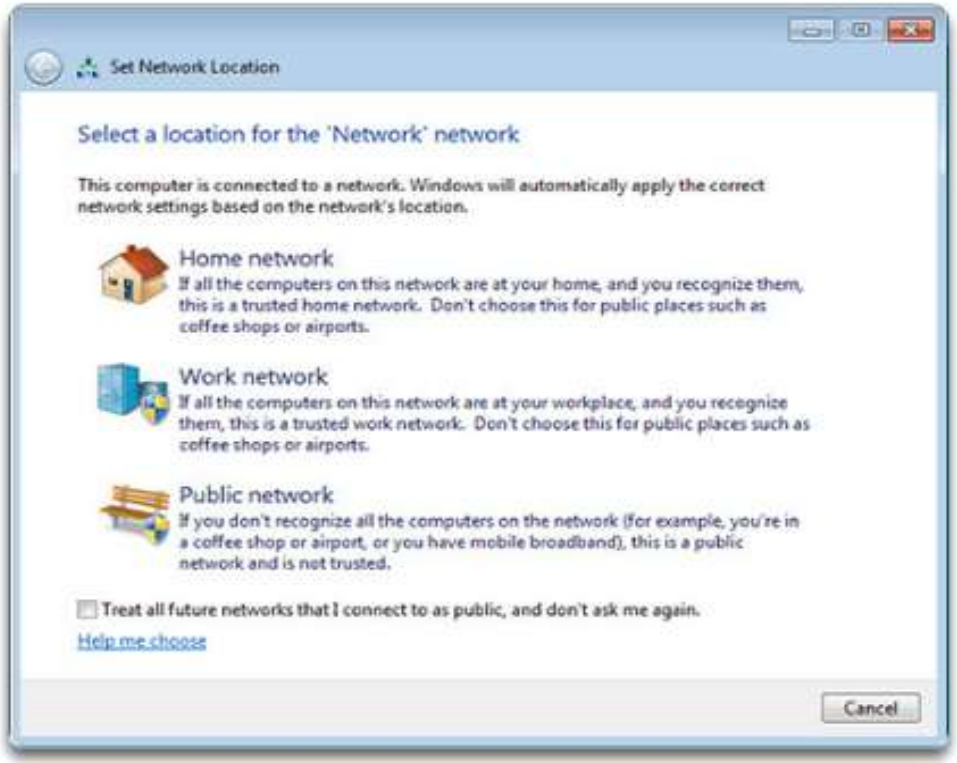


Cable Modem

- A **cable modem** connects your computer to the cable company using the same coaxial cable that connects to your cable television.
  - You can connect the computer directly into the cable modem.
  - You can connect a router, switch, hub, or multipurpose network device so multiple computers can share the Internet connection.

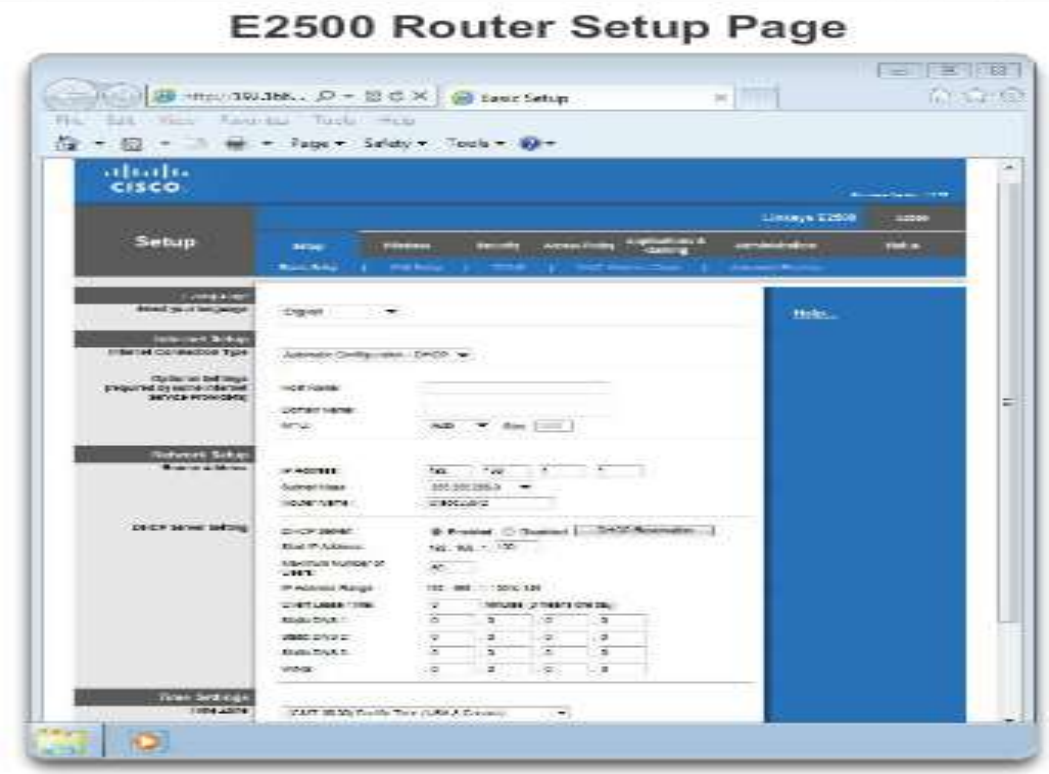
Connecting to the Router

- After connecting the network cable, activity should be verified by looking at the LEDs.
- Set the network location.
- Log into the router via web browser using 192.168.1.1.



Basic Router Setup

- It is good practice to change the following default settings:
  - **Router Name**
  - **Network Device Access Permissions**
  - **Passwords!!!!**



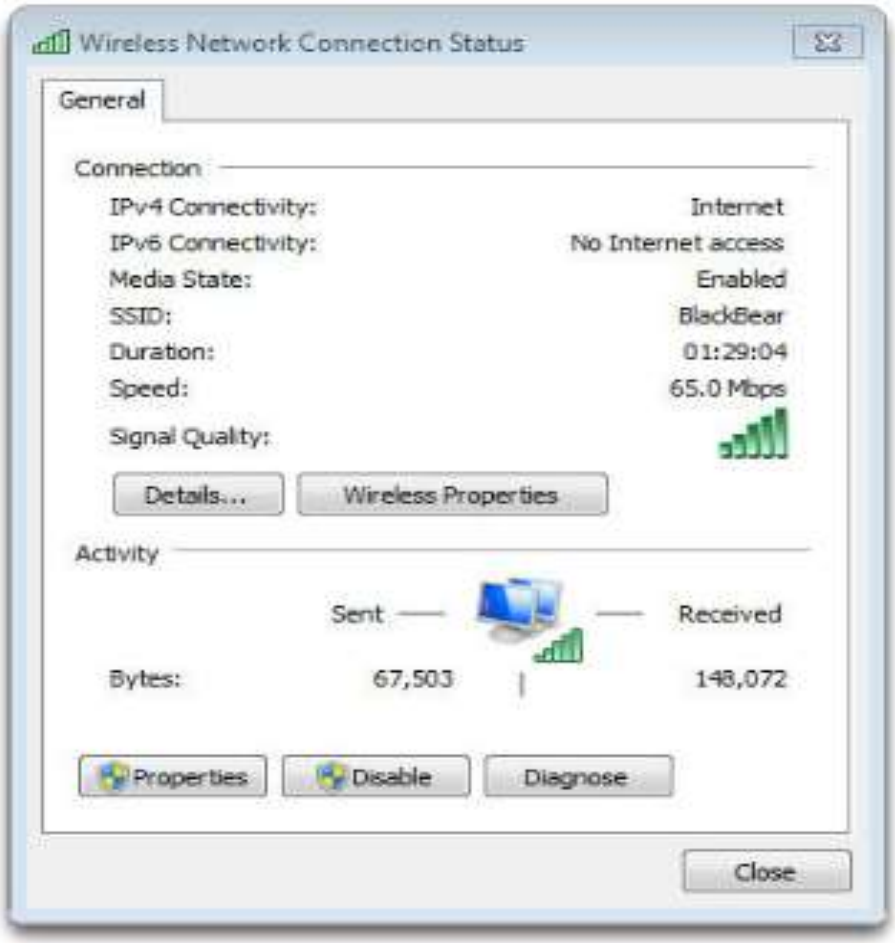
Basic Wireless Settings

- Configure basic settings to secure and increase the speed of the wireless network:
  - **Network mode** - A mixed-mode allows 802.11b, 802.11g, and 802.11n devices.
  - **Service Set Identifier (SSID)** - The name of the wireless network.
  - **Channel** - 1 and 11 do not overlap with the default channel 6. Use one of these three channels for best results.
  - **Wireless security modes**
    - Wired Equivalent Privacy (WEP)
    - Temporal Key Integrity Protocol (TKIP)
    - Advanced Encryption Standard (AES)
    - Wi-Fi Protected Access (WPA)
    - Wi-Fi Protected Access 2 (WPA2)

Testing Connectivity

- Use Windows GUI

Wireless Network Connection Status Window



Testing Connectivity

- Using Windows CLI
  - **Ipconfig** – displays basic configuration for all network adapters.
  - **Ping –** tests basic connectivity between devices.
  - **Net commands –** manage network computers, servers, and resources.
  - **Tracert** – trace the routes that packets take from your computer to a destination host.
  - **Nslookup –** tests and troubleshoots DNS servers.

Selecting an ISP

- Four main considerations:
- **Cost / Speed / Reliability / Availability**

Type	Advantages	Disadvantages	Speed
POTS	Widely available	Very slow speeds cannot receive phone calls while connected	MAX 56 kbps
ISDN	Higher speeds than POTS	Still much slower than other broadband technologies	BRI - up to 128 kbps PRI - up to 2.048 Mb/s
DSL	Low cost	Distance from CO impacts speed	24 kbps - 100 Mb/s
Cable	Very high speed	Slow upload speeds	27 kbps - 160 Mb/s
Satellite	Available where DSL and cable are not	More expensive than other broadband technologies, and it is susceptible to weather conditions	9 kbps - 24 Mb/s
Cellular	Available to mobile users	Not accessible every where	20 kbps and up depending on the technology used

Connectivity

- Phone, cable, satellite, and private telecommunications companies provide Internet connections.
- In the 1990s, low-speed modems used the **Plain Old Telephone System (POTS)** to send and receive data.
- Today, many businesses and home users have switched to high-speed Internet connections, which allows for transmission of data, voice and video.

Dial-up Networking (DUN)

- When computers use the public telephone system to communicate, it is called **dial-up networking** (**DUN**).
- Modems communicate with each other using audio tone signals. DUN creates a Point-to-Point Protocol (PPP) connection between two computers over a phone line.
- After the line connection has been established, a "handshaking sequence" takes place between the two modems and the computers.
- The digital signals from the computers must be converted to an analog signal to travel across telephone lines. They are converted back to the digital form, 1s and 0s, by the receiving modem so that the receiving computer can process the data.

Broadband Connectivity

- **Broadband** is a technique used to transmit and receive multiple signals using multiple frequencies over one cable.
- Broadband uses a wide range of frequencies that may be further divided into **channels**.
- Some common broadband network connections include:
  - Integrated Services Digital Network (ISDN)
  - Digital Subscriber Line (DSL)
  - Cable

Integrated Services Digital Network (ISDN)

- A standard for sending voice, video, and data over telephone wires.
- Provides higher-quality voice and higher-speed data transfer than traditional analog telephone service.
- Three services offered by ISDN digital connections: Basic Rate Interface (BRI), Primary Rate Interface (PRI), and Broadband ISDN (BISDN).
- ISDN uses two different types of communications channels:

  "B" channel is used to carry the information - data, voice, or video.

  "D" channel is usually used for controlling and signaling, but can be used for data.

ISDN Types

Type	Description
BRI	ISDN Basic Rate Interface offers a dedicated 128 Kbps connection using two 64 Kbps B channels. ISDN BRI also uses on 16 Kbps D channel for call setup, control, and teardown.
PRI	ISDN Primary Rate Interface offers up to 1.544 Mbps over 23 B channels in North America and Japan or 2.048 Mbps over 30 B channels in Europe and Australia. ISDN PRI also uses one D channel for call maintenance.
BISDN	Broadband ISDN manages different types of service all at the same time. BISDN is mostly used only in network backbones.

Digital Subscriber Line (DSL)

- An "always-on" technology; there is no need to dial up each time to connect to the Internet.
- Uses the existing copper telephone lines to provide high-speed data communication between end users and telephone companies.
- The copper wires have lots of room for carrying more than phone conversations, they are capable of handling a much greater bandwidth, or range of frequencies than that demanded for voice.
- DSL exploits this "extra capacity" to carry information on the wire without disturbing the line's ability to carry conversations
- Asymmetric DSL (ADSL) is currently the most commonly used DSL technology.
  - Has a fast downstream speed, typically 1.5 Mbps.
  - Upload rate of ADSL is slower.
  - Not the best solution for hosting a web server of FTP server.

DSL Types

Type	Description
ADSL	Asymmetric DSL is most common. Downstream speed from 384 Kbps to 6 Mbps. Upstream speeds lower than downstream speeds.
HDSL	High Data Rate DSL provides equal bandwidth in both directions. Needs 2 phones lines. Replaced by SDSL
SDSL	Symmetric DSL provides the same speed, up to 3 Mbps, for uploads and downloads.
VDSL	Very High Data Rate DSL is capable of bandwidths between 13 and 52 Mbps downstream, and 16 Mbps upstream.
IDSL	ISDN DSL is DSL over ISDN lines. Uses ordinary phone lines. Requires ISDN adapters.

Cable Broadband

- Cable - uses coaxial cable lines originally designed to carry cable television, a cable modem connects your computer to the cable company.

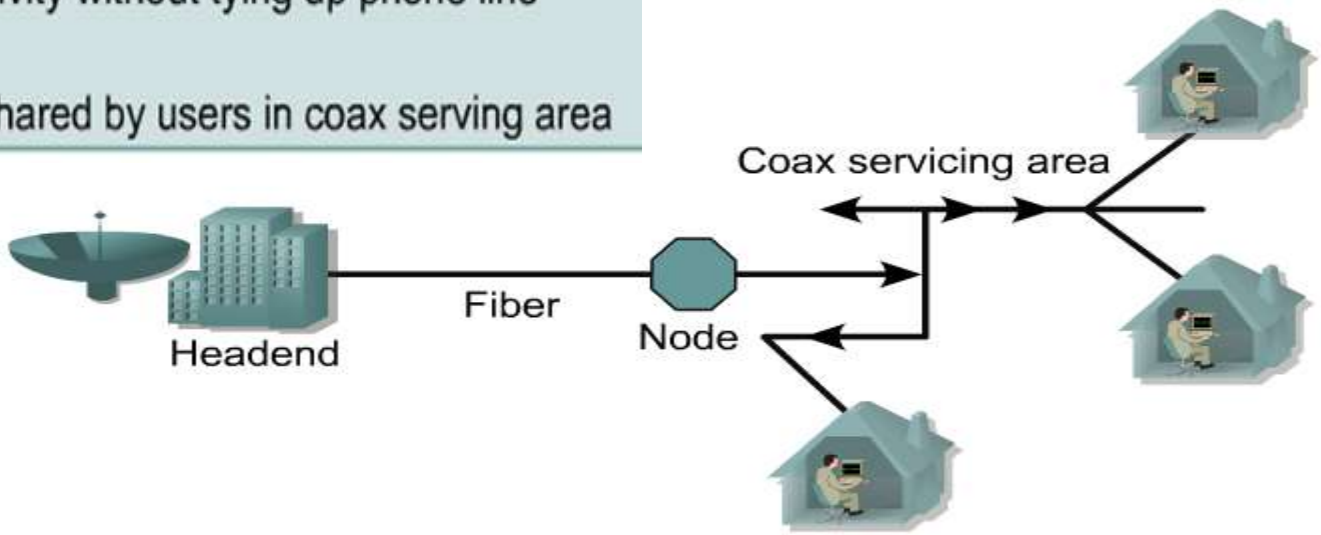
Modern Cable Benefits and Drawbacks

Benefits

- High speed asymmetric access
- Constant connectivity without tying up phone line

Drawbacks

- Cable bandwith shared by users in coax serving area



Other Broadband Technologies

- **Cellular –** enables the transfer of voice, video, and data.
  - 3G - Data speeds between 144 Kbs and 2 Mbs
  - 4G - Data speeds from 5.8 Mbs and up
- **Satellite -** uses a satellite dish for two-way communication.
- **Bluetooth –** provides a wireless technology for exchanging data over short distances.
- **Line of Sight -** uses radio signals for transmitting Internet access.

Technologies Resulting From Broadband

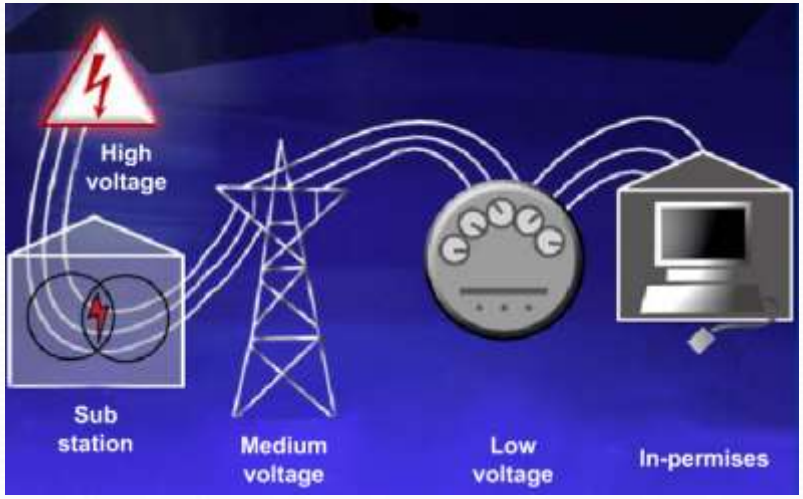
With the advent of broadband technology we now have access to always on high speed communication.

This has also resulted in new technologies available to companies and end user at home.

- Power Line Communication
- Voice over IP
- Virtual Private Network

Power Line Communication (PLC)

- Uses power distribution wires (local electric grid) to send and receive data.
- May be available in areas without any other service and is faster than an analog modem.
- May cost less than other high-speed connections and in time it is expected to be more common.
- Can be used in a home or office environment through an electrical outlet and can control lighting and appliances.



Voice over IP (VoIP)

- Is a method used to carry telephone calls over data networks and the Internet.
- Converts the analog signals of voices into digital information that is transported in IP packets.
- Can also use an existing IP network to provide access to the public switched telephone network (PSTN).
- Depends on a reliable Internet connection. When a service interruption occurs the user cannot make phone calls.

Virtual Private Network (VPN)

- **Virtual Private Network (VPN)** - a private network that connects remote sites or users together over a public network like the internet.
- When connected via the VPN, users have access to all services and resources as if they were physically connected to their corporate LAN.
- Remote-access users must install the VPN client software which encrypts data before sending it over the Internet.
- VPN gateways establish, manage, and control VPN connections (also known as VPN tunnels).