Lecture 1

INTRODUCTION TO COMPUTER NETWORKS

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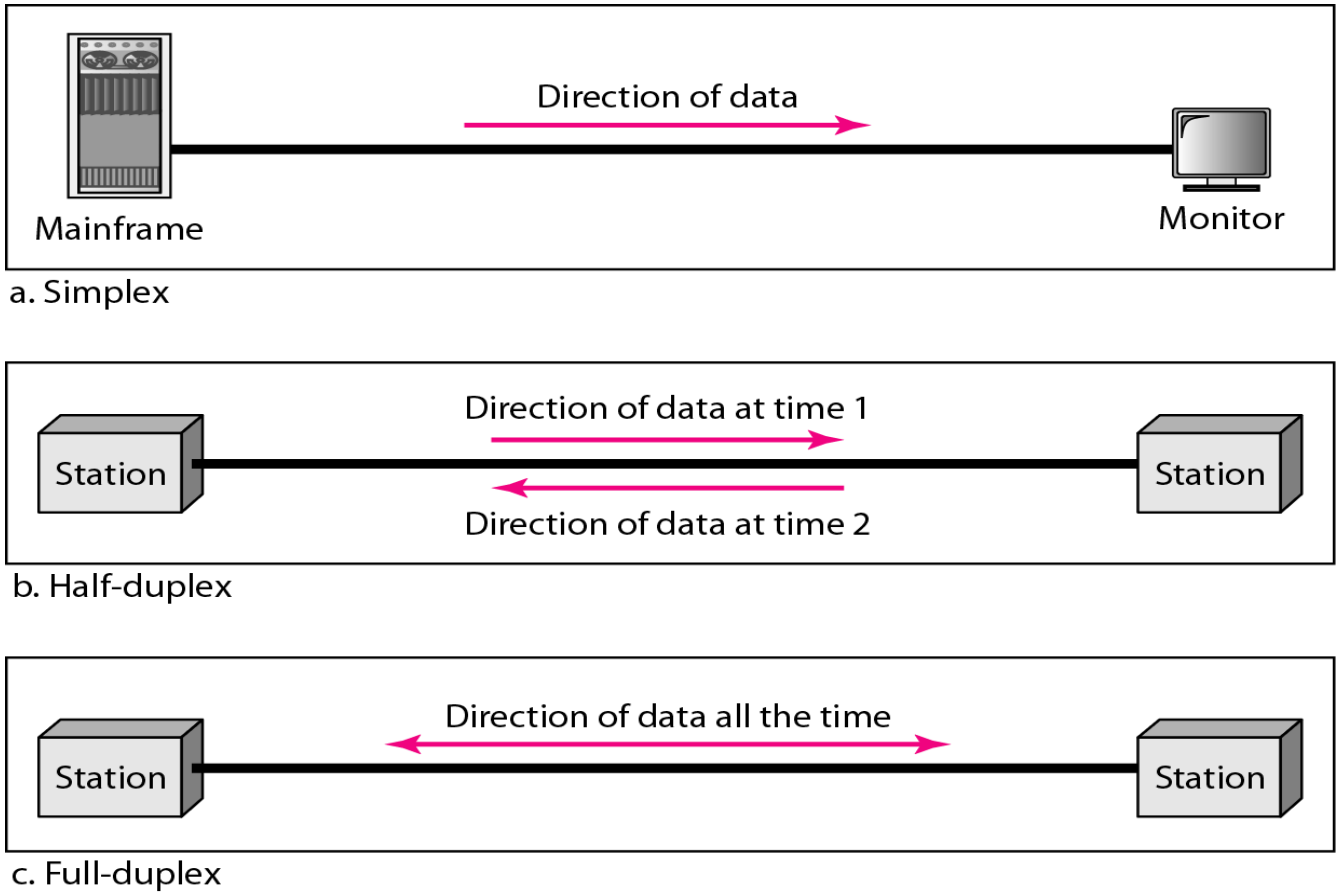
What is a Network?

A network is a set of devices (nodes) connected by communication links. A node can be a computer, printer, CCTV cameras or any other device capable of sending and/or receiving data generated by other nodes on the network. A link can be a cable, air, optical fiber, or any medium which can transport a signal carrying information.

Why we need Networking?

- **Sharing information**
- **Sharing hardware or software.**
- **Centralize administration and support.**

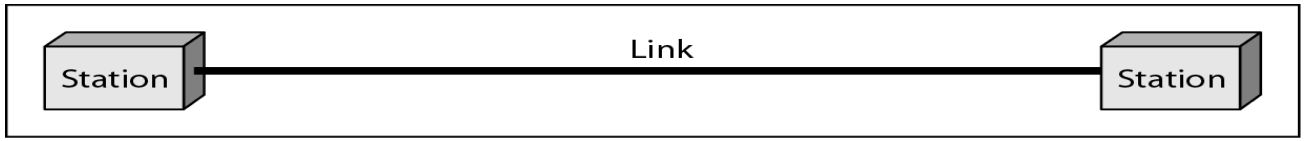
Data flow (simplex, half-duplex, and full-duplex)



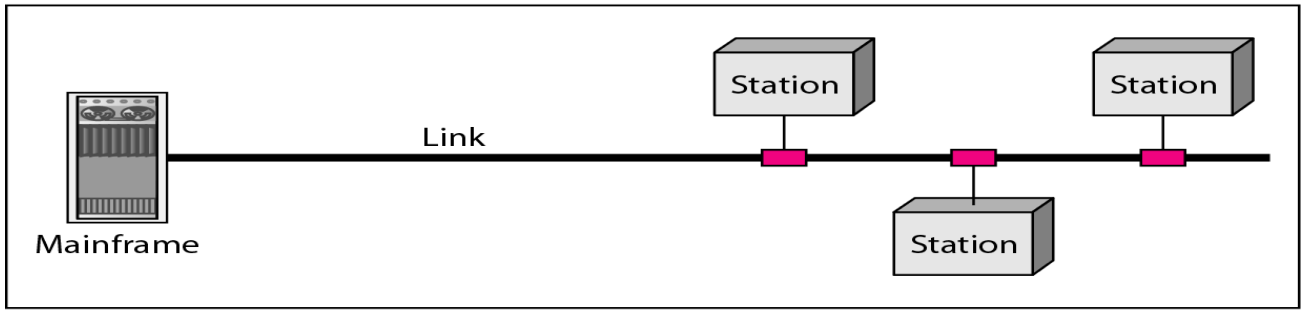
Simplex : one way like radio broadcast, Paging system satellite broadcasting.
Half-duplex: two-way of communication Like: walky-talky,
Full: like cellular system, Telephone.

Physical Structures

- **Type of Connection**
  - **Point to Point - single transmitter and receiver**
  - **Multipoint - multiple recipients of single transmission**



a. Point-to-point



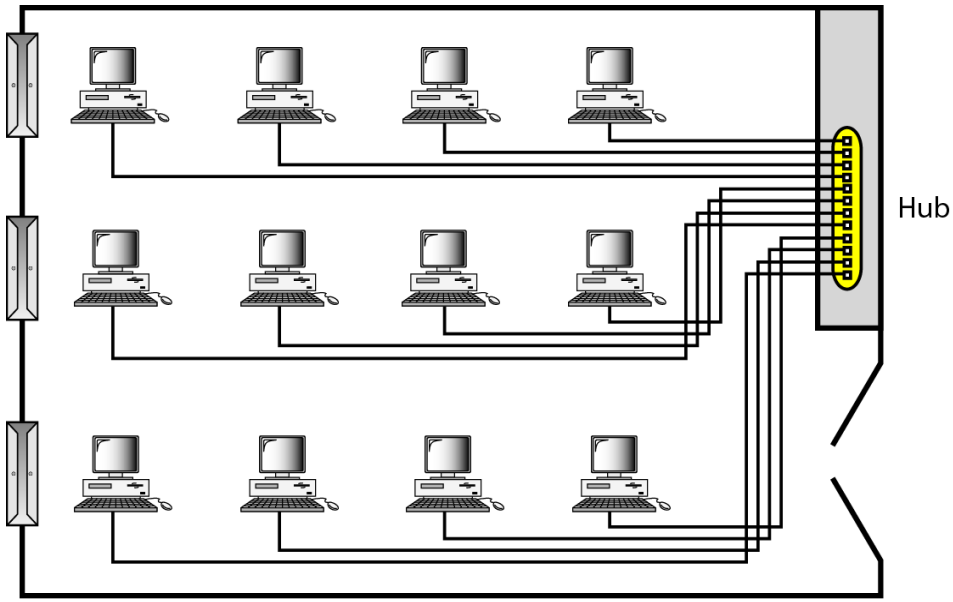
b. Multipoint

How many kinds of Networks?

- **we can classify networks in different ways:**
- **Based on network size: LAN and WAN (and MAN)**
- **Based on management method: Peer-to-peer and Client/Server**
- **Based on topology (connectivity): Bus, Star, Ring ..**
- **Based on transmission media: Wired (UTP, coaxial cables, fiber-optic cables) and Wireless**

Network Size

- **Local Area Network (LAN)**
  - **Small network, short distance suitable for a room, a floor, and building. It is limited by number of computers and distance covered or serve a department within an organization**
  - **Examples: Network inside your home**



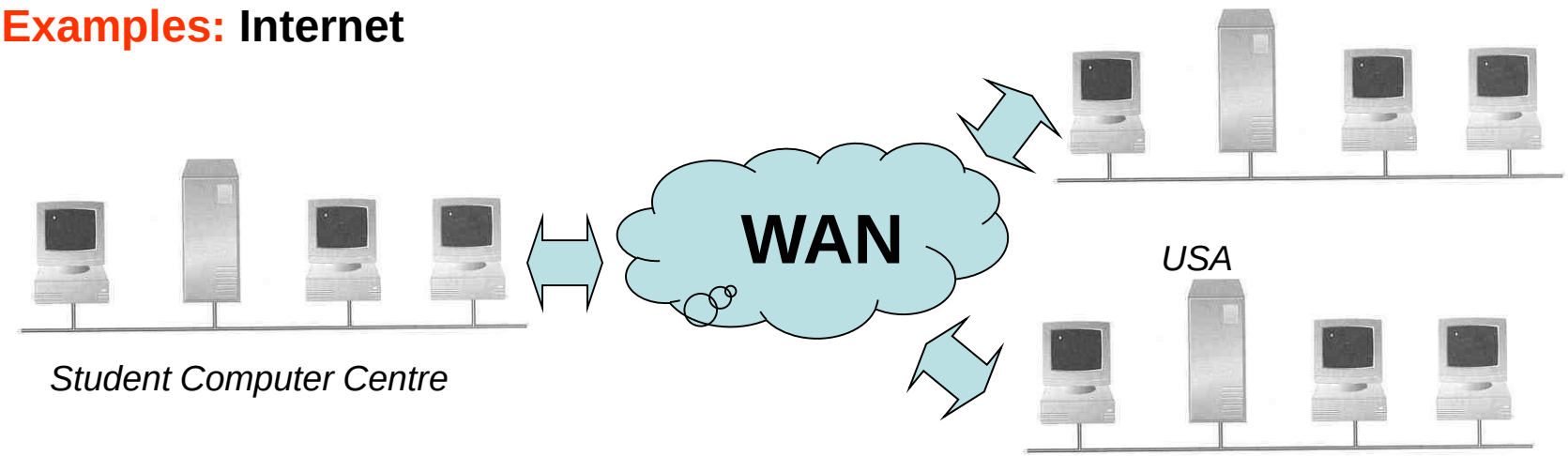
An isolated LAN connecting 12 computers to a hub

Network Size

A metropolitan area network (MAN) is a network that interconnects users with computer resources in a geographic area or region larger than that covered by LAN but smaller than the WAN. The term is applied to the interconnection of networks in a city into a single larger network. It is also used to mean the interconnection of several local area networks by bridging them with backbone lines.

Wide Area Network (WAN)

- **A network that uses long-range telecommunication links to connect 2 or more LANs/computers housed in different places far apart.**
  - **Towns, states, countries**
- **Examples: Internet**



Network Size

- **Example WAN technologies:**
  - **ISDN – Integrated Service Digital Network**
    - **Basic rate: 192 Kbps Primary rate: 1.544Mbps**
  - **T-Carriers — basically digital phone lines**
    - **T1: 1.544Mbps T3: 28×T1**
  - **Frame relay**
    - **Each link offers 1.544Mbps or even higher**
  - **ATM – Asynchronous Transfer Mode**
    - **Support : 155Mbps or 622Mbps or higher**
  - **SONET – Synchronous Optical Network**
    - **Basic rate OC1: 51.84Mbps**
    - **Support OC12 and up to OC192 (9953.28Mbps) or even higher in the future**

Peer-to-Peer Networks

- **No hierarchy among computers ⇒ all are equal.**
- **No administrator responsible for the network.**

- **Where peer-to-peer network is appropriate:**
  - **10 or less users**
  - **Security is not an issue**
  - **Only limited growth in the future**

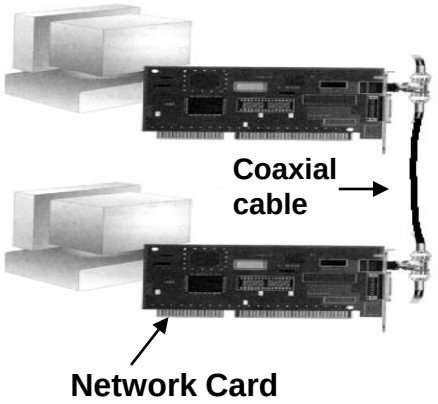
Clients and Servers

- Network Clients (Workstation)
  - Computers that request network resources or services
- Network Servers
  - Computers that manage and provide network resources and services to clients.
    - Usually have more processing power, memory and hard disk space than clients.
    - Run Network Operating System that can manage not only data, but also users, groups, security, and applications on the network.

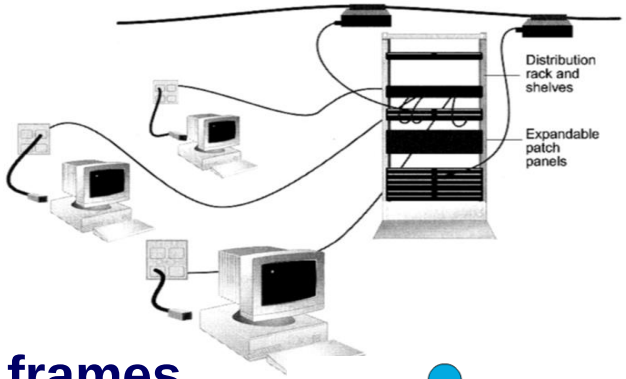
- Advantages of client/server networks
  - Enhance security – only administrator can have access to Server.
  - Support more users – difficult to achieve with peer-to-peer networks

Network Topology

- **Bus Topology**
  - Simple and low-cost
  - A single cable called a trunk (backbone, segment)
  - Only one computer can send messages at a time

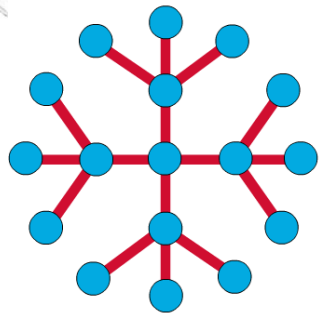


- **Star Topology**
  - Each computer has a cable connected to a single point
  - All signals transmission through the hub; if down, entire network down.



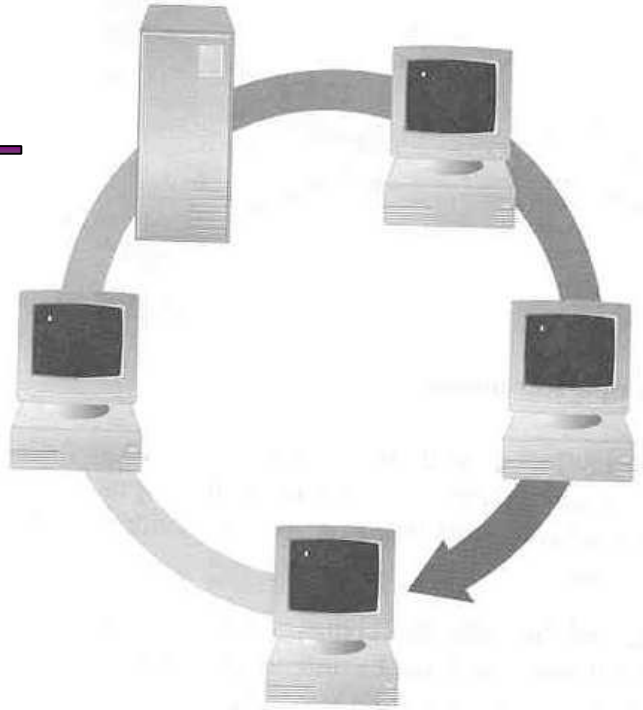
Extended Star or Tree Topology

- When used with network devices that filter frames or packets, like bridges, switches, and routers, this topology significantly reduces the traffic on the wires by sending packets only to the wires of the destination host.



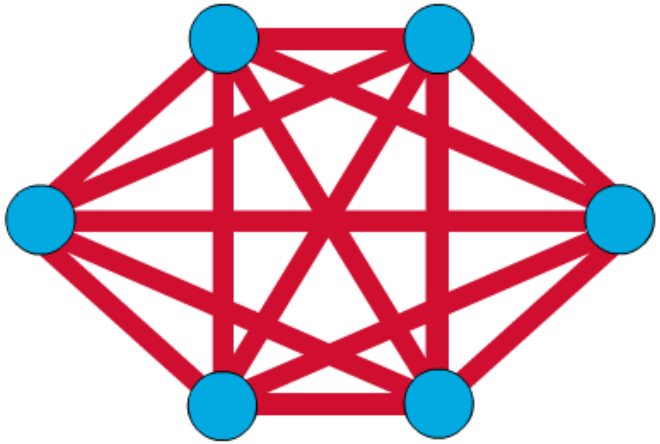
Ring Topology

- Every computer serves as a repeater to boost signals
- Typical way to send data:
  - Difficult to add computers
  - If one computer fails, whole network fails



Mesh Topology

- The mesh topology connects all devices (nodes) to each other for redundancy and fault tolerance.
- Implementing the mesh topology is expensive and difficult.

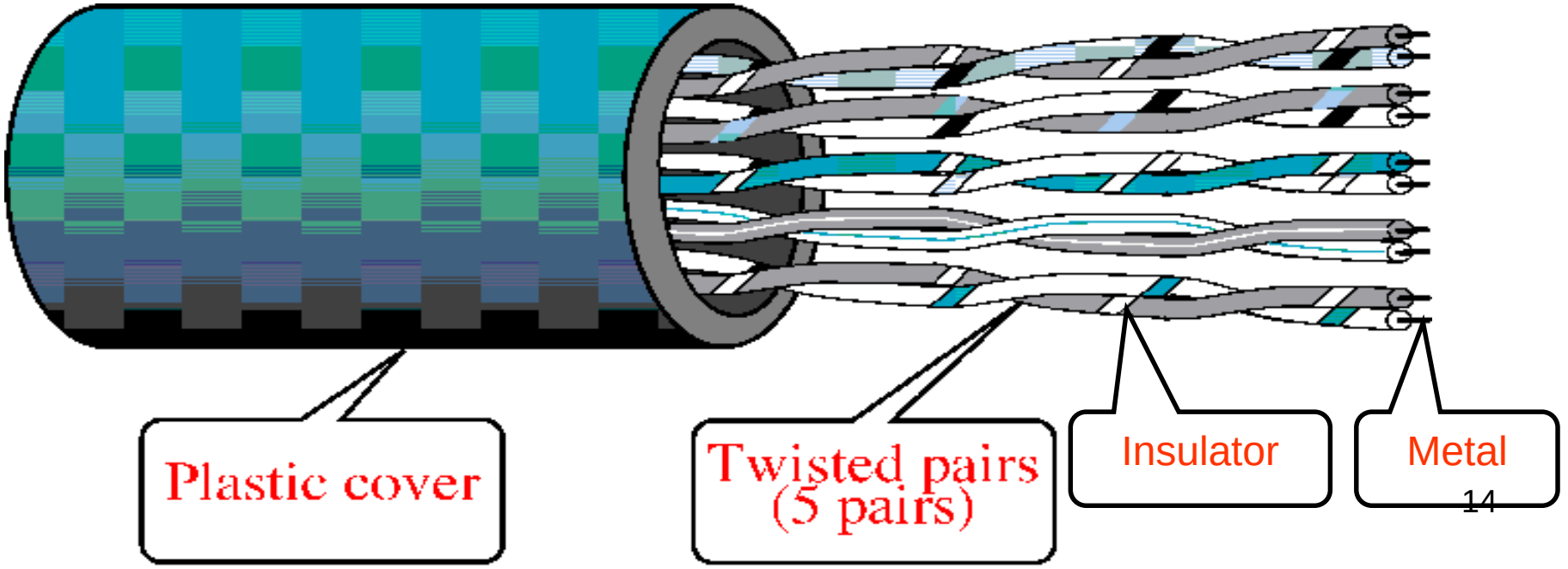


Transmission Media

- **Two main categories:**
  - **Guided — wires, cables**
  - **Unguided — wireless transmission, e.g. radio, microwave, infrared, sound, sonar**
- **We will concentrate on guided media here:**
  - **Twisted-Pair cables:**
    - **Unshielded Twisted-Pair (UTP) cables**
    - **Shielded Twisted-Pair (STP) cables**
  - **Coaxial cables**
  - **Fiber-optic cables**

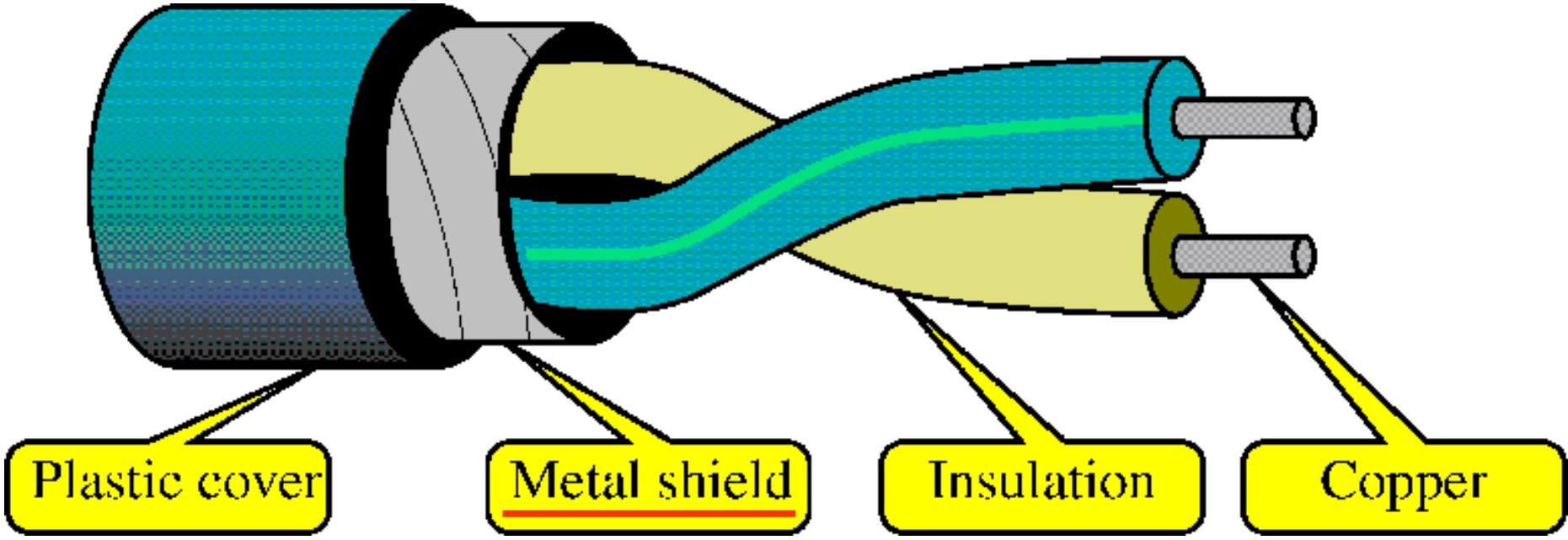
Unshielded Twisted-Pair (UTP)

- **Typically wrapped inside a plastic cover (for mechanical protection)**
- **A sample UTP cable with 5 unshielded twisted pairs of wires**



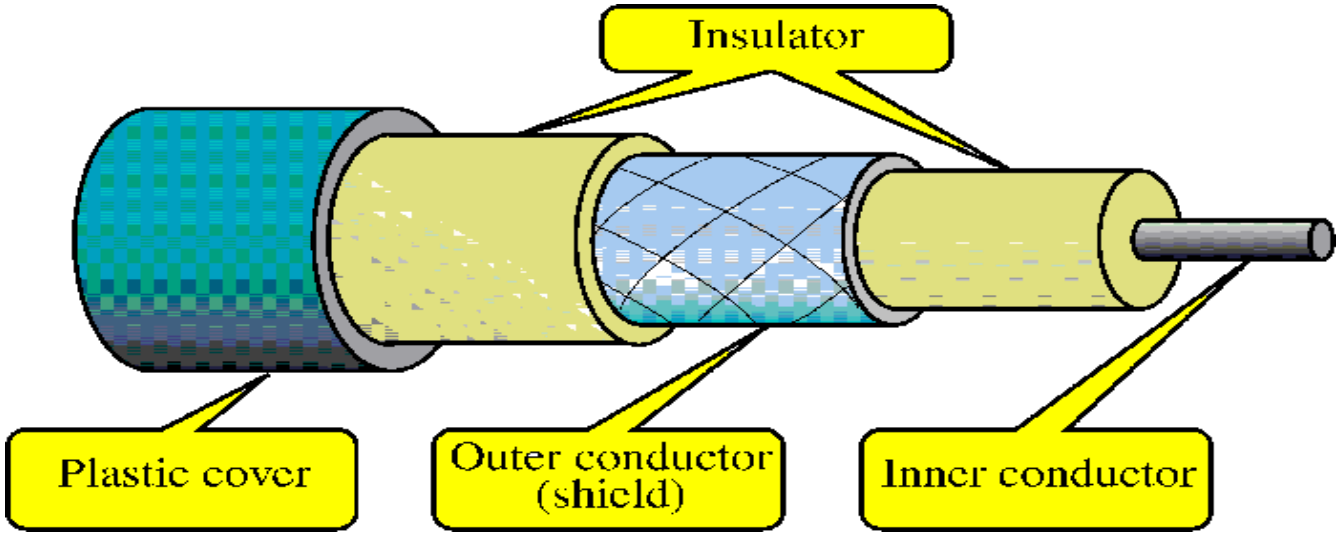
Shielded Twisted-Pair (STP)

- **STP cables are similar to UTP cables, except there is a metal foil or braided-metal-mesh cover that encases each pair of insulated wires**



Coaxial Cables

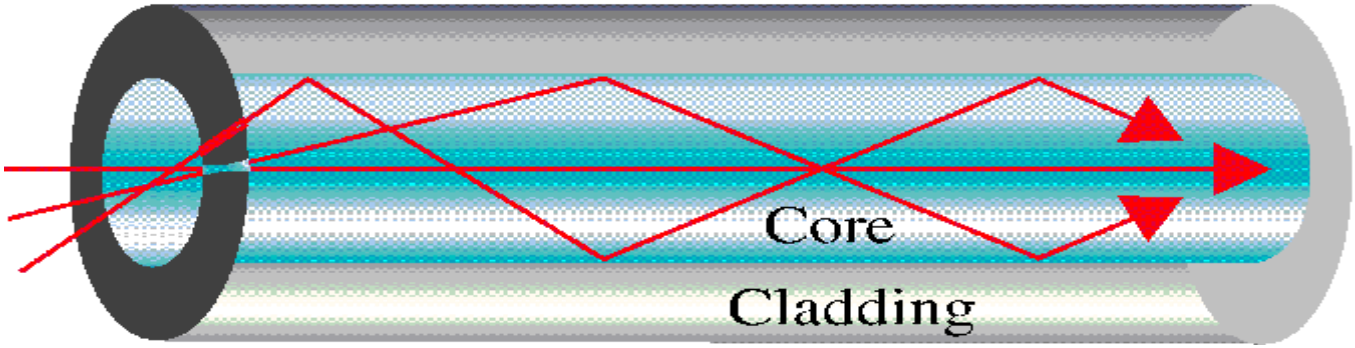
- In general, coaxial cables, or coax, carry signals of 100KHz–500MHz, and speed of up to 10Mbps.
- Outer metallic wrapping serves as a shield against noise.
- Advantage: It is very resistant to Electromagnetic Interference, easy to cut it and adjust the size.
- Disadvantage: not supported by fast Internet standard, more expensive.



Fiber-Optic Cables

- **Light travels at $3\times10^{8}\ ms^{-1}$ in free space and is the fastest possible speed in the Universe**
- **Light slows down in denser media, e.g. glass**
- **Refraction occurs at interface, with light bending away from the normal when it enters a less dense medium.**
- **We have also Diffraction and Reflection.**

- **An optical fiber consists of a core (denser material) and a cladding (less dense material).**
- **Simplest one is Single mode (with single path 10 Microns).**
- **Multimode 50-100 Microns = multiple paths, whereas step-index = refractive index follows a step-function profile (i.e. an abrupt change of refractive index between the core and the cladding).**
- **Light bounces back and forth along the core.**
- **Common light sources: LEDs and lasers**



Advantages and Disadvantages

- ☺ Noise resistance — external light is blocked by outer jacket
- ☺ Less signal attenuation — a signal can run for miles without regeneration (currently, the lowest measured loss is about ~4% or 0.16dB per km)
- ☺ Higher bandwidth — currently, limits on data rates come from the signal generation/reception technology, not the fiber itself
- ☹ Cost — Optical fibers are expensive
- ☹ Installation/maintenance — any crack in the core will degrade the signal, and all connections must be perfectly aligned

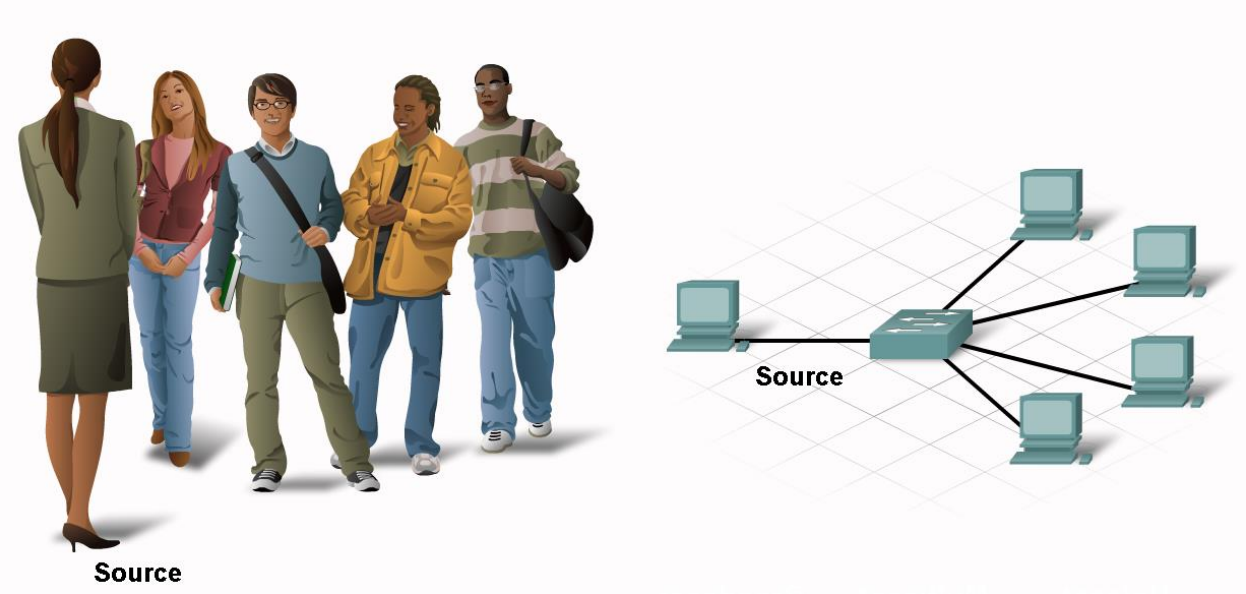
Communication Protocols

Message Patterns

Unicast – single destination

Multicast – same message to a group

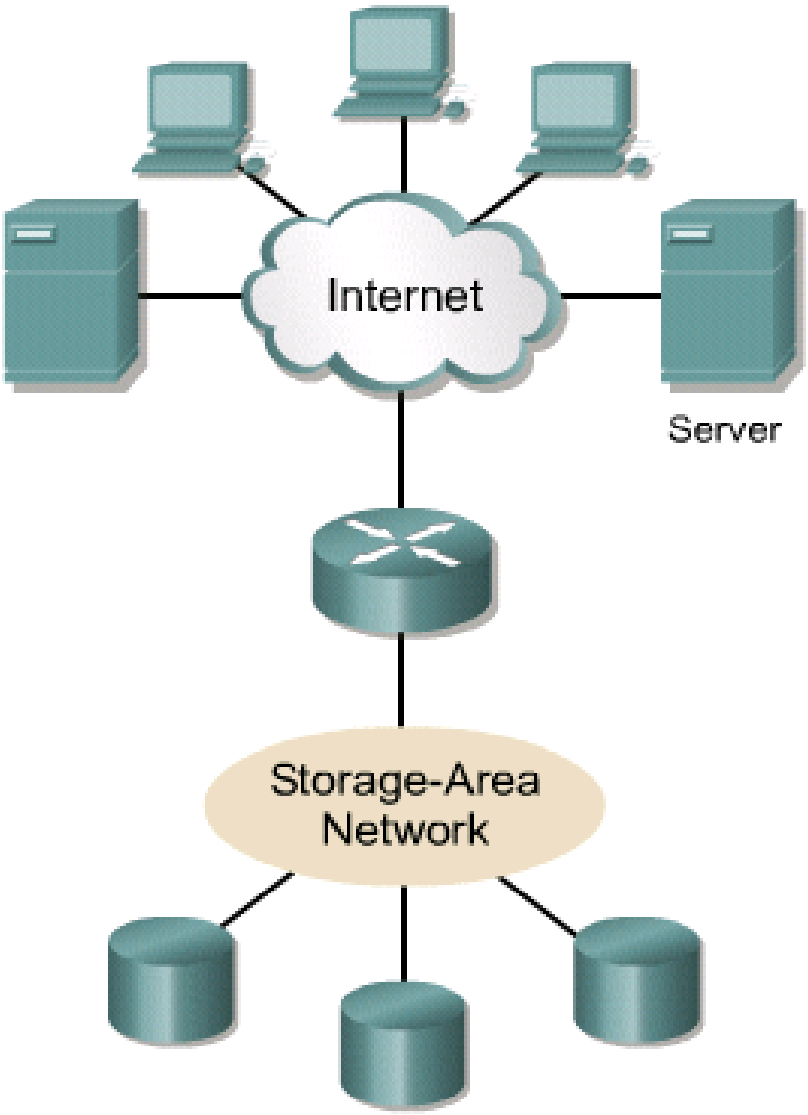
Broadcast – all hosts need to receive the message



Storage-Area Networks (SANs)

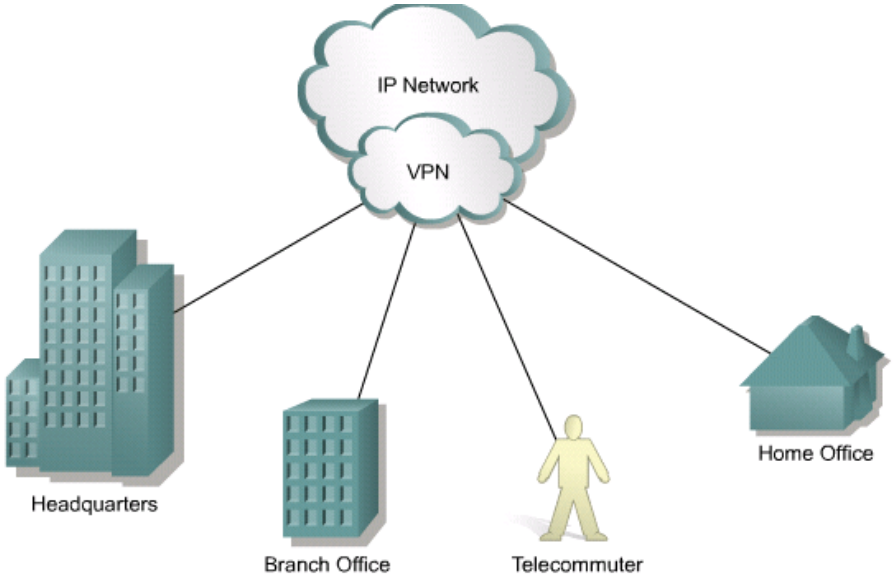
- A SAN is a dedicated, high-performance network used to move data between servers and storage resources.
- Separate, dedicated network, that avoids any traffic conflict between clients and servers
- SANs offer the following features:
  - **Performance** – allows concurrent access of disk or tape arrays by two or more servers at high speeds
  - **Availability** – have disaster tolerance built in, because data can be mirrored using a SAN up to 10km or 6.2 miles away.
  - **Scalability** – Like a LAN/WAN, it can use a variety of technologies. This allows easy relocation of backup data, operations, file migration, and data replication between systems.

SAN



Virtual private network (VPN)

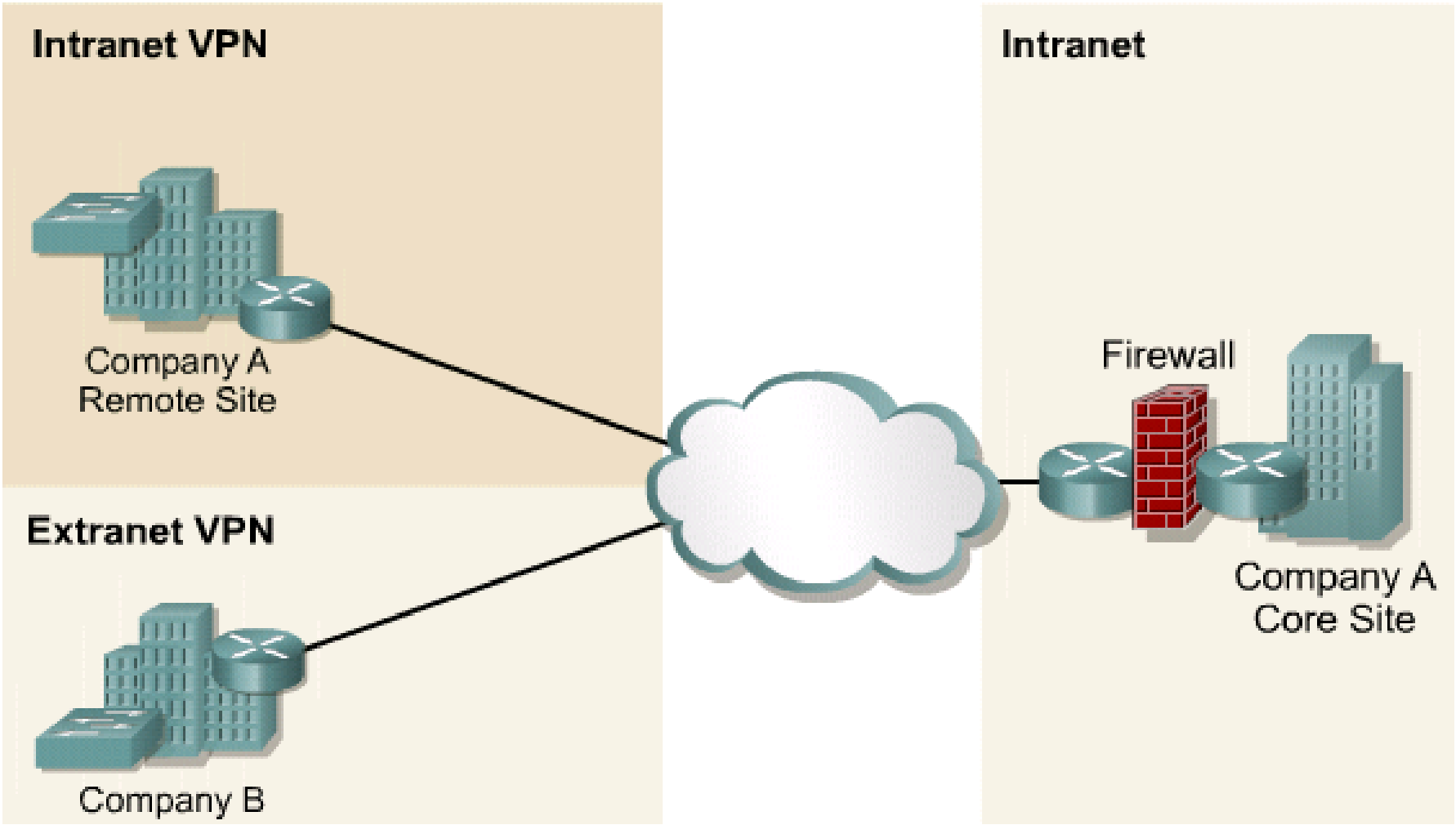
- A VPN is a private network that is constructed within a public network such as the Internet.
- It offers secure, reliable connectivity over a shared public network infrastructure such as the Internet.
- A telecommuter can access the network of the company through the Internet by building a secure tunnel between the telecommuter's PC and a VPN router in the company



Benefits of VPNs

- Three main types of VPNs:
  - **Access VPNs** – provide remote access to a mobile worker and a SOHO to the hq of the Intranet or Extranet over a shared infrastructure.
  - **Intranet VPNs** – link regional and remote offices to the hq of the internal network over a shared infrastructure using *dedicated connections*. They allow access only to the employees of the enterprise.
  - **Extranet VPNs** – link business partners to the hq of the network over a shared infrastructure using *dedicated connections*. They allow access to users outside the enterprise

Intranets and extranets



Importance of bandwidth

- Bandwidth is the amount of information that can flow through a network connection in a given period of time.
- **Bandwidth is finite**
  - the bandwidth of a modem is limited to about 56 kbps by both the physical properties of twisted-pair phone wires and by modem technology
- **Bandwidth is not free**
  - For WAN connections bandwidth is purchased from a service provider
- A key factor in analyzing network performance and designing new networks
- The demand for bandwidth is ever increasing

Measurement

- In digital systems, the basic unit of bandwidth is bits per second (bps)
- The actual bandwidth of a network is determined by a combination of the physical media and the technologies chosen for signaling and detecting network signals

Typical Media	Maximum Theoretical Bandwidth	Maximum Theoretical Distance
50-Ohm Coaxial Cable (10BASE2 Ethernet; Thinnet)	10 Mbps	185 m
50-Ohm Coaxial Cable (10BASE5 Ethernet; Thicknet)	10 Mbps	500 m
Category 5 Unshielded Twisted Pair (UTP) (10BASE-T Ethernet)	10 Mbps	100 m
Category 5 Unshielded Twisted Pair (UTP) (100BASE-TX Ethernet)	100 Mbps	100 m
Category 5 Unshielded Twisted Pair (UTP) (1000BASE-TX Ethernet)	1000 Mbps	100 m
Multimode Optical Fiber (62.5/125mm) (100BASE-FX Ethernet)	100 Mbps	2000 m
Multimode Optical Fiber (62.5/125mm) (1000BASE-SX Ethernet)	1000 Mbps	220 m
Multimode Optical Fiber (50/125mm) (1000BASE-SX Ethernet)	1000 Mbps	550 m

Limitations

- Bandwidth is limited by a number of factors
  - Media
  - Network devices
  - Physics
- Each have their own limiting factors
- Actual bandwidth of a network is determined by a combination of the physical media and the technologies chosen for signaling and detecting network signals

Throughput

- Throughput is the actual, measured, bandwidth, at a specific time of day, using specific internet routes, while downloading a specific file. The throughput is often far less than the maximum bandwidth
- Factors that determine throughput:
  - Internetworking devices
  - Type of data being transferred
  - Network topology
  - Number of users on the network
  - User computer
  - Server computer

Data transfer calculation

Best Download

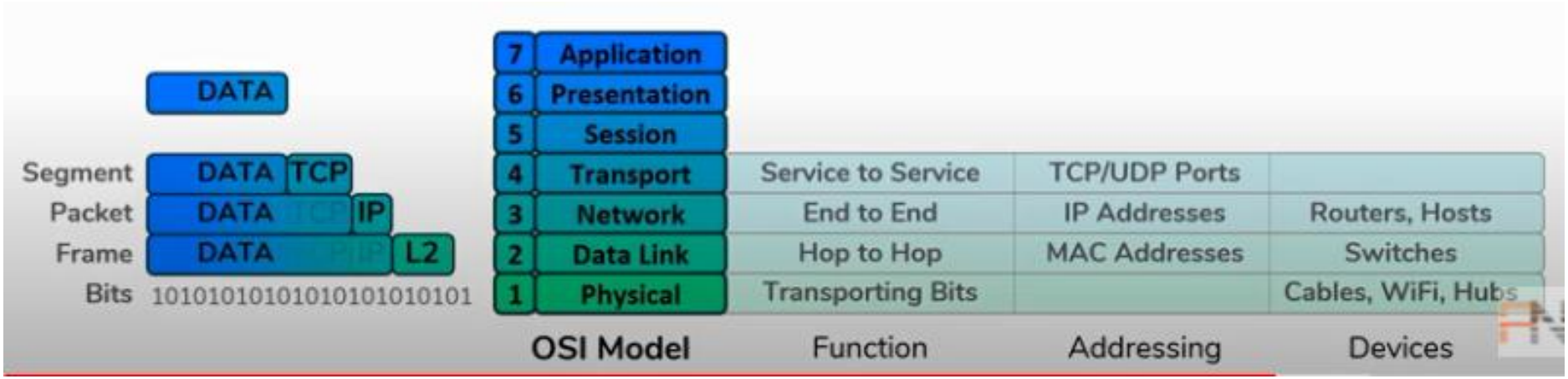
$$T = \frac{S}{BW}$$

Typical Download

$$T = \frac{S}{P}$$

BW	Maximum theoretical bandwidth of the "slowest link" between the source host and the destination host (measured in bits per second)
P	Actual throughput at the moment of transfer (measured in bits per second)
T	Time for file transfer to occur (measured in seconds)
S	File size in bits

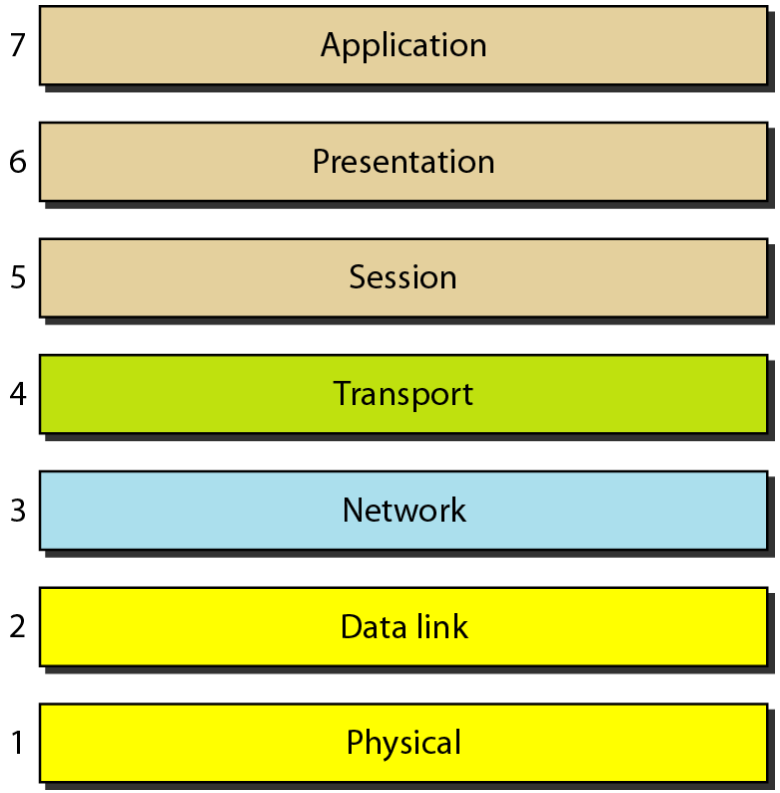
Network Models



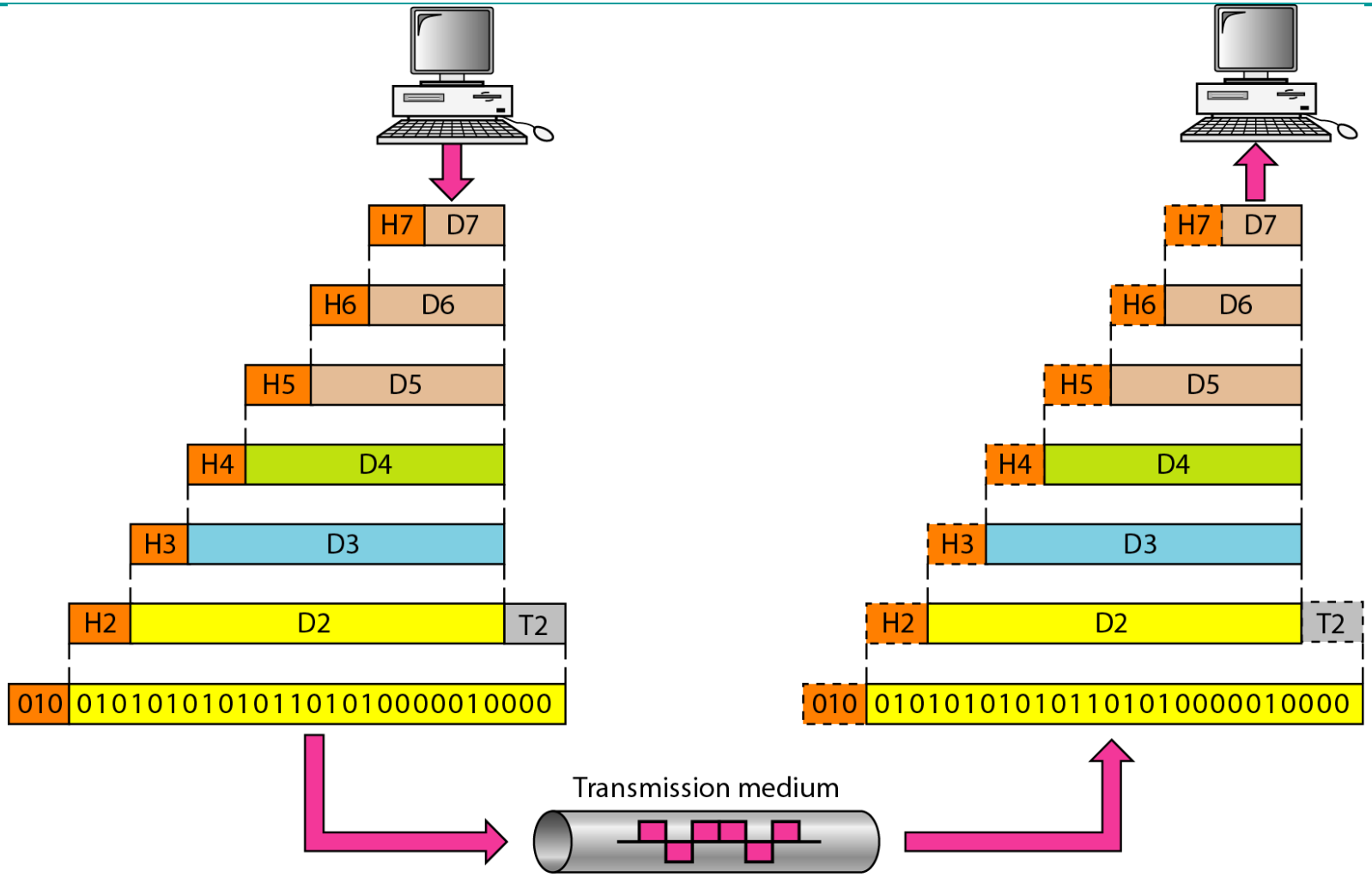
THE OSI MODEL

Established in 1947, the International Standards Organization (ISO). An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model. It was first introduced in the late 1970s.

Seven layers of the OSI model



An exchange using the OSI model

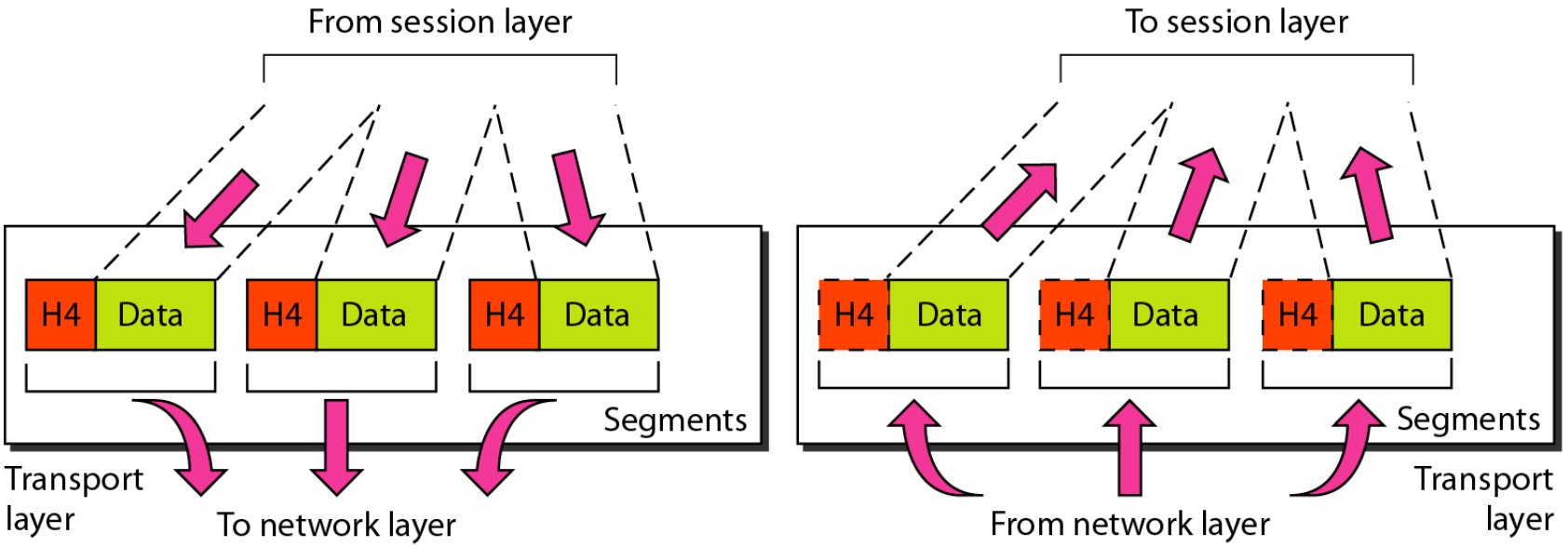


The data link layer is responsible for moving frames from one hop (node) to the next.

Network layer:

The network layer is responsible for the delivery of individual packets from the source host to the destination host.

Transport layer:

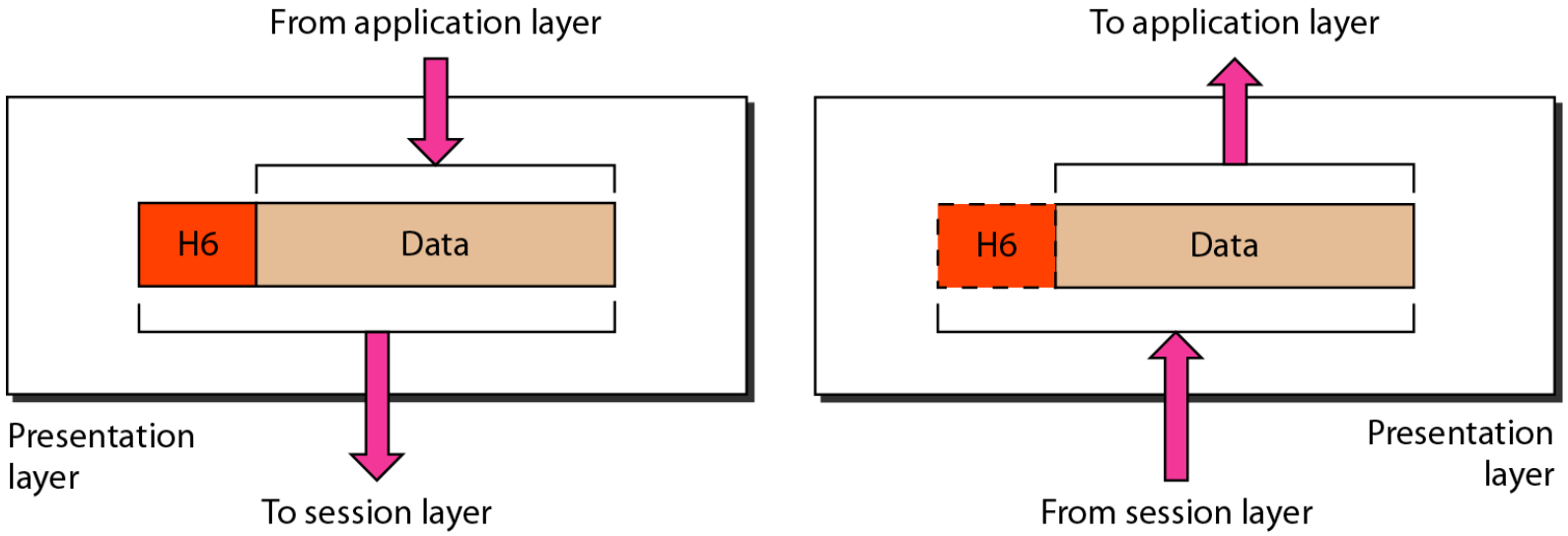


The transport layer is responsible for the delivery of a message from one process to another.

Session layer:

The session layer is responsible for dialog control and synchronization.

Presentation layer:



The presentation layer is responsible for translation, compression, and encryption.

Application layer:

The application layer is responsible for providing services to the user.

Summary of layers