CSIT985
Strategic Network Design

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UNIVERSITY
OF WOLLONGONG
AUSTRALIA

Lecture 2:

Fundamentals Of Network

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Outline

❑ Network elements

❑ Network Categories

❑ Network Protocols

❑ Network Topology

❑ Network Addressing

❑ Network Performance

Network Elements

What is a network?

Two or more end devices connected to each other via wired or wireless connection form a computer network.

Ethernet: a computer network architecture consisting of various specified local-area network protocols, devices, and connection methods.
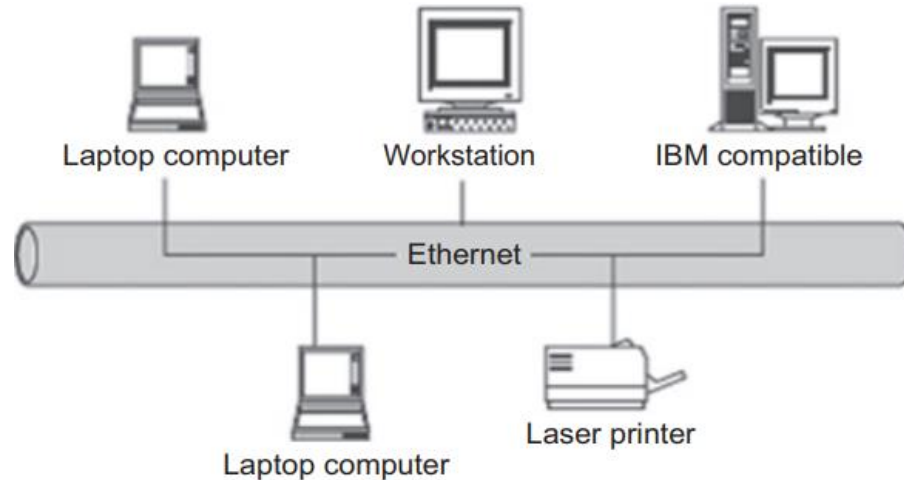

Figure. A Computer Network (Kizza, 2020, p.4)

Network elements: Hosts or End Devices

- On a network, each computer is called an end device or a host.

- An end device is where a message originates from or where it is received. Data originates with an end device, flows through the network, and arrives at an end device.

PC

Tablet

Laptop

Softphone

IP Phone

Network elements: Networking Devices

- Networking devices are intermediate devices in a computer network. They enable the communication and interaction between connected devices within the network.

- Types of networking devices: hub, switch, router, bridge, gateway, modem, repeater, or access point.

Workgroup switch

Small Hub

Router

Programmable Switch

Wireless Router

Network elements: Networking Devices

- **Hub**: A hub (i.e., a physical layer device) is a device that connects multiple twisted pair cables or optical fibers to the same physical medium. It usually works at the physical layer and is used to connect LAN segments. A hub has multiple ports. When one of the ports receives a signal, it will reshape and amplify the decayed (distorted) signal, and then broadcast the amplified signal to all other ports so that all segments of the LAN can see the data packet. In a network, a hub acts as a common connection point for devices.

Hub

Network elements: Networking Devices

- **Switch**: A switch is a network device used for forwarding optical/electrical signals. It usually works at the data link layer or the network layer and supports various data packet protocols. Currently, there are many types of switches, such as LAN switches and Ethernet switches. Among them, LAN switches are mainly used for data exchange within switched LANs; while Ethernet switches are mainly used for data transmission within Ethernet. In the network, a switch is a device used to filter and forward data packets between LAN segments.

Network elements: Networking Devices

Difference between Hub and Switch:

- For a hub, the signal will be transmitted along its port and broadcast to other ports, so it is easy to generate broadcast storms. When the network is large, its performance will be affected.

- For a switch, only the port that sends the request and the destination port will respond to each other, and it will not affect other ports. Therefore, the switch can effectively suppress the generation of broadcast storms to a certain extent.
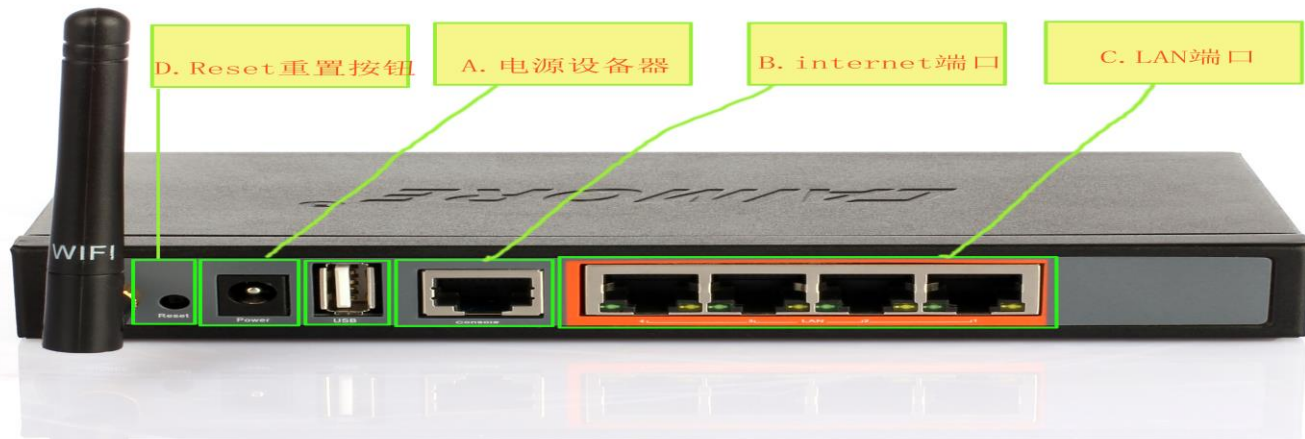
Network elements: Networking Devices

▪ **Router**: A router connects LANs and WANs in the Internet. It is usually located at the gateway of two or more networks and works at the network layer. It is used to achieve network connections between two LANs or two WANs or a LAN and an Internet service provider. A routing table is usually stored in the router, which automatically selects and sets routes according to the channel conditions and then sends signals along the ideal path.


D. Reset重置按钮

A. 电源设备器

B. internet端口

C. LAN端口

Network elements: Networking Devices

- **Router**: routers are used to connect two or more data lines from different networks. When a data packet enters one of the lines, the router reads the network address information in the data packet to determine the final destination, and then forwards the data packet to the next network through the information in the routing table or routing policy. In addition, routers can allow multiple network clients to share one IP address..

Network elements: Networking Devices

- **Bridge**: A network bridge is a computer networking device that creates a single, aggregate network from multiple communication networks or network segments.
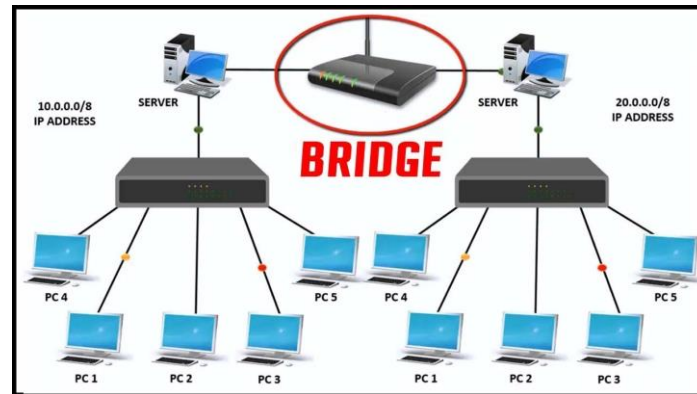
Network elements: Networking Devices

- **Gateway**:

A gateway is a gateway that connects one network to another. It is also called a network connector or a protocol converter. In the Internet, a gateway is an intermediate device that connects an intranet to other networks on the Internet. The gateway address can be understood as the address of a channel for information transmission between the intranet and the Internet.

All networks have a boundary that limits communication to devices directly connected to it. Therefore, if networks want to communicate with devices, nodes, or networks outside of that boundary, they require the functionality of a gateway. A gateway is often characterized as a combination of a router and a modem.

Network elements: Networking Devices

- A modem is a network device that both modulates and demodulates analog carrier signals (called sine waves) for encoding and decoding digital information for processing.

V.S.

Modem   Modem-Router

Network elements: Networking Devices

- **Repeater:** A repeater operates at the physical layer. Its job is to regenerate the signal over the same network before the signal becomes too weak or corrupted so as to extend the length to which the signal can be transmitted over the same network.

- **Access point (AP)**: AP is a networking hardware device that allows other Wi-Fi devices to connect to a wired network. As a standalone device, the AP may have a wired connection to a router, but, in a wireless router, it can also be an integral component of the router itself. An AP is differentiated from a hotspot which is a physical location where Wi-Fi access is available.
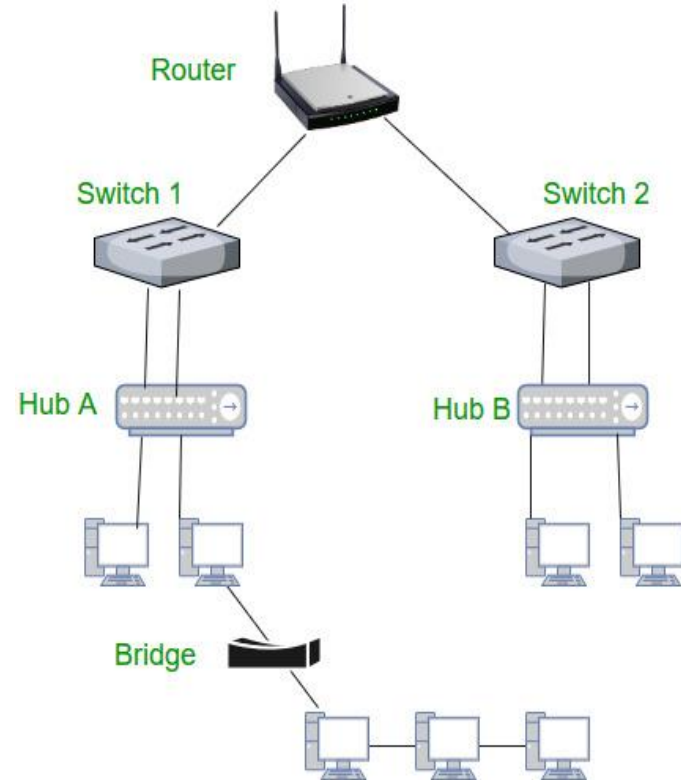
Network elements: Transmission Media

- Transmission media play a vital role in the performance of a network.

- Without it, the communication between network elements can not happen and there will no connection between the elements.

- Media types

  - Wired transmission media

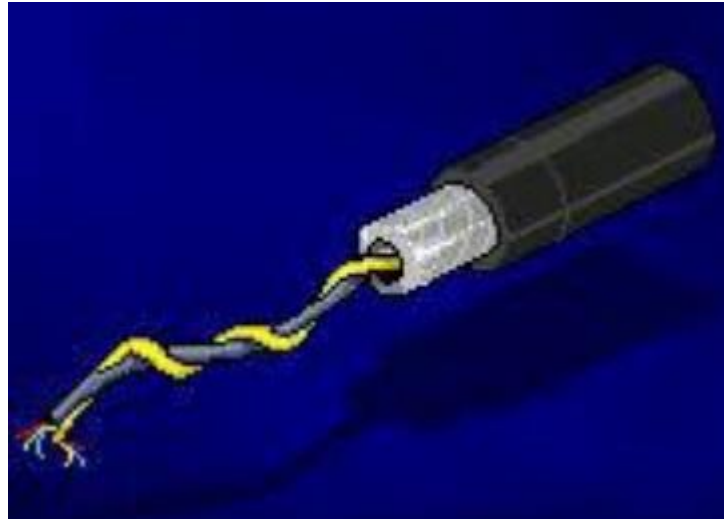 - Wireless transmission media

Network elements: Transmission Media

- Wired transmission media

    - Copper wires

Network elements: Transmission Media
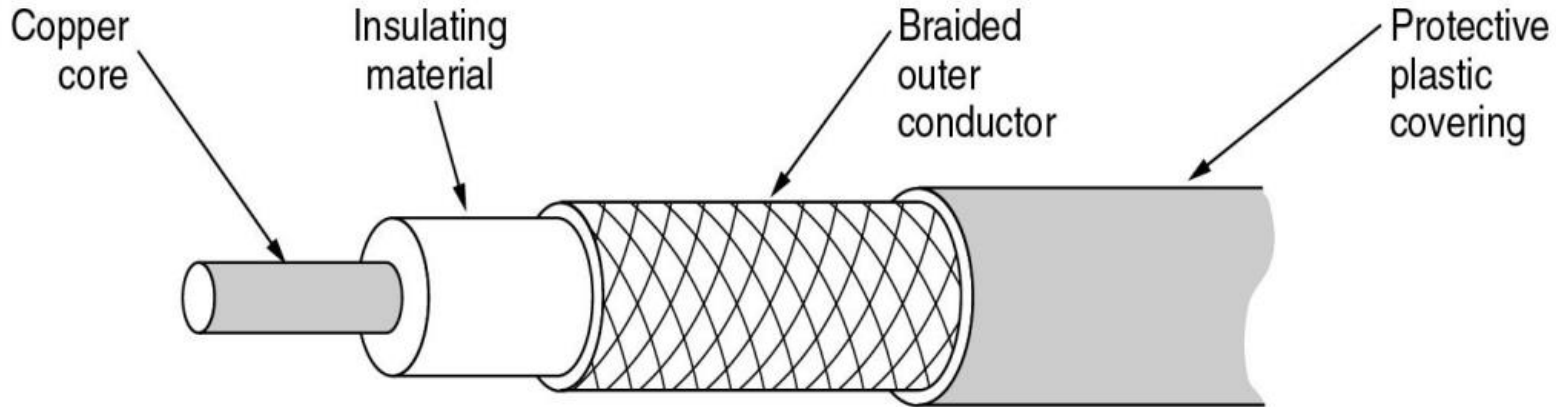
- Wired transmission media

Twisted pair wires: A data transmission cable consisting of two insulated conductors twisted tightly together to reduce electromagnetic interference and improve signal transmission quality.
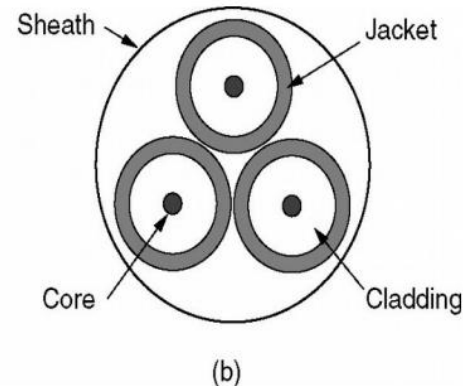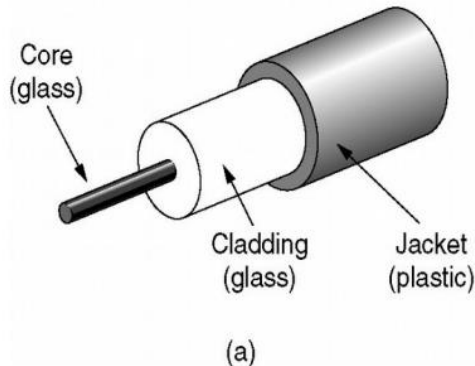
Network elements: Transmission Media

Coaxial Cable: A cable used to transmit **high-frequency** signals consisting of a center conductor and a concentric outer conductor separated by an insulating material.

Network elements: Transmission Media

Optical fiber cables: Optical fiber consists of a thin core made of glass or plastic, surrounded by a cladding, also glass or plastic, but with different properties from the core and finally there is a protective jacket (plastic). In general, light confined to the central core by a phenomenon called total internal reflection, whereby it cannot escape through the discontinuity in optical properties at the core-cladding interface.

Network elements: Transmission Media

Properties	Twisted Pair	Co-axial Cable	Fiber optic cable
Cost	Inexpensive	Twice or Thrice than twisted pair	Expensive
Installation	Easy	Easy	Difficult
Attenuation	More	More	Very Less
EMI Effect	Maximum	Minimum	No effect
Bandwidth	1 to 100 Mbps/100m	500 Mbps/100m	Gega bps/km
Signal Type	Electrical	Electrical	Light Signals

Network elements: Transmission Media

- **Wireless transmission media** results in three wireless network categories depending on distances:

  ① **Restricted Proximity Network**: it involves LANs with a combination of wireless and fixed devices.

  ② **Intermediate/Extended Network**: it is made of two fixed LAN joining together by a wireless element.

  ③ **Mobile Network**: the network uses a base station to provide a radio network over land areas.

Network elements: Transmission Media

- Wireless transmission media

  - **Infrared wave** is the electromagnetic wave that carries coded instructions exchanged between network elements. It uses line-of-sight propagation.

  - **High-Frequency Radio wave** is the high-frequency electromagnetic radio wave. Its range is greater than that of infrared wave. The radio transmission is good for long distances, but it is affected by interferences and rains.

  - **Microwave** is a higher version of radio wave. It uses a pair of parabolic antennas. It is unidirectional and do not go through buildings.

  - **Laser light** is used for transmitting data for several thousand yards via the air and optical fibers. The restriction is that it works in the context of no obstacles in the line of sight.

Network elements: Client-Server network

- A **server** is a computer which give information to the hosts or ends devices, e.g. file server, web server, or email server, etc.

- A **client** is a computer which sends requests to the server to get information,

  - Retrieving emails from an email server

  - Retrieving web pages from a web server

Computer network models

- **A centralized network model includes:**

  ✓ One central computer called master
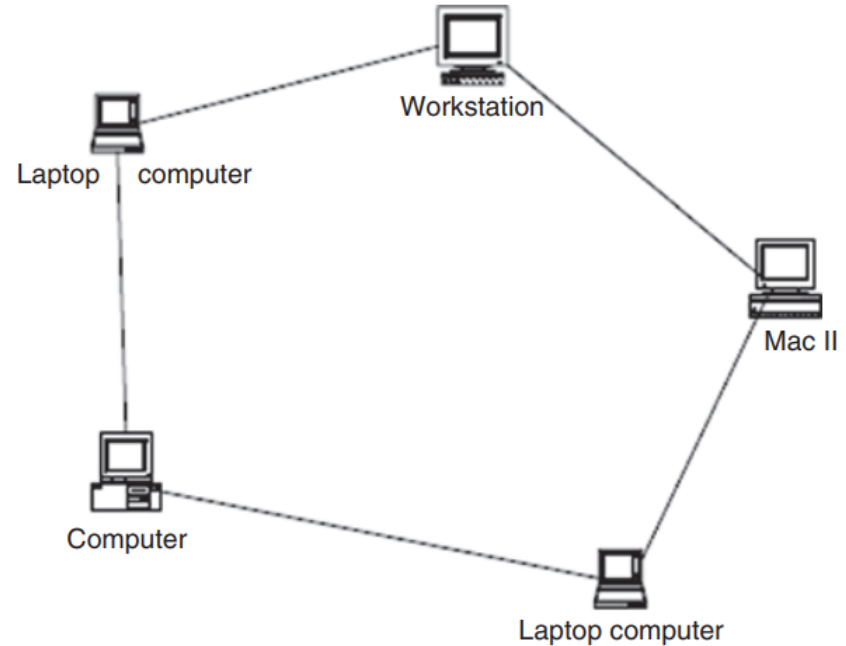
  ✓ Dependent computers called surrogates
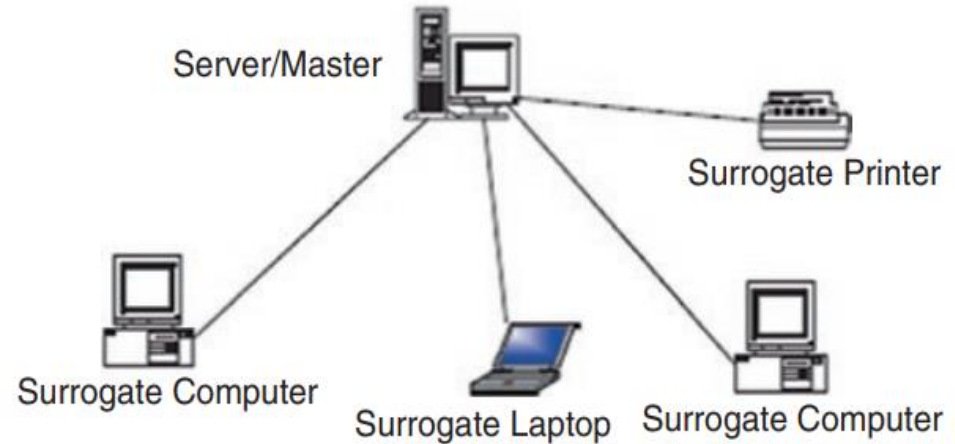
A centralized network model (Kizza, 2020, p.5)

Computer network models

- **A distributed network model**

  ✓ Computers may own their local resources

  ✓ Computers in the network can work as standalone

A distributed network model (Kizza, 2020, p.5)

Computer network models

Peer-to-peer network (P2P)

- Peer-to-peer networks are created by connecting each device together through a hub or switch.

- Each computer, codec, or access control panel is equal in the eyes of the switch.

- Any system may act as a client, a server, or both, depending on the data needs.

- The peer-to-peer network design is suitable for small networks.
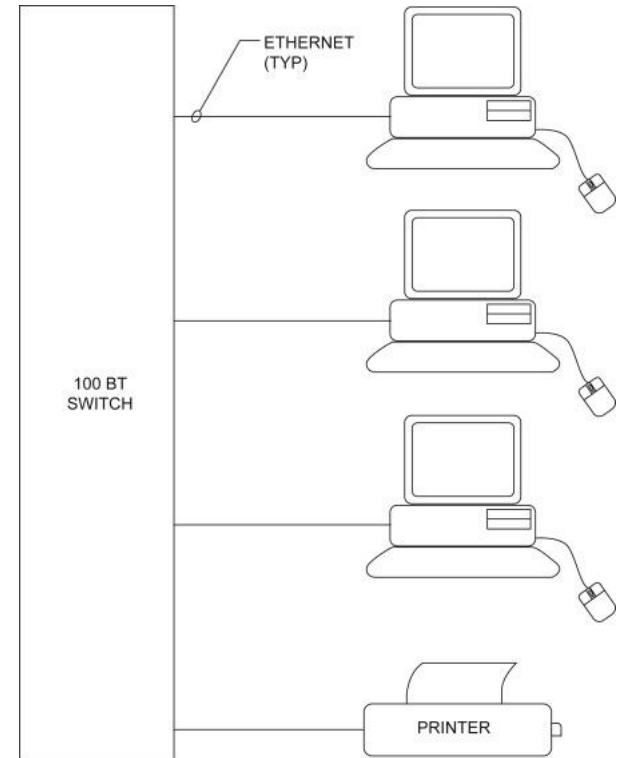
A peer-to-peer network model

Computer network models

Some of the characteristics of Peer-to-peer network

① Individual users have responsibility over who can access data and resources on their computers.

② Operating systems such as Windows XP and Windows Vista allow accounts to be set up that will be used when other users connect to an individual user's computer.

③ Accounts, passwords, and permissions are saved in a local database and are used to determine what someone can do when connecting to your computer.
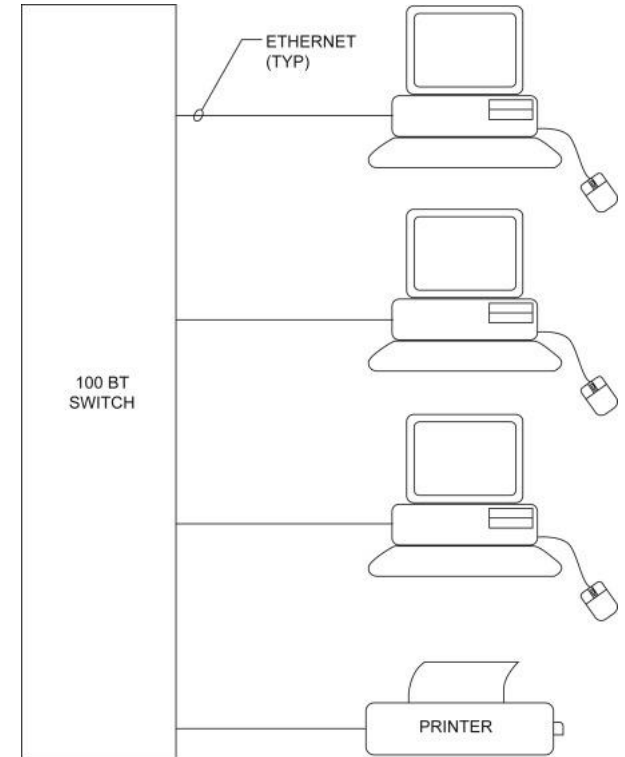
A peer-to-peer network model

Network Categories

Network categories

The network is categorized based on:
    ① Network size
    ② Network ownership
    ③ Number of connected users
    ④ The distance it covers and physical architecture
    ⑤ Available services in the area

Main categories include:
    ① Small home networks
    ② Small Office and Home Office Networks (SOHO)
    ③ Medium to Large Networks
    ④ Worldwide Networks

Local Area Network (LAN)

- LAN covers a small geographical area (few kilometers).

- It is designed mainly for sharing resources such as printers, programs, disks, and data.

- It is managed and administered by an individual or a single organization.

- It enables a high-speed bandwidth communication within the internal network.

- The common LAN types are star, bus, ring, or tree topologies.

Metropolitan Area Network (MAN)

- The MAN is designed for covering an entire city.

- It has a larger geographical scope in comparison with a LAN and can range from 10km to a few hundreds km in length.

- It may be operated and owned by a private company or a public server provider.

Wide Area Network (WAN)

- A WAN interconnects LANs that span a wide geographical area.

- It is designed for the interconnection of computer systems over large area like a continent, a country or even over the world.

- It possibly uses the public, leased or private communication devices, usually in combinations, and thus can span an unlimited number of miles.

- **The Internet** is a good example of WAN. The Internet has a connection to similar networks in other regions.

- The WAN typically has slower speed connections between LANs.

Comparison between LAN, MAN and WAN

Benchmark	LAN	MAN	WAN
Area Covered	Small geographical area (e.g., building, office)	Metropolitan area (e.g., city)	Large geographical area (e.g., cities, countries, continents)
Typical Speed	100 Mbps to multiple Gbps	Few Mbps to multiple Gbps	Varies widely, from Kbps to Gbps
Latency	Very low (microseconds to milliseconds)	Low (few milliseconds to tens of milliseconds)	High (tens to hundreds of milliseconds)
Ownership	Owned and managed by a single organization	Owned and managed by a single organization or service provider	Owned and managed by multiple service providers
Transmission Media	Ethernet cables, Wi-Fi	Fiber optic cables, wireless links	Leased lines, satellite links, public Internet
Common Technologies	Ethernet, Wi-Fi, Bluetooth	Ethernet, FDDI, ATM, SONET/SDH	PPP, Frame Relay, ATM, MPLS, Internet protocols
Security	Physical security, firewalls, VPNs, encryption	Similar to LAN, plus dedicated leased lines	Encryption, VPNs, firewalls, access control
Fault Tolerance	Redundant components, STP, LACP	Redundant links, load balancing	Multiple service providers, load balancing, BGP
Cost	Relatively low	Higher than LAN	Highest, depending on bandwidth and distance
Primary Use	Interconnecting devices within a limited area	Interconnecting LANs within a metropolitan area	Interconnecting LANs, MANs, and remote sites globally

The Internet

- LAN are connected to each other using WANs.

- WANs may use copper wires, fiber optic cables, and wireless transmissions.

- The internet is not owned by any individual or group. The following groups were developed to help maintain structure on the internet:

  - **IETF** (Internet Engineering Task Force) develops Internet standards.

  - **ICANN** (Internet Corporation For Assigned Names and Numbers) for managing domain name system and allocating IP addresses.

  - **IAB** (Internet Architecture Board) oversees the evolution of the Internet standards and protocols.

- To connect users and organization to the Internet uses broadband cable, broadband digital subscriber line (DSL), wireless WANs, and mobile services, business DSL, leased lines, and Metro Ethernet.

The Internet – Home and Small Internet Connections

| Connection	Description
Cable	high bandwidth, always on, internet offered by cable television service providers.
DSL	high bandwidth, always on, internet connection that runs over a telephone line.
Cellular	uses a cell phone network to connect to the internet.
Satellite	major benefit to rural areas without Internet Service Providers.
Dial-up telephone	an inexpensive, low bandwidth option using a modem.

Business Internet Connections

Type of Connection	Description
Dedicated Leased Line	These are reserved circuits within the service provider's network that connect distant offices with private voice and/or data networking.
Ethernet WAN	This extends LAN access technology into the WAN.
DSL	Business DSL is available in various formats including Symmetric Digital Subscriber Lines (SDSL).
Satellite	This can provide a connection when a wired solution is not available.

Network Protocol

What is a computer networking protocols?

*"A **protocol** defines the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other event."*
(Kurose, 2017, p.37)

Figure. A human protocol and a computer network protocol (Kurose, 2017, p.35)
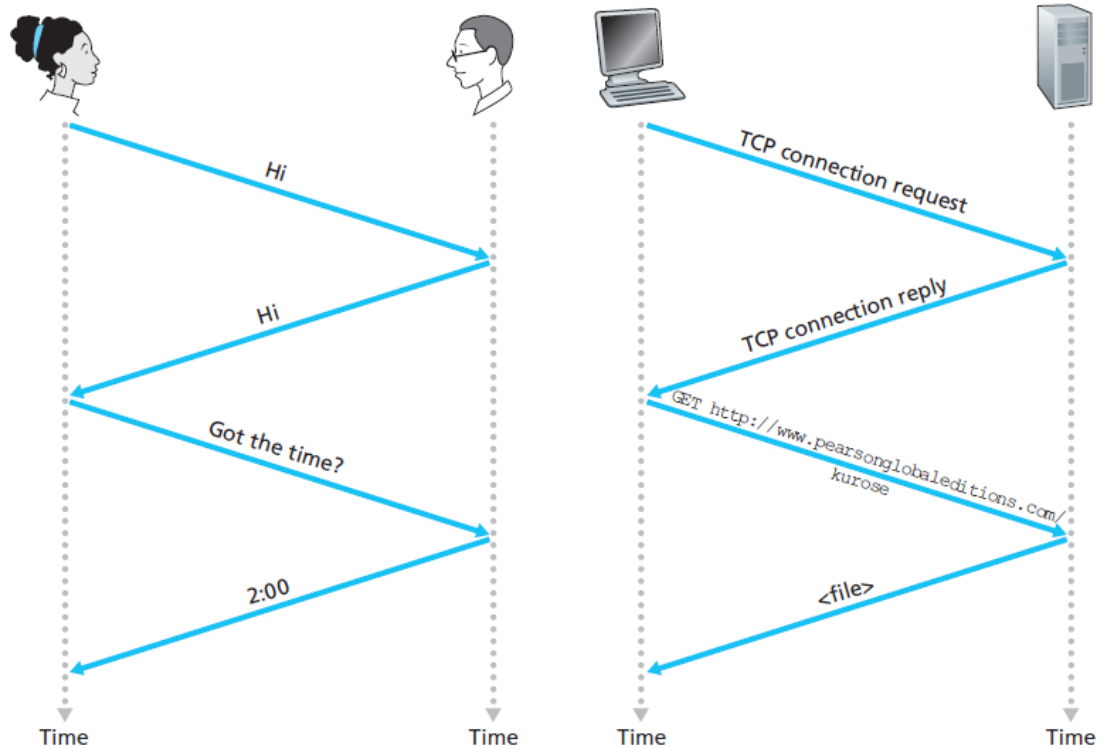
Network Protocol

- The Network protocol defines a common set of communication rules between networking devices.

- It can be implemented in hardware or software or both.

- It has its own format, rules, and functions.

- Protocol types:

    - Network communications

    - Network security

    - Routing

    - Service discovery

Network Protocol

- The Network protocol must be suitable with other protocols in the same communication channel.

- The protocol is viewed in terms of layer

    - Higher layers

    - Lower layers

Network Protocol Models

- **Internet Protocol Suite or TCP/IP**

- **Open Systems Interconnection (OSI) protocols**

- **AppleTalk**

- **Novell NetWare**

Network Protocol Models

- **Internet Protocol Suite or TCP/IP**

TCP/IP Model Layer	Description
Application	Represents data to the user, plus encoding and dialog control.
Transport	Supports communication between various devices across diverse networks.
Internet	Determines the best path through the network.
Network Access	Controls the hardware devices and media that make up the network.

Network Protocol Models

Open Systems Interconnection (OSI) protocols:
It has 7 layers.

OSI Model Layer	Description
7 - Application	Contains protocols used for process-to-process communications.
6 - Presentation	Provides for common representation of the data transferred between application layer services.
5 - Session	Provides services to the presentation layer and to manage data exchange.
4 - Transport	Defines services to segment, transfer, and reassemble the data for individual communications.
3 - Network	Provides services to exchange the individual pieces of data over the network.
2 - Data Link	Describes methods for exchanging data frames over a common media.
1 - Physical	Describes the means to activate, maintain, and de-activate physical connections.

Network Protocol Models

- ## **Comparison of the two models**

  - The OSI model divides the network access layer and the application layer of the TCP/IP model into multiple layers.

  - The TCP/IP protocol suite does not specify which protocols to use when transmitting over a physical medium.

  - OSI Layers 1 and 2 discuss the necessary procedures to access the media and the physical means to send data over a network.

Network Topology

Network Topology

The term "topology" refers to the approach in which network elements are interconnected. The common LAN topologies are as below.

- Mesh network

- Tree network

- Bus network

- Star network

- Ring network

Network Topology – Mesh Network

- Multiple access links between network devices

- Most often applied in MAN

- Advantages:
  - High reliability
  - Easy fault identification and fault isolation
  - Robust

- Disadvantages:
  - High cost with high demand for cabling
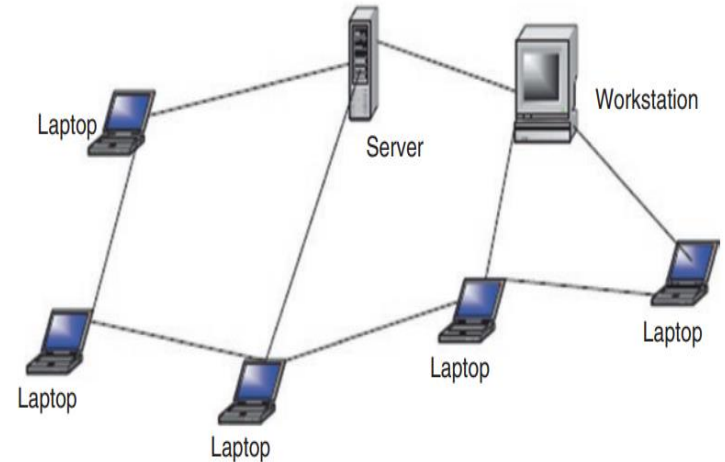 - High demands for the number of I/O ports

Figure. A distributed network model (Kizza, 2020, p.14)

Network Topology – Tree Network

- Hierarchical structure

- The most predominant element is the root of the tree and all other elements in the same network sharing a child-parent relationship.

- Advantages:
  - High reliability
  - Easy fault identification and fault isolation
  - Robust

- Disadvantages:
  - High cost with high demand for cabling
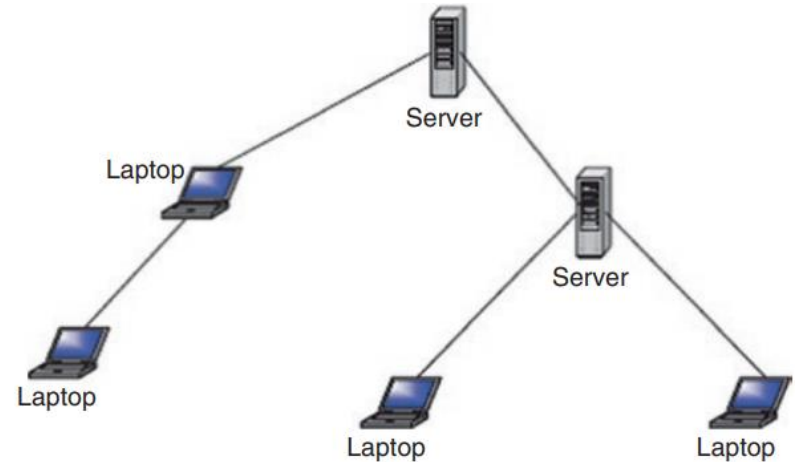 - High demands for the number of I/O ports

Figure. A distributed network model (Kizza, 2020, p.14)

Network topology – Bus Network

- A bus network is multipoint.

- One long cable acts a backbone connecting all devices in a network

- Advantages:
  - Simple, reliable and easy to use
  - Less cabling

- Disadvantages:
  - Can be used in relative small networks
  - Difficult to add new nodes
  - All network devices share the same bus
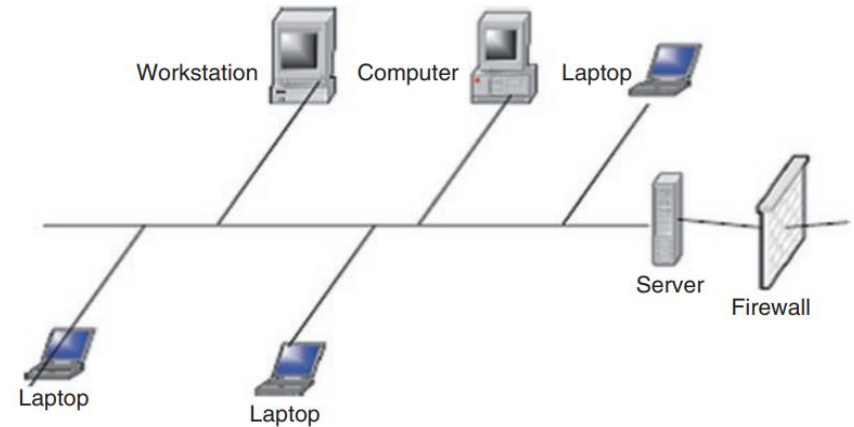 - Reconfiguration is difficult

Figure. A distributed network model (Kizza, 2020, p.15)

Network Topology – Star Network

- It needs a central node connects with other devices in the network

- The central point is referred as a **hub**.

- Advantages:
  - Easy to diagnose network faults
  - Single device failure does not affect the network
  - Easy to add new device
  - Ordinary telephone cables can be used

- Disadvantages:
  - The central hub failure causes the failure of the entire network
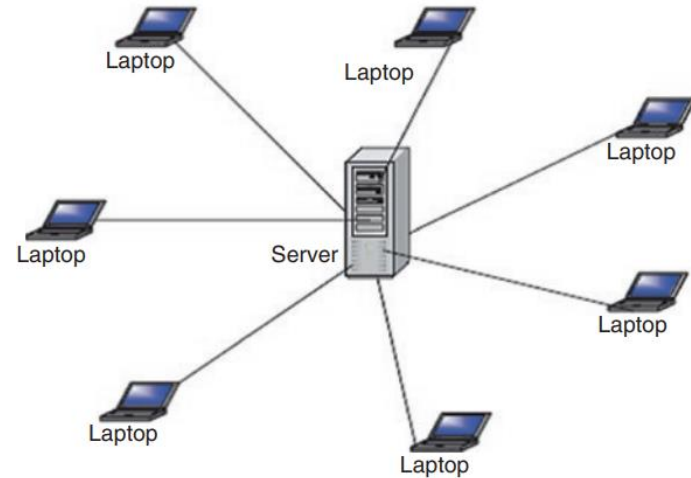

Figure. A distributed network model (Kizza, 2020, p.16)

Network Topology – Ring Network

- In the ring network, each device has a repeater

- Advantages:
  - No terminators is required
  - Fault isolation is simple

- Disadvantages:
  - A break in the ring will stop the transmission of the entire network
  - Adding/removing a device disrupts the whole network

Figure. A distributed network model (Kizza, 2020, p.16)
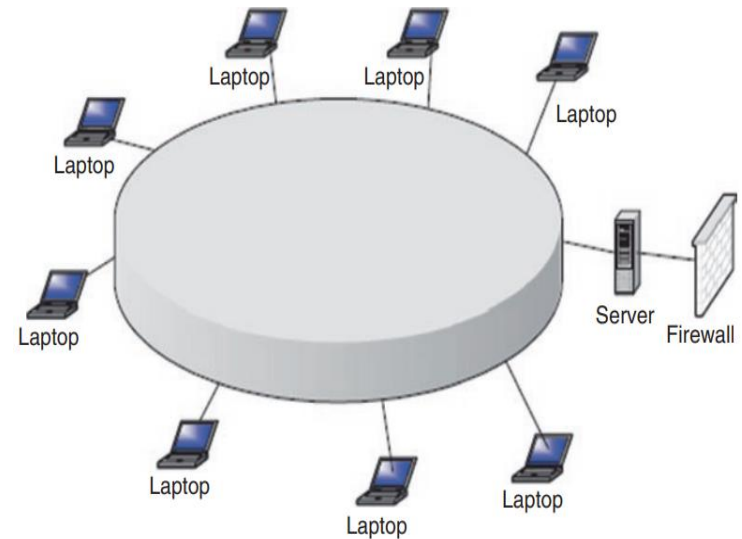
Network Topology

- Ring and mesh topologies are suitable for peer-to-peer network

- Star and tree network are more convenient for client server

- Bus network can be used for either of them.

- Different from other types of network topologies, mesh network enables multiple connections between network elements.

- The choice of network topologies is dependent on transmission medium, reliability of the network, the network size, and prediction of the future growth.

Network Addressing

Network Addressing

Address Type	Meaning
Local addresses	Addresses that are recognised locally, at the LAN or subnet. Usually at the data link layer (MAC)
Global addresses	Addresses that are recognised worldwide. Usually at the network (IP) layer
Private addresses	Network-layer addresses that are not routed through the public internet. Used in Network Address Translation
Public addresses	Network-layer addresses that are routed through the public internet.
Temporary addresses	Addresses that are assigned for a short duration. Usually through Dynamic Host Configuration Protocol (DHCP)
Persistent addresses	Addresses that are assigned for a long duration of time or permanently configured

Network Performance

Network Performance Metrics

➢ **Fault Tolerance:** limits the failures in the network connections

➢ **Scalability:** enable future expanding the network capacity

➢ **Quality of Service (QoS):** ensure the quality to services like voice or video transmissions

➢ **Security:** secure the network connections with three goals as confidentiality, integrity, and availability

References and Reading

❖ **Chapter 1** - Kizza, J. M. (2020). Computer Network Fundamentals. In J. M. Kizza (Ed.), *Guide to Computer Network Security* (pp. 3-40). Cham: Springer International Publishing. *(Available online via UOW library)*

❖ **Chapter 1 -** Kurose, J. F. (2017). *Computer networking : a top-down approach* (Seventh, global edition. ed.). Boston: Pearson.

❖ **Chapter 4** - Shinde, S. (2000). *Computer network*. New Age International Ltd.

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