COP4635: Systems & Network II

Course Overview

Tomsho *et al.*, Guide to Networking Essentials,
Kurose and Ross, Computer Networking: A Top-Down Approach,
Tanenbaum and Wetherall, Computer Networks

Instructor

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See syllabus for office hours

Instructor Expectations

- Must attend class regularly.
  - take notes and ask plenty of questions
- Must complete all projects and homework assignments.
  - all projects are critical to develop a deeper understanding of the subject
  - homework assignments provide critical feedback on your understanding of theoretical topics
- Must complete assigned readings.
- Must prepare exceptionally well for exams.

Overview of Computer Networks

- Definition and benefits of networking.
- Network types and structures.
- Network protocols.
  - OSI Reference Model
- Network Application Architectures.

What is a Computer Network?

- Definition: A collection of computers and devices that are physically connected to each other via a wired or wireless medium.

- Network sizes may vary from home networks to the Internet.
  - Home network may include 2 computers and a printer.
  - Internet includes millions of computers and other network devices.

Overview of Network Components

- Active components:
  - Routers and switches for distributing data packages.
  - Network interface cards for connecting computers and devices to networks.

- Passive components
  - Twisted pair network cables, coax cables, fiber-optic cables, …
  - Patch panels

Motivation for Building Computer Networks

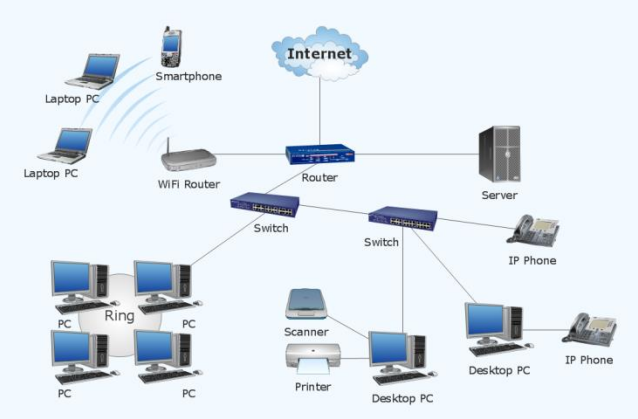
- Resource distribution and sharing
  - files and devices such as printers or scanners may be shared
  - personal files can be accessed from remote locations
- Communication between hosts
  - message passing between hosts supporting information exchange and services (e.g. email, e-learning, Web, etc.)
- Distributed computing
  - computers in network may solve a computing problem jointly (e.g. Seti@home, …)
- Improved reliability
  - replication of data across a network aids in securing data access should individual hosts storing the data fail

Network Types

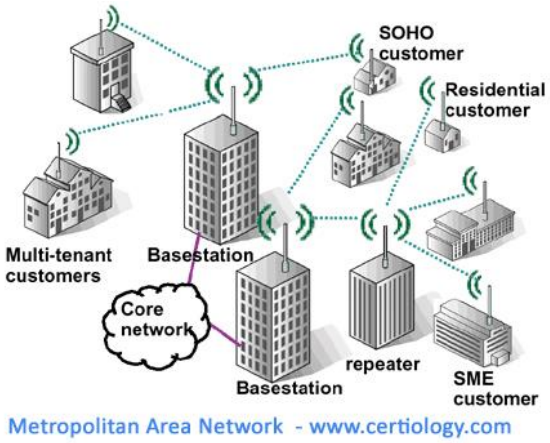
- Local-Area Network (LAN)
  - Usually covers one building (sometimes a few nearby buildings or a campus)
  - Links multiple computers and devices
  - Can be very fast (e.g. Gigabit Ethernet)
- Metropolitan-Area Network (MAN)
  - Usually covers the area of a city or a small geographical region
  - Links multiple LANs within a geographical region
  - Speed varies between 30 to 150 Mbits/sec.

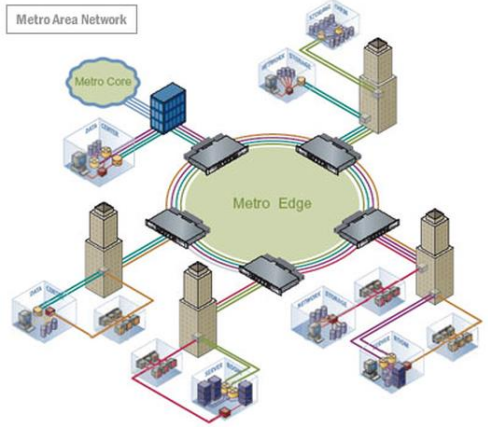
Network Types

- Local-Area Network (LAN)



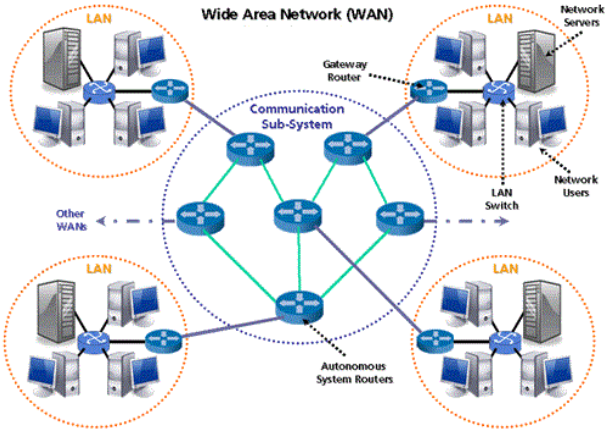
- Metropolitan-Area Network (MAN)





Network Types

- Wide-Area Network (WAN)

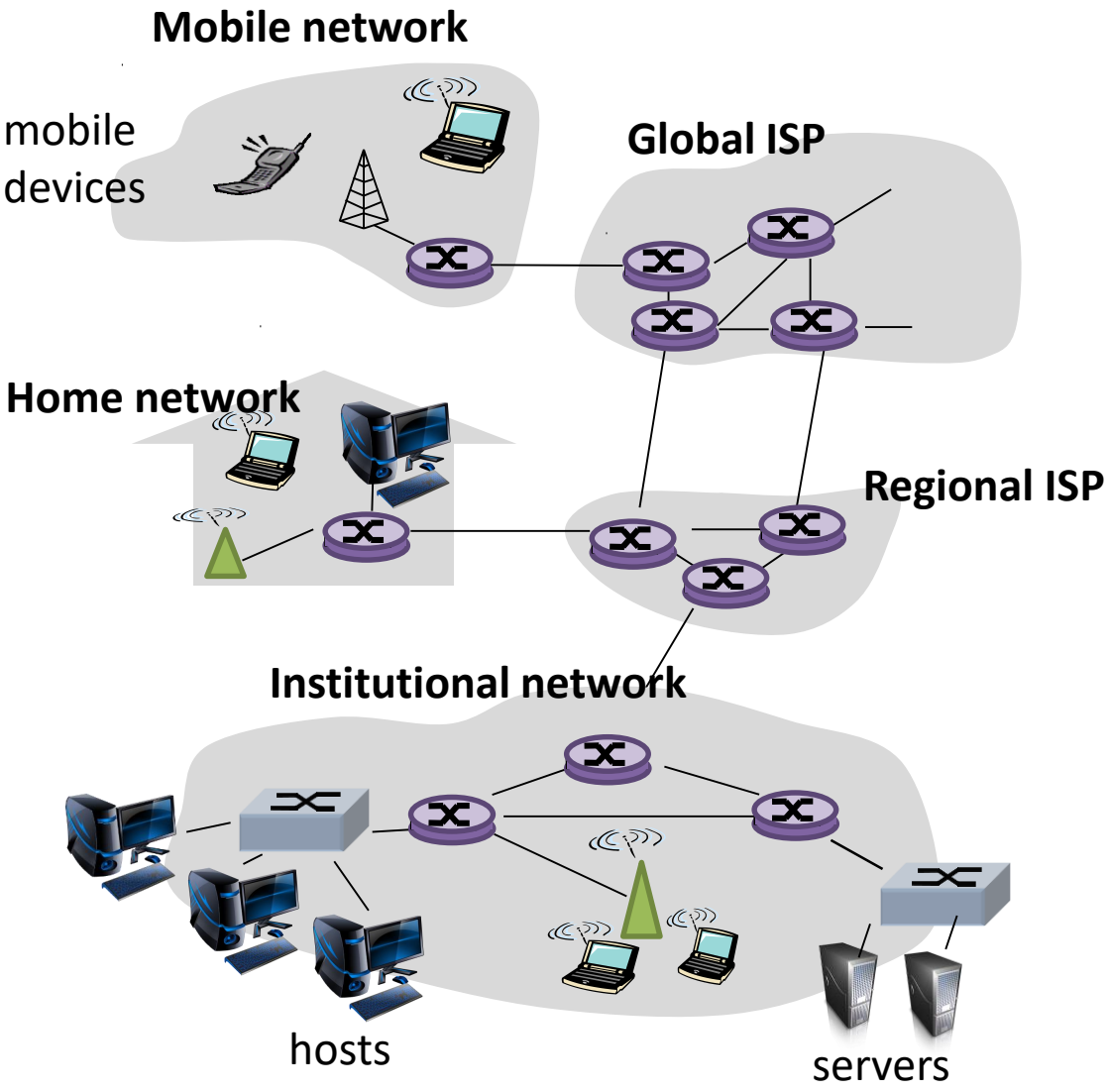


- Internet is the largest WAN spanning the entire globe.

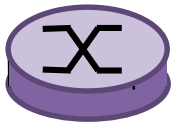
Network Types

- Wide-Area Network (WAN)
  - Usually spans large geographical area such as country.
  - Connects multiple MANS within a large region using high-bandwidth links
  - Speed varies greatly
    - depending on network traffic
    - underlying technology that implements the network.
- Internet is the largest WAN spanning the entire globe.

Large Networks Overview



communication link:
- fiber optic, copper, radio
- transmission rate = bandwidth



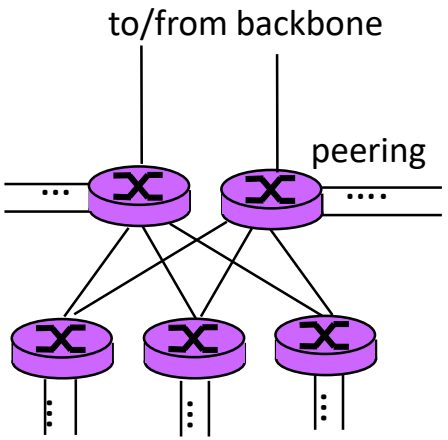
routers:
forwards packages

switch:
distributes package

wireless access points

Tier-1 ISP

POP: point-of-presence

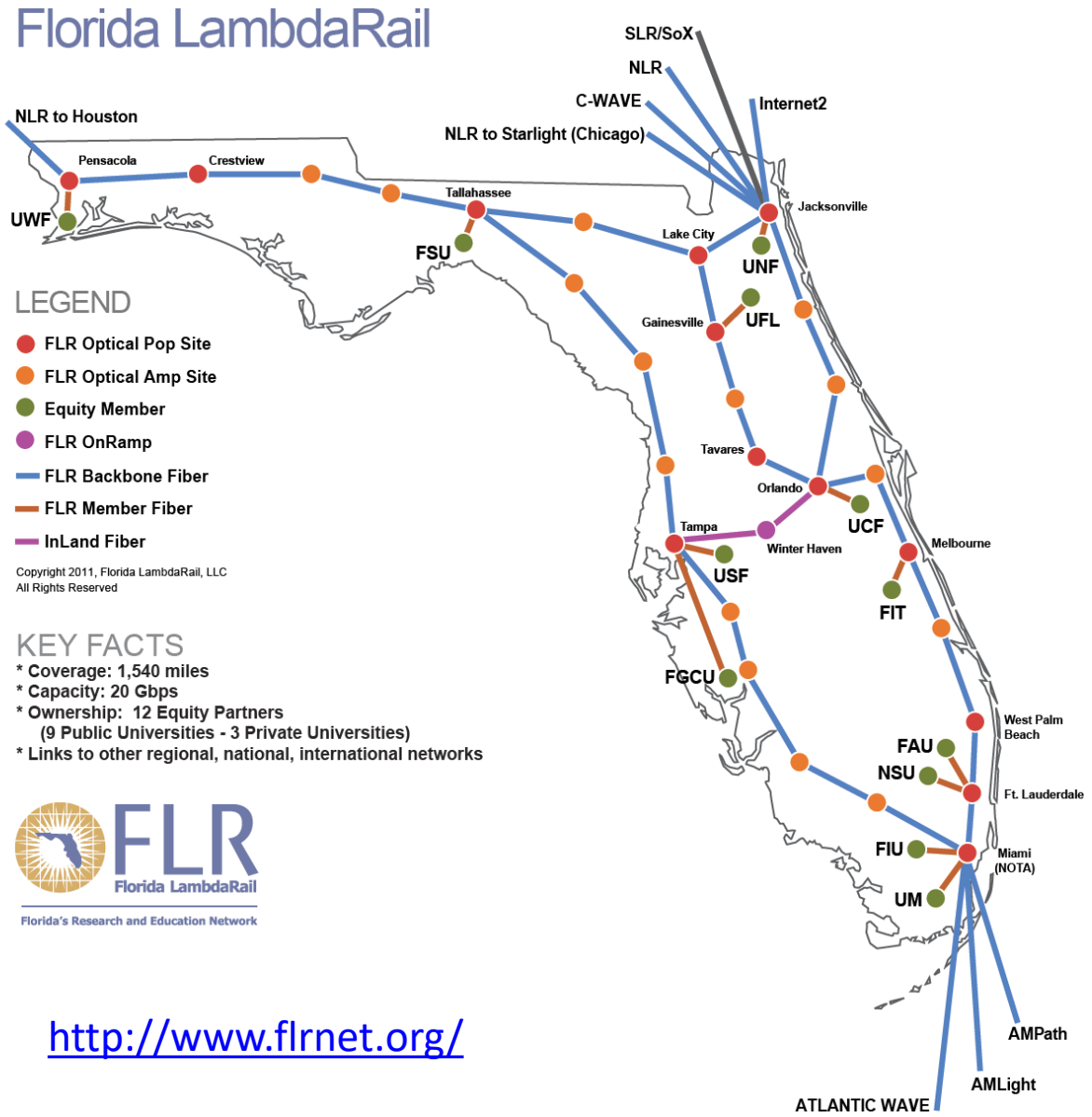


http://www.centauricom.com/assets/inc/

Florida Lambda Rail

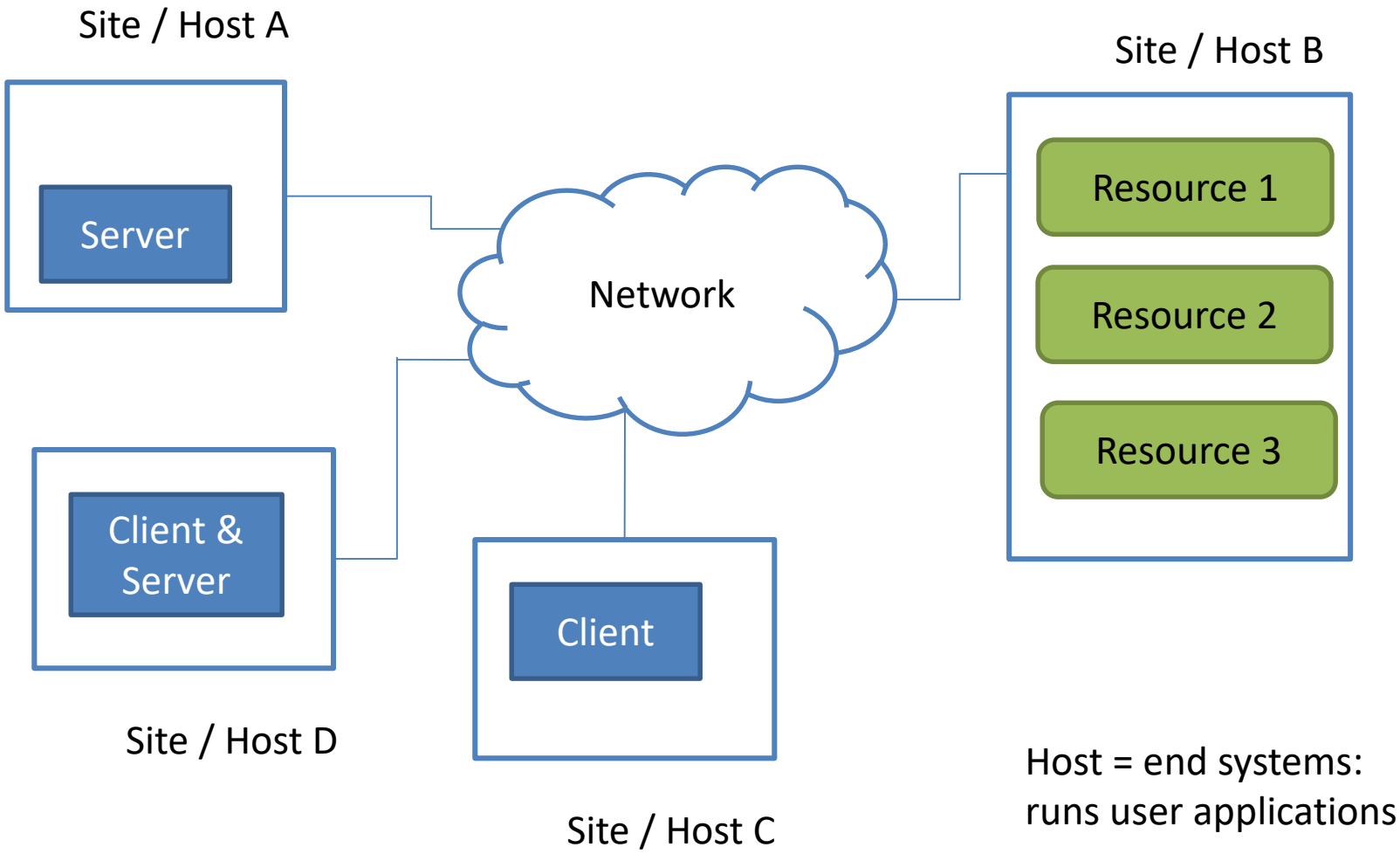
Connecting Florida's Universities:

- optical system,
- 32 wavelengths per fiber pair,
- each wavelength supports transmission speed of 100 Gbps.



http://www.flrnet.org/

Distributed System Architecture

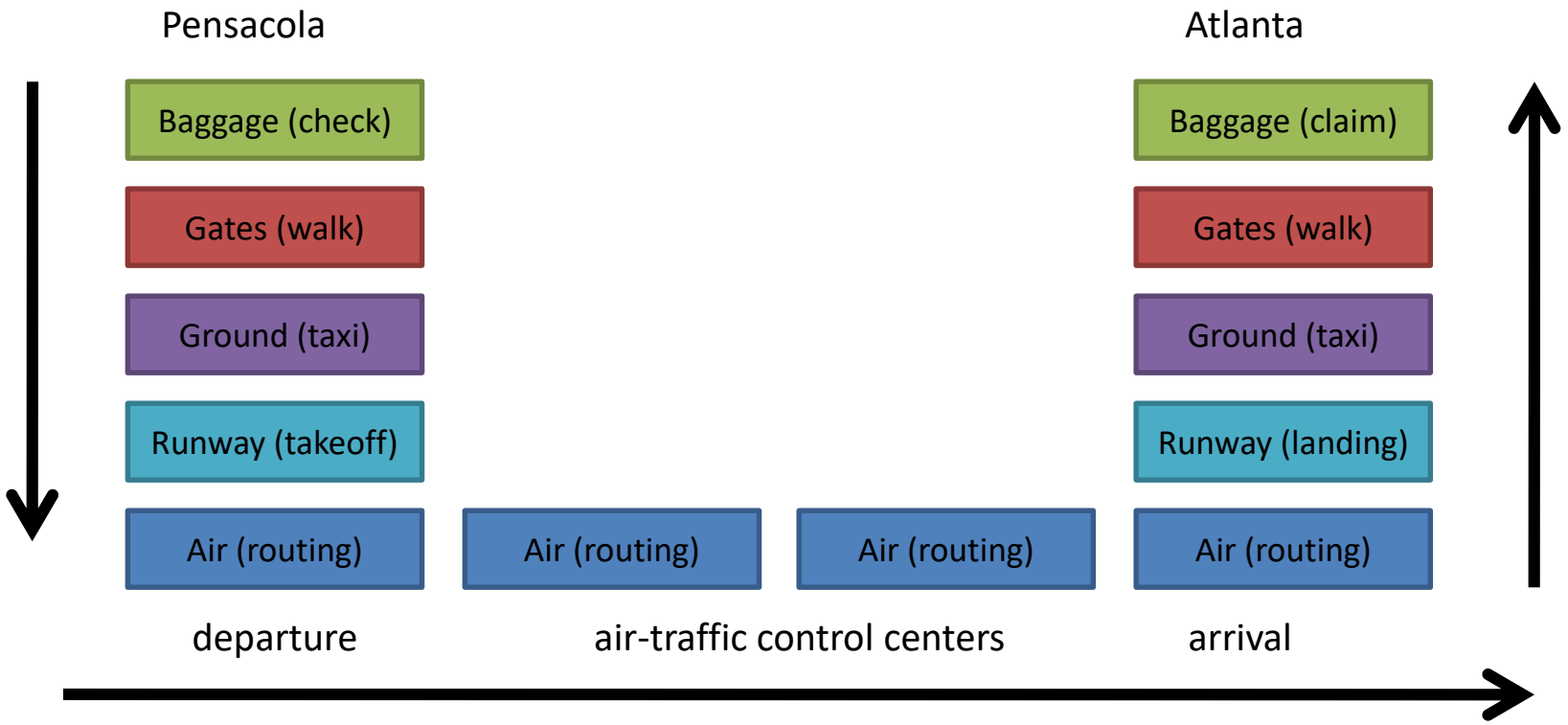


Host = end systems:
runs user applications

Network Protocols – An Analogy

What is the process for flying from Pensacola to Atlanta?

assume a direct flight, the purchase of an electronic ticket, and bags that must be checked



OSI Reference Model - Background

- Open Systems Interconnection (OSI) reference model
  - developed by International Organization for Standardization (ISO) in 1970,
  - describes networks in 7 layers,
  - common framework for developing networking technology and studying networks
  - emerged when Internet protocols where in infancy

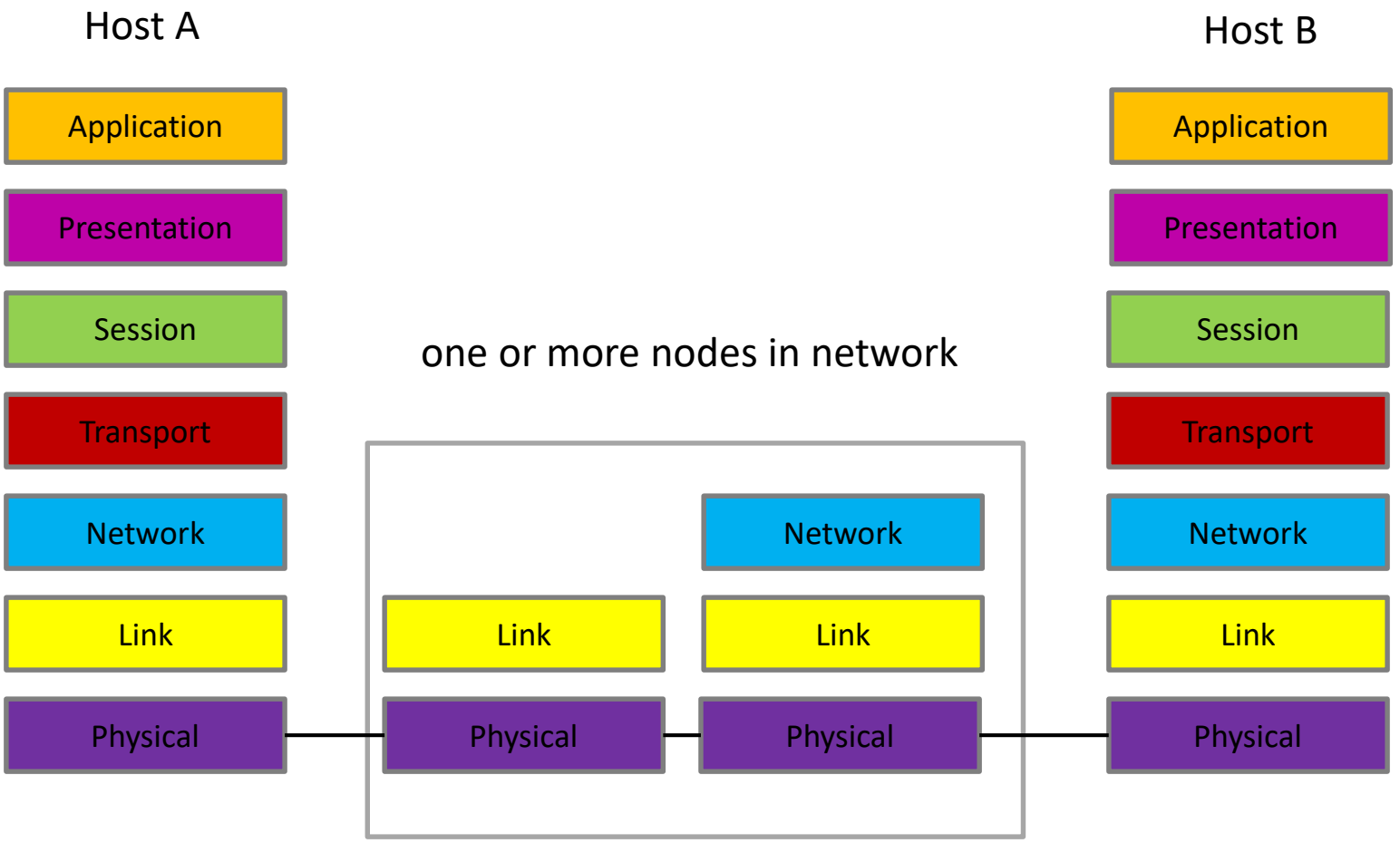
OSI Reference Model - Fundamentals

- OSI abstracts networks into layers.
  - describes important events and steps in network communication
- Layers aid in
  - separating different tasks to implement them in either software or hardware,
  - supporting changes in one or a few layers without impacting other layers

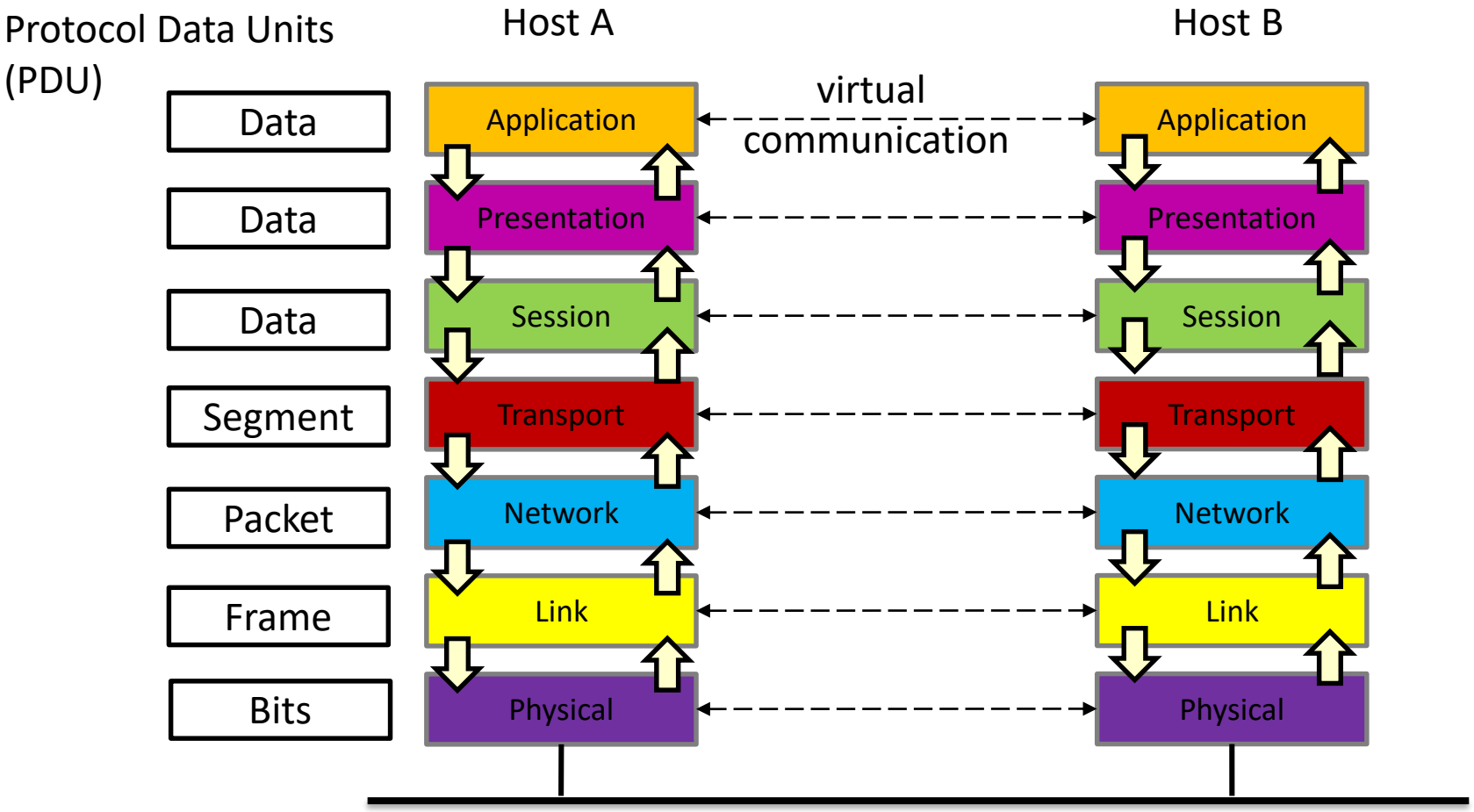
OSI Reference Model – Fundamentals (cont.)

- Layers have
  - a protocols that describes behavior,
  - interfaces to communicate with other layers.
- Not all layers are implemented in today's Intranet and Internet.
  - TCP/IP stack includes 5 layers
  - some layers may be merged into a single layer

OSI Reference Model



Communication Based on OSI Reference Model



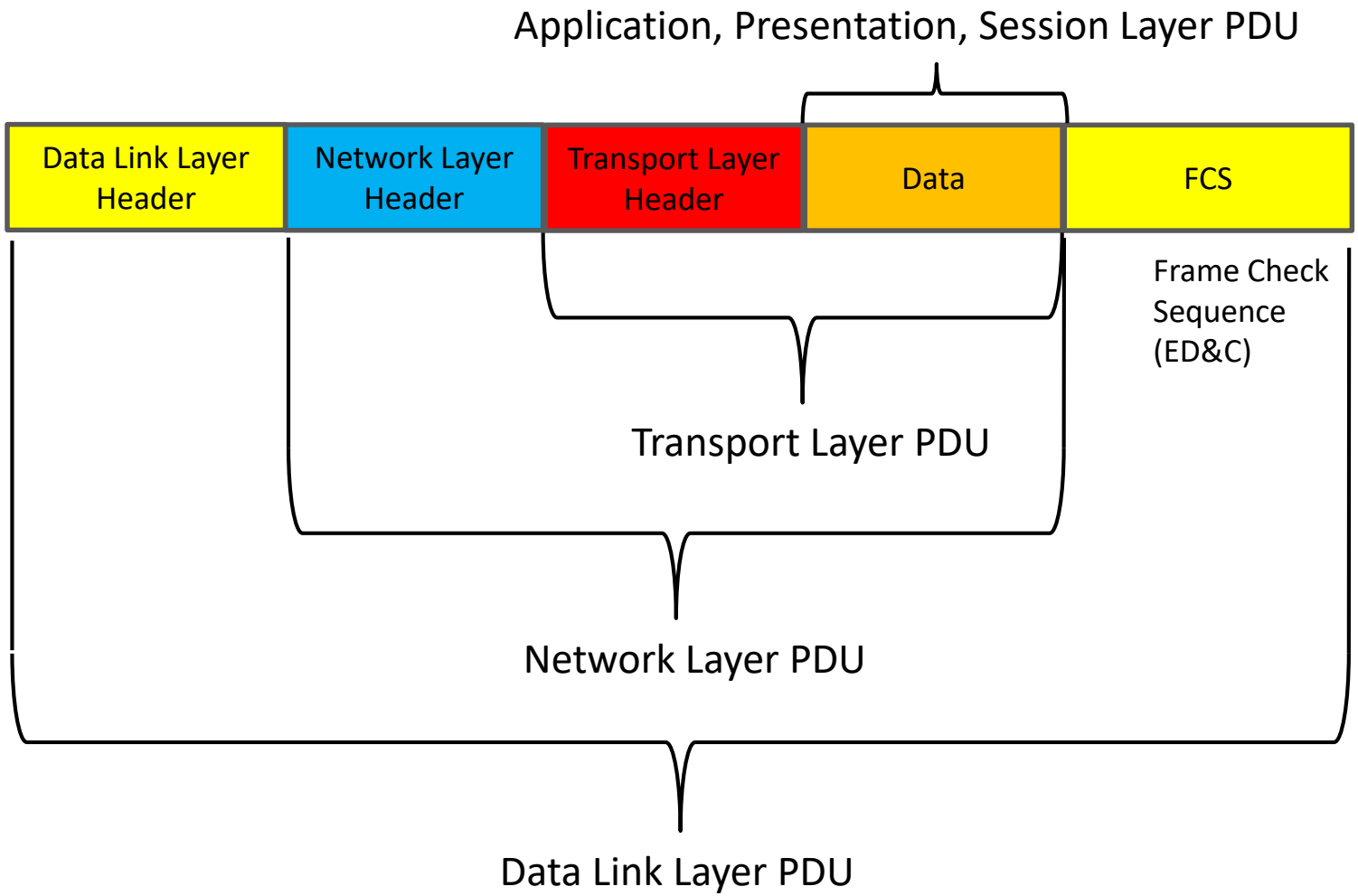
Layer Definitions

OSI Layer	Description
Application	•provides access to networking services to user applications •PDU is called data
Presentation	•represent data so that sender and receiver can interpret the data correctly •serialization of complex data structures •encryption of data •PDU is called data
Session	•creates and maintains a communication channel between sender and receiver •PDU is called data
Transport	•ensures reliability of data transfer •data is broken into multiple segments •handles sequencing •PDU is called segment
Network	•handles packet routing, access control in routers as well as logical addressing •access control through packet inspection •PDU is called packet

Layer Definitions (cont.)

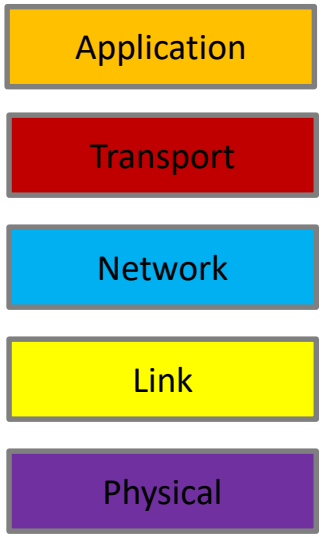
OSI Layer	Description
Data Link	•provides physical device addressing and device-to-device delivery services, •provides error detection and correction services •implemented in NICs and switches •PDU is called frame
Physical	•handles bit encoding and decoding into and from binary signals •requires networking equipment such as cables, connectors, antennas, …

PDU of Layers in OSI Model

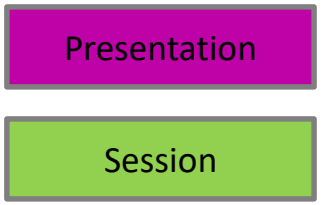


Internet Protocol Stack

- Uses 5 of the 7 layers from the OSI reference model

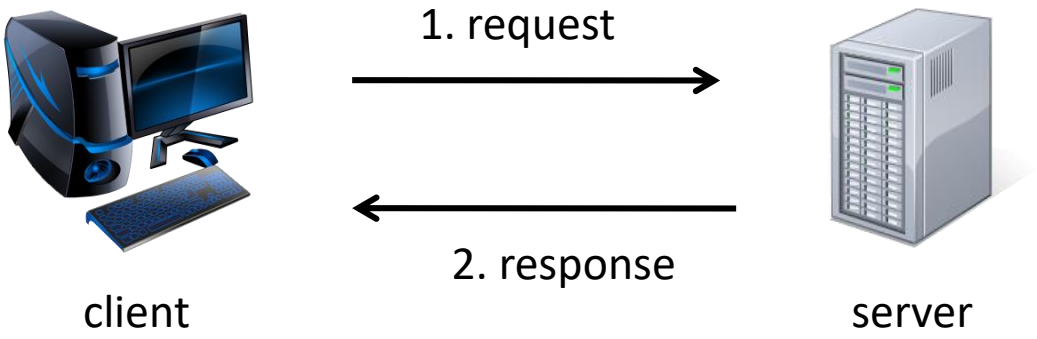


Dropped layers:



Client-Server Networking

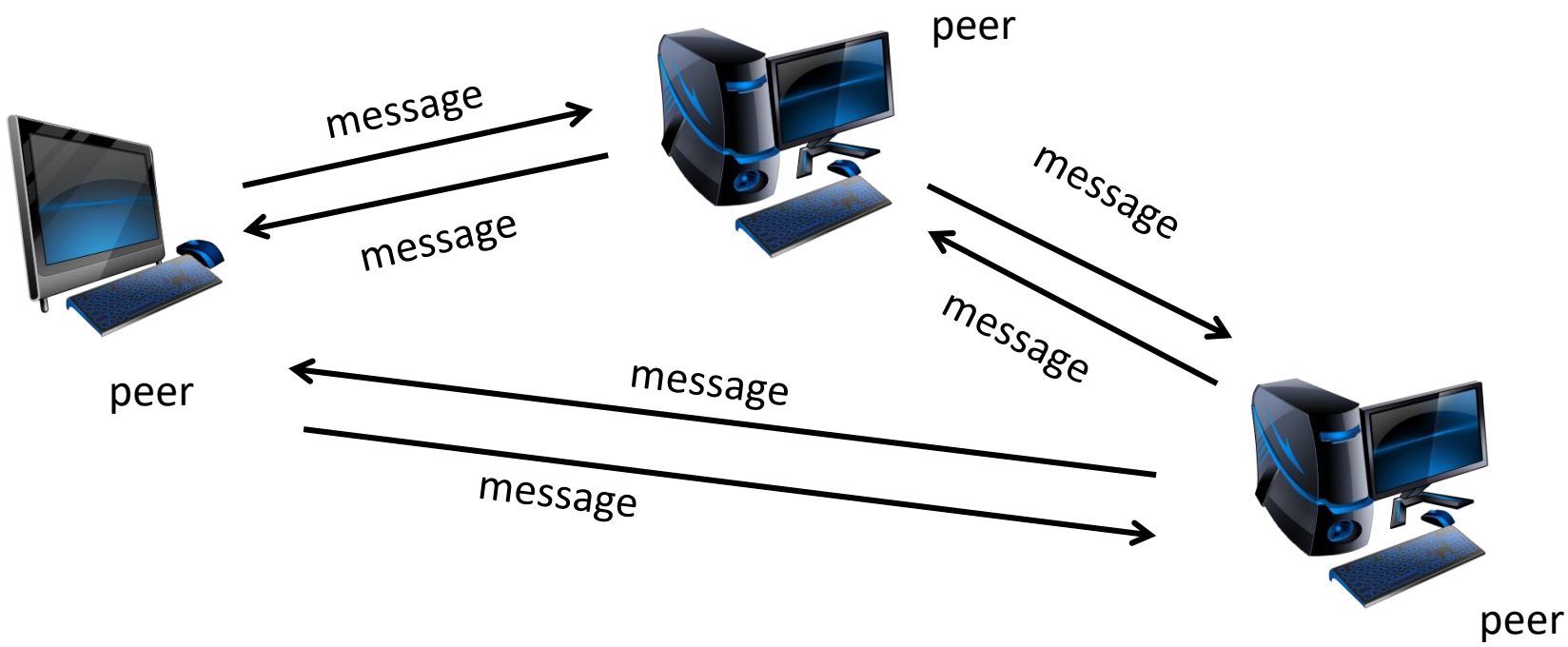
- A host may act as a client or a server.
- Communication:



- Server examples:
  - File server: provides access to files centrally stored
  - Web server: provides access to statically and dynamically generated Web pages.

Peer-to-Peer Networking

- A host acts as both client and a server.
- Communication:

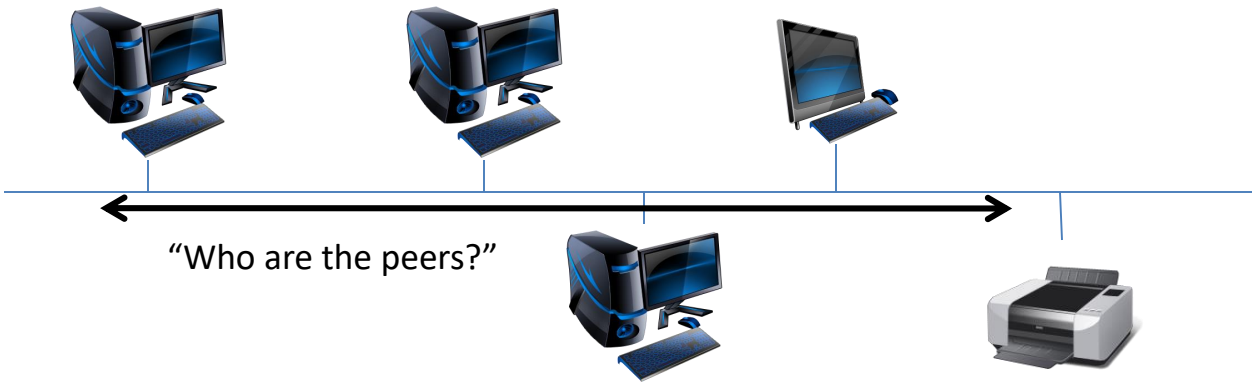


- Peer-to-Peer networking examples:
  - Windows work group.

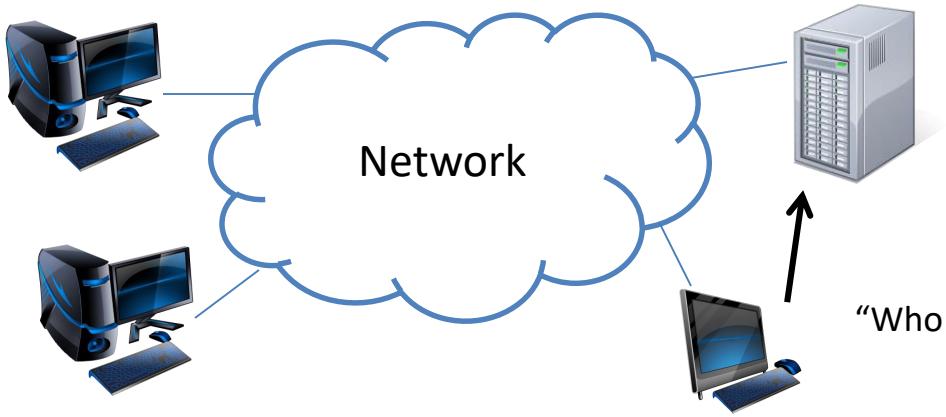
Locating Peers in a Peer-to-Peer (P2P) Network

- P2P on a LAN

peers broadcast messages



- P2P on a WAN



peers register with central server

Network Topology

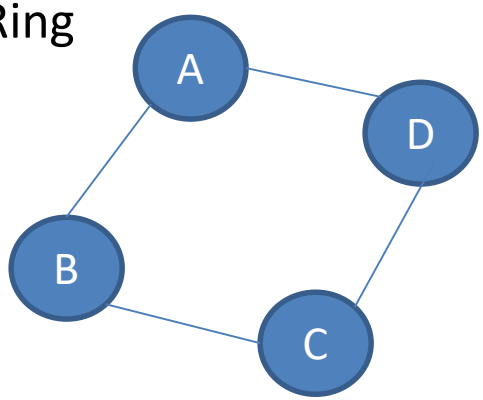
- Computer networks form a variety of different structures.
- Structure may be represented as graphs
  - nodes representing _____,
  - edges representing _____.

Influences on Network Topology

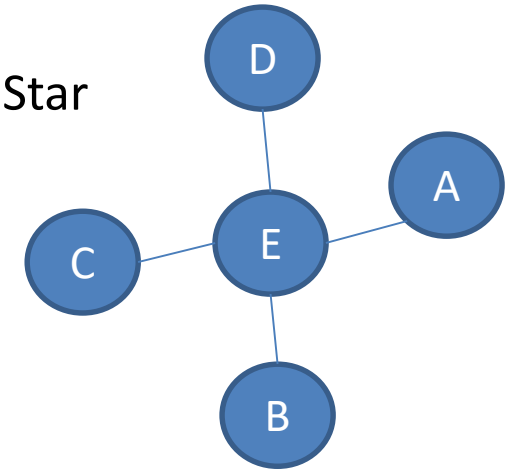
- Cost of infrastructure:
  - network nodes
  - cost to connect sites
- Bandwidth/Latency:
  - how much data can be transported,
  - how long will it take to send messages between sites.
- Reliability:
  - If a network link fails, how will it affect the exchange of messages between all sites in the network?

Network Topology Examples

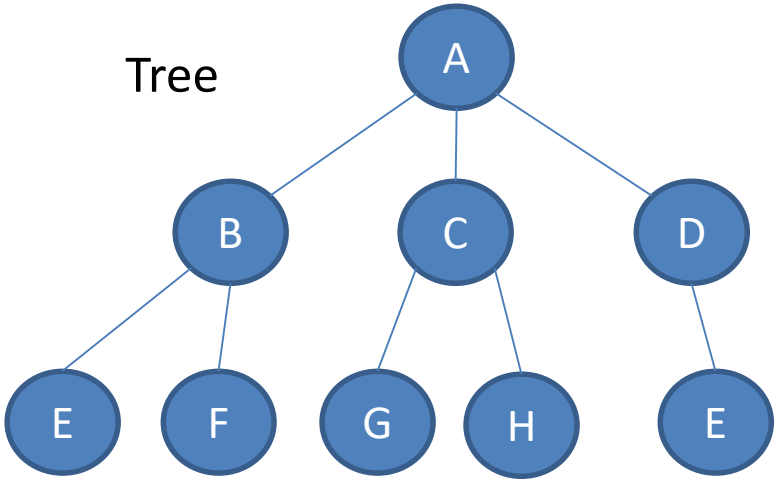
Ring



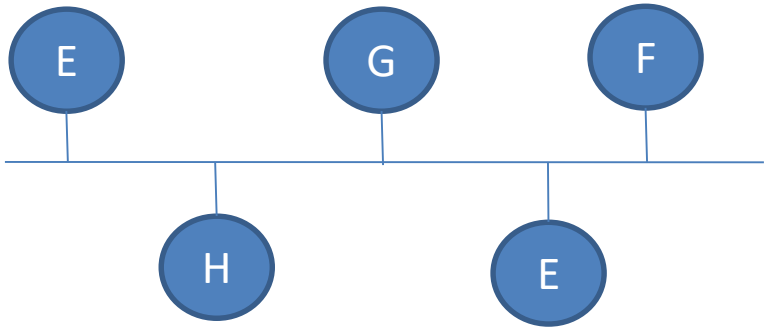
Star



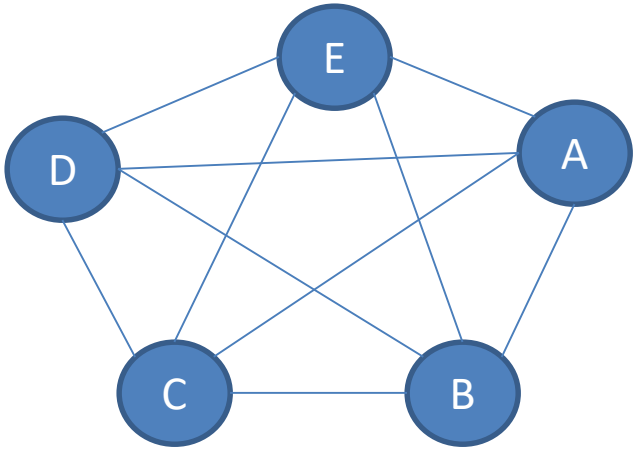
Tree



Bus



Network Topologies Examples (cont.)

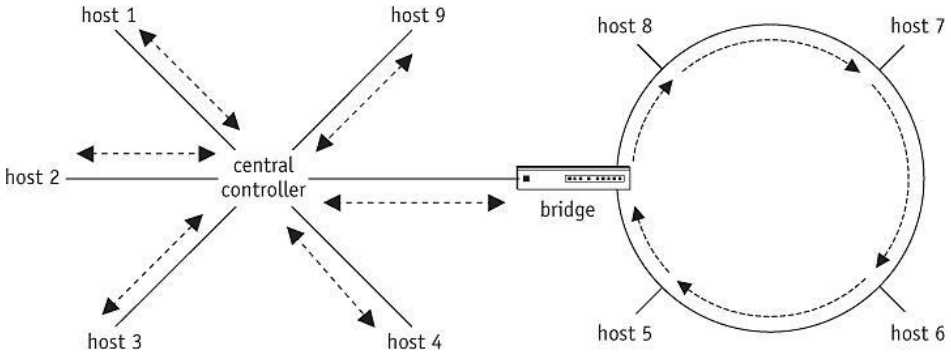


Mesh

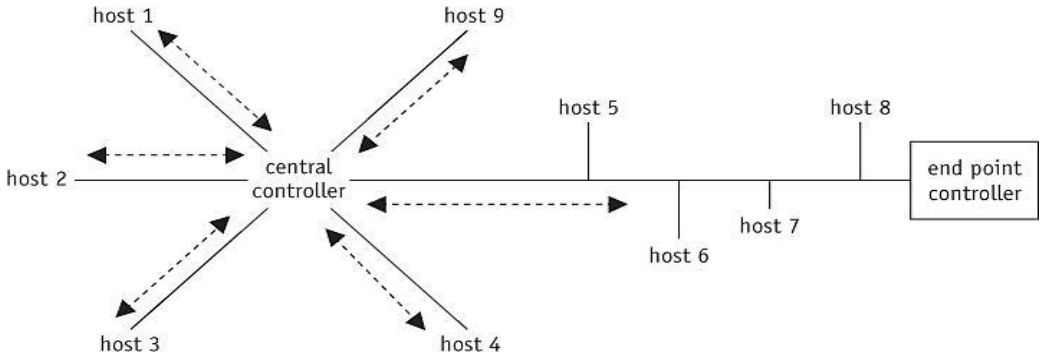
Given n nodes in network,
then the number of edges in a mesh network is:

$$\frac{n(n-1)}{2} = \sum_{k=1}^{n-1} k = 1 + 2 + 3 + 4 + \cdots (n-1)$$

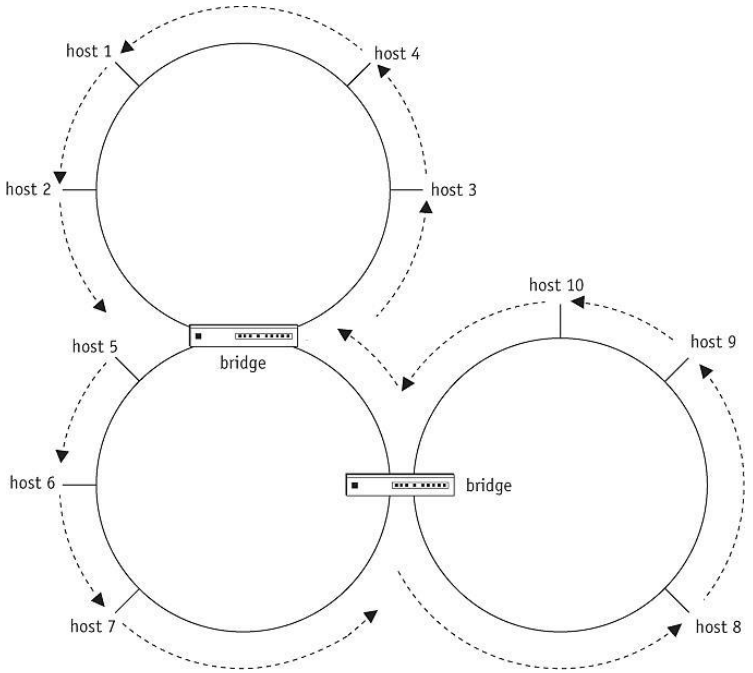
Network Topology Examples (cont.)



Hybrid topology, version 1. This network combines a star and a ring, connected by a bridge. Hosts 5, 6, 7, and 8 are located on the ring. *© Cengage Learning 2018*

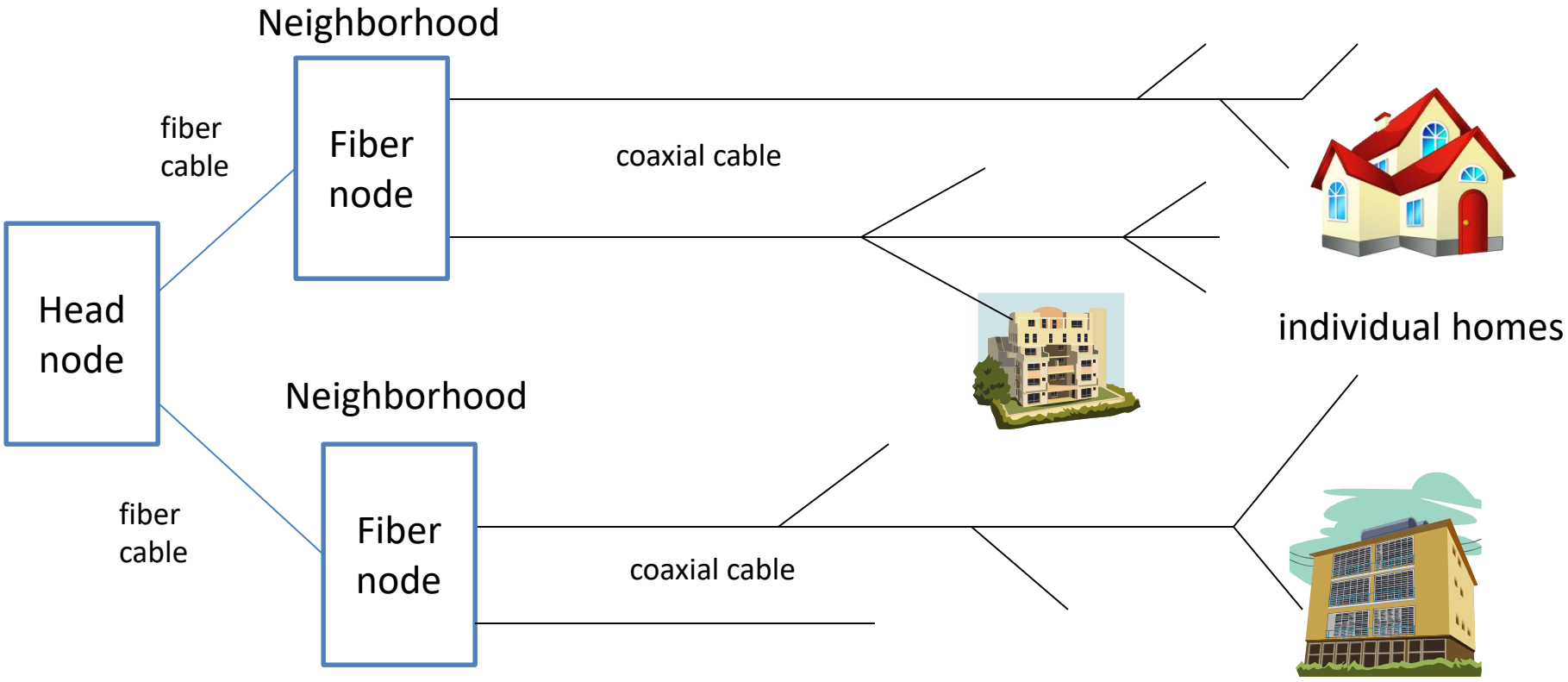


Hybrid topology, version 2. This network combines star and bus topologies. Hosts 5, 6, 7, and 8 are located on the bus. *© Cengage Learning 2018*



Multiple rings bridged together. Three rings connected to each other by two bridges. This variation of ring topology allows several networks with the same protocol to be linked together. *© Cengage Learning 2018*

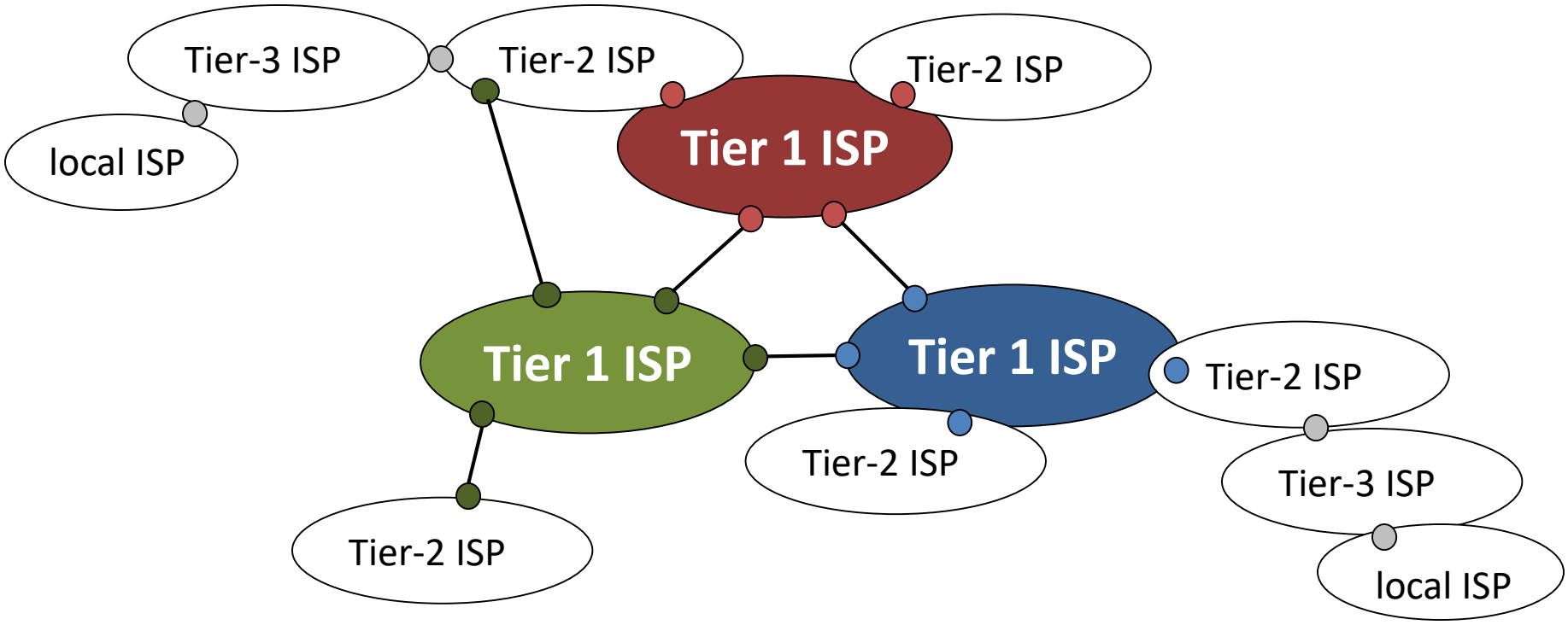
Hybrid Fiber-Coaxial (HFC) Access Network



- Cable modem divides HFC network into two channels for uploading and downloading data.

Internet Structure

- Roughly hierarchical structure between regional and global ISPs.
  - Tier-2 IPSs connect to Tier-1 ISP
  - Tier-2 ISP is customer of Tier-1 ISP
  - etc.



Robustness of Network Topologies

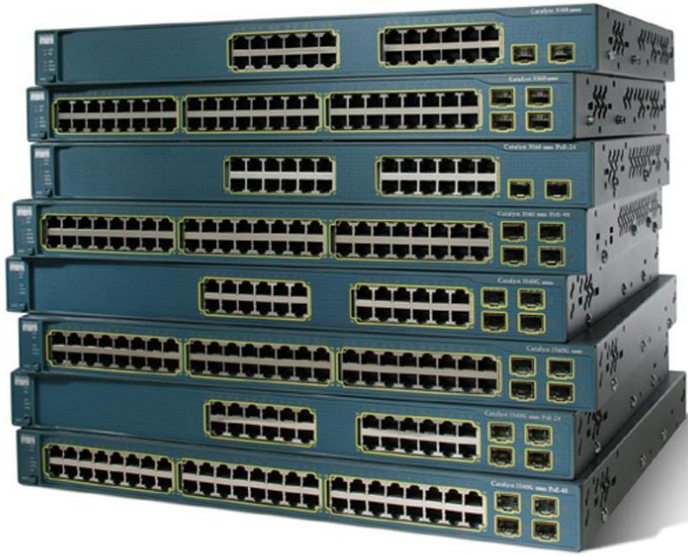
- Ring Topology
  - less robust because a cable break or a network card failure shuts down the entire network
- Bus Topology
  - less robust because a cable break shuts down the entire network
- Star Topology
  - more robust because a cable break only disconnects one host from the network
  - failure of hub, switch, router at center of network shuts down the network

Network Devices

- Patch Panel
  - serves as junction points between cables coming from switch/hub and wall
  - no signal strengthening or filtering
- Hubs (not in use anymore)
  - distribute signal across multiple connected ports
  - regenerates signal to original signal level (signal strengthening)
  - filters any noise
  - operates at physical layer in OSI reference model

Network Devices: Switches

- similar to hub, strengthens signal and filters noise
- selects destination port instead of broadcasting on all ports
  - reduces overall traffic on network compared to hub
  - may broadcast on all ports to learn destination port
- operates at data link layer in OSI reference model (layer 2)

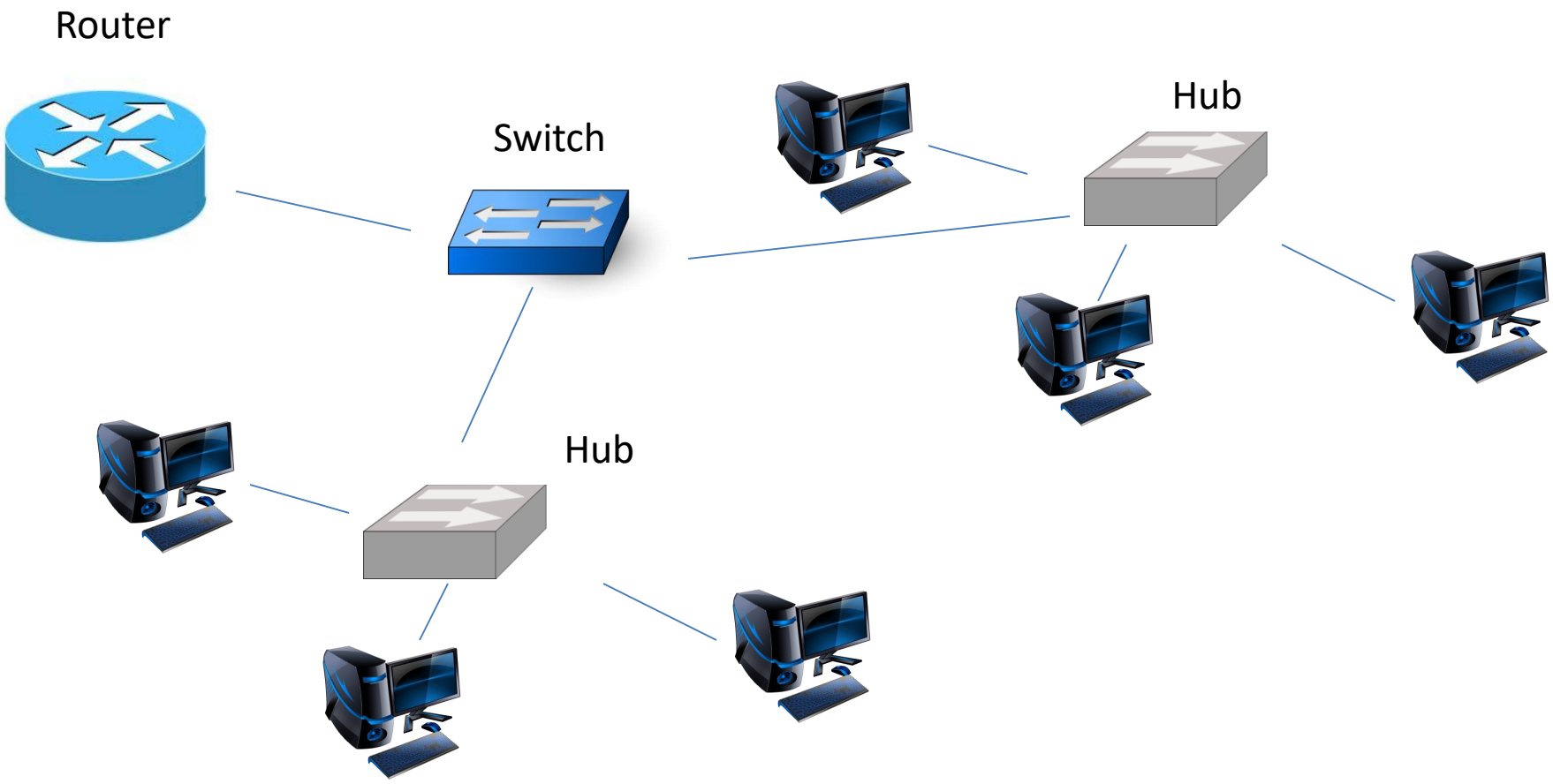


Network Devices: Routers

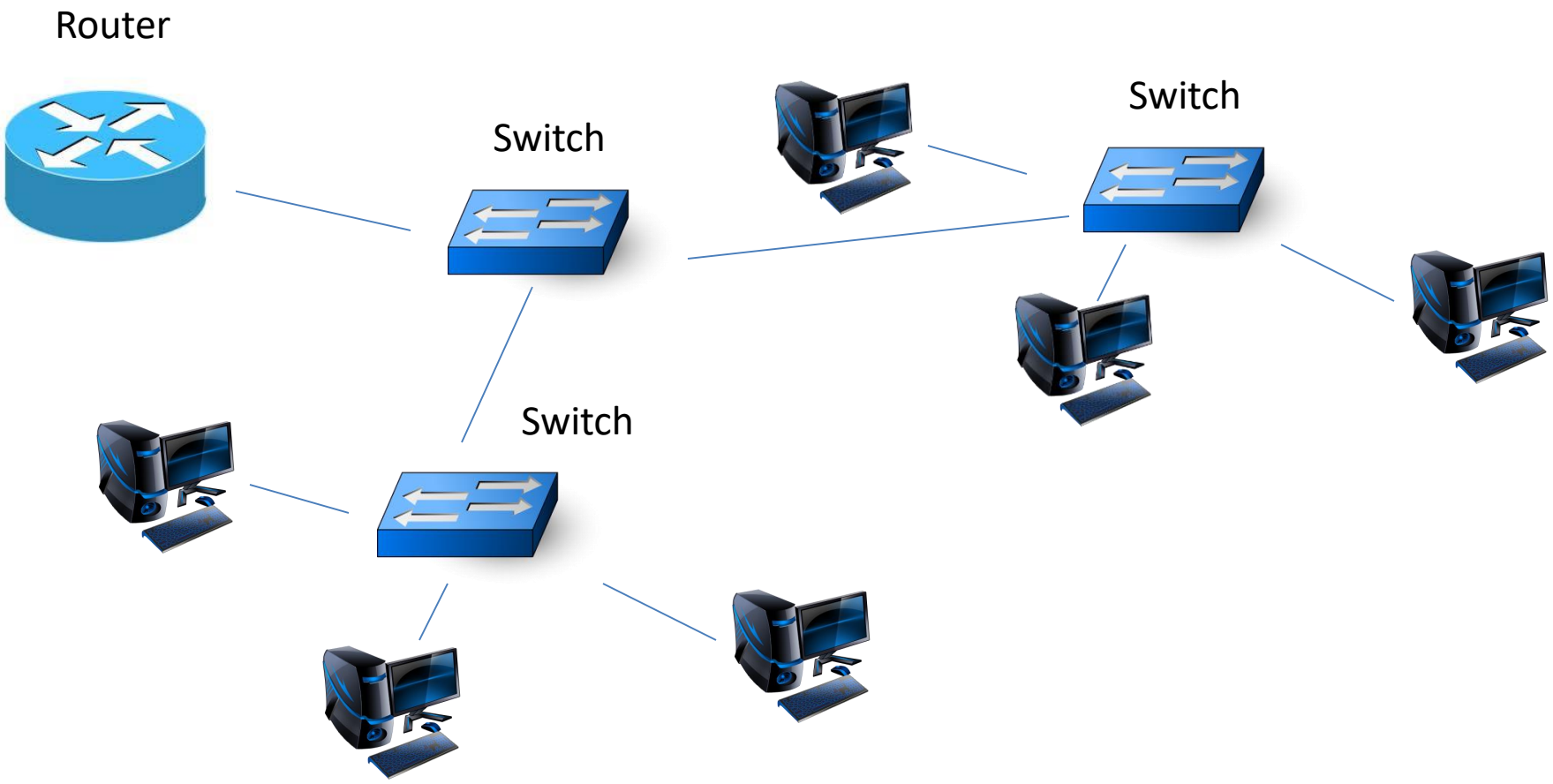
- similar to switch, strengthen and filters signal
- connects different networks to build larger networks
- directs traffic: routing tables in each router determines the flow of network traffic

- operates at network layer in OSI reference model (layer 3)
- may bridge different types of networks

Sample Network



Sample Network



Connecting Hosts to Network

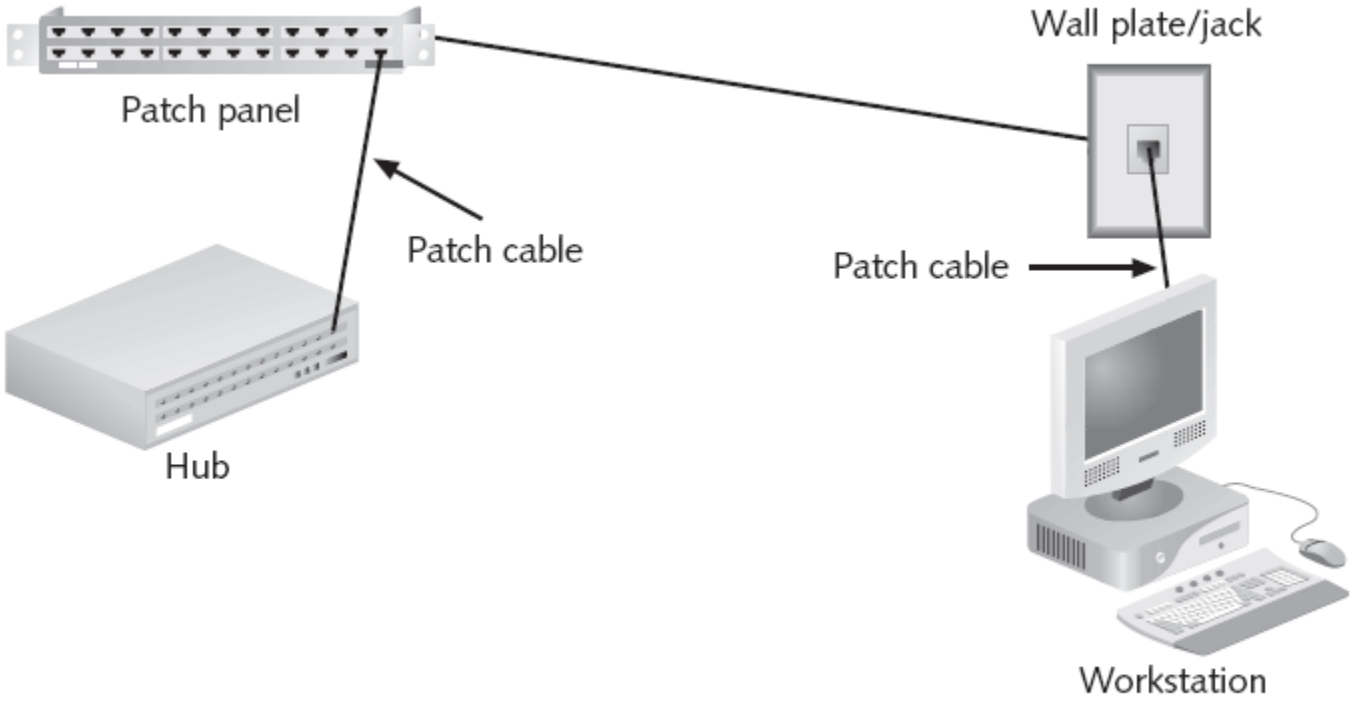


Figure 2-12: Guide to Networking Essentials, 5th Edition, Tomsho *et al.*

Cabling and Cable Characteristics

- Cable provide a medium for transporting signals
  - electrical signal
  - light pulses
- Cable characteristics
  - maximum length of segment
  - susceptibility to interference from outside
  - bandwidth
- Cable types include
  - Coaxial cable
  - Twisted pair cable
  - Fiber optic cable

Complex Local Network

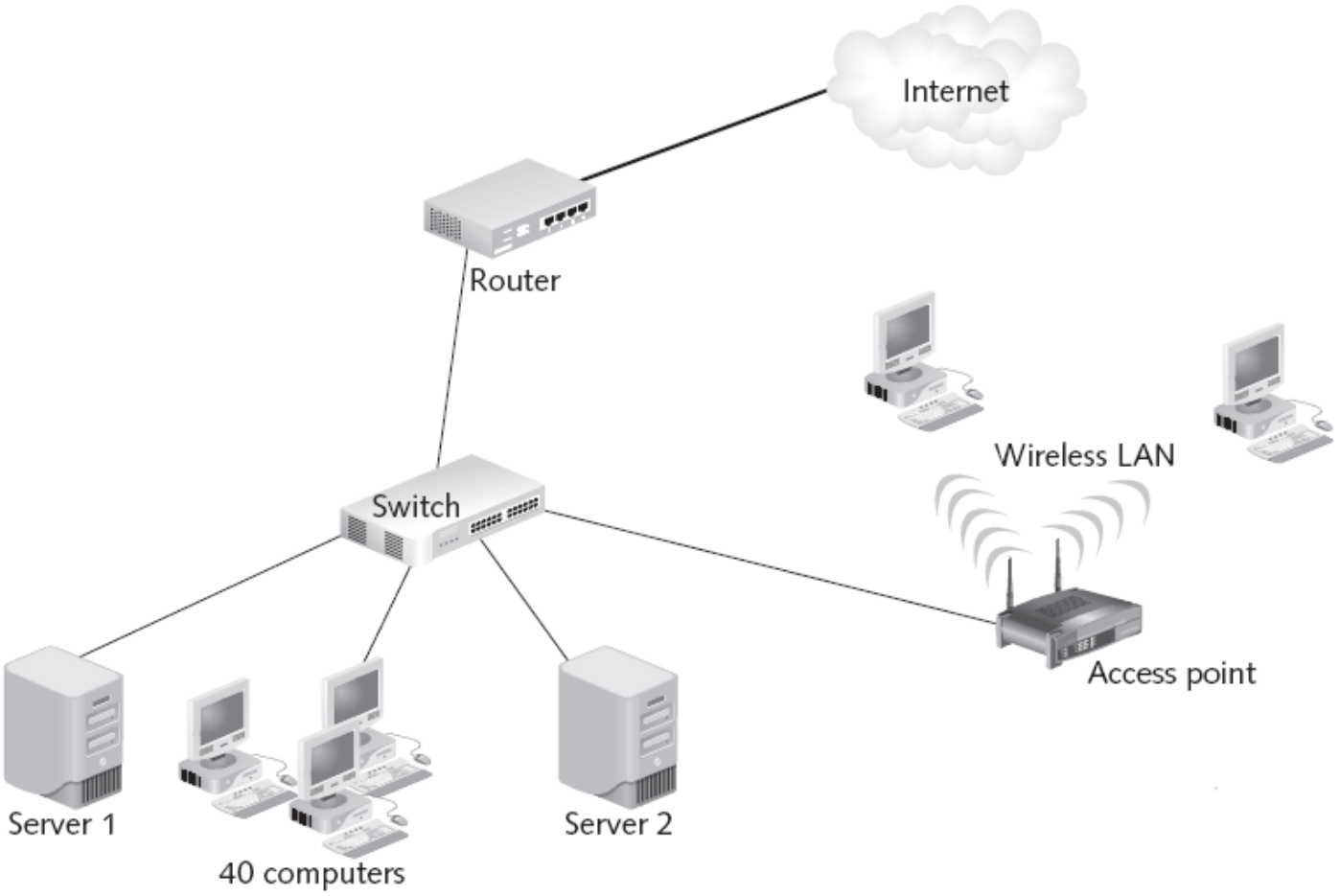
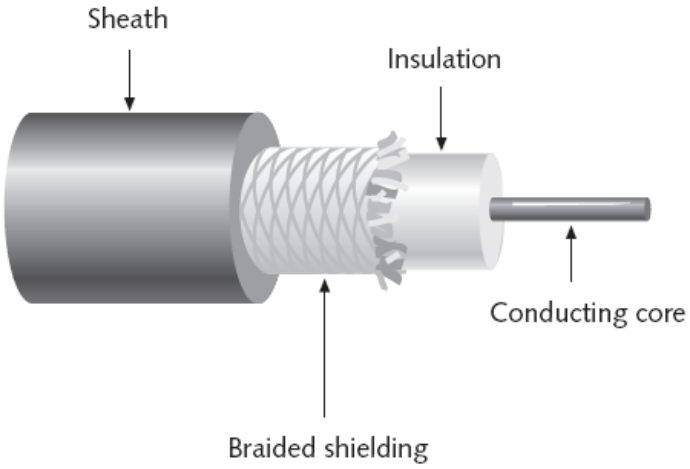


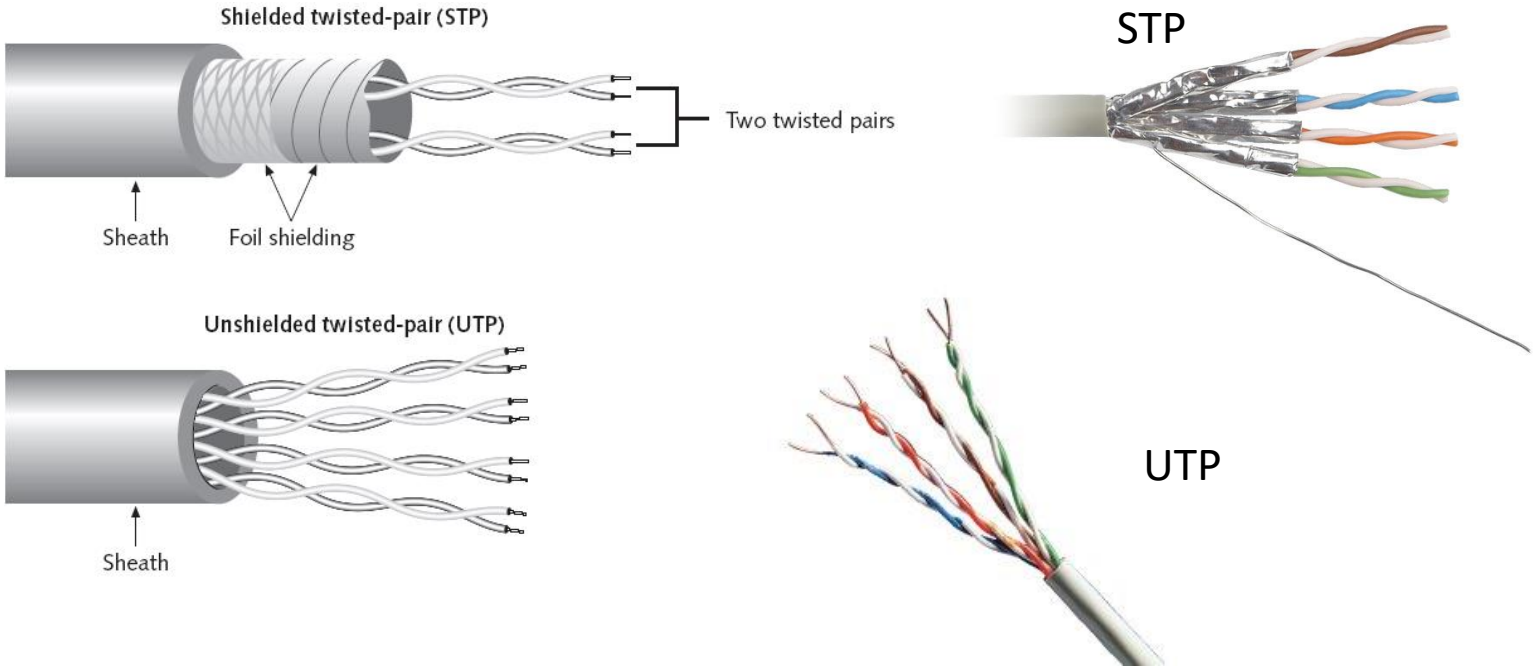
Figure 2-13 Guide to Networking Essentials, 5th Edition, Tomsho *et al.*

Coaxial Cable

- Was predominantly used in early Ethernet.
- Has protective shield to protect against interference.
- Less susceptible to attenuation than twisted pair.
- Higher cost than twisted pair.

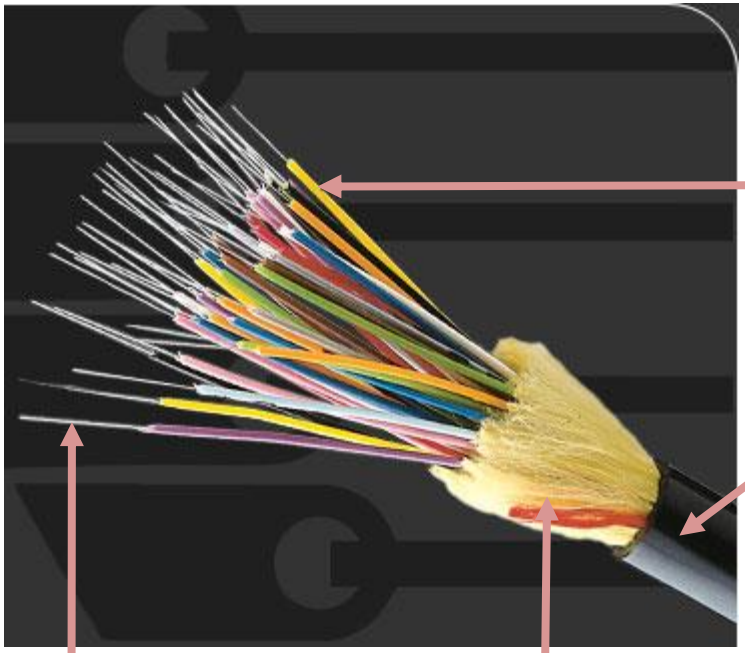


Twisted Pair Cable



- Unshielded Twisted-Pair used widely in LANs.
- Shielded Twisted-Pair may be also used in LANs.
  - shielding reduces cross-talk and interference

Fiber Optic Cable

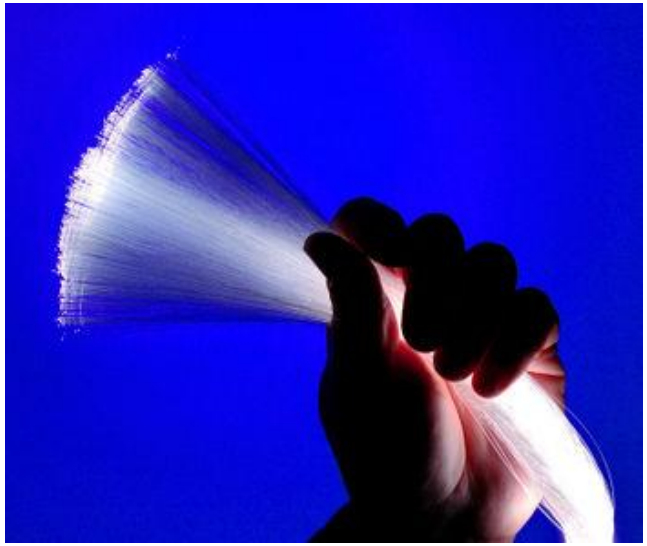


inner sheath

outer sheath

kevlar for strengthening cable

optical fiber (glass or plastic)

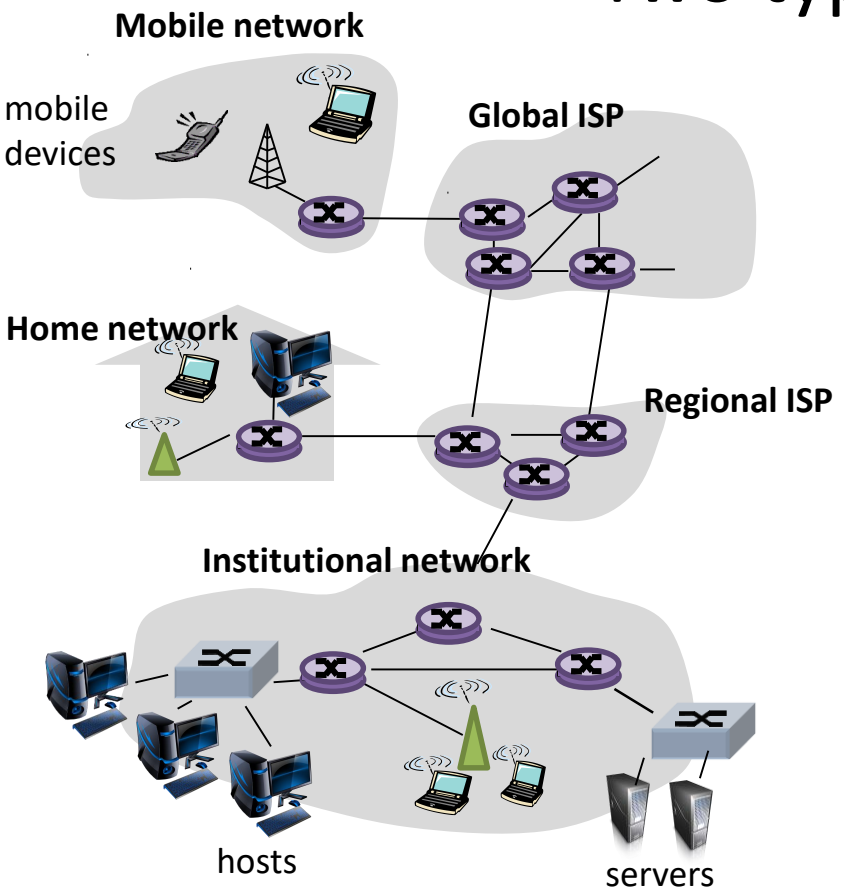


UTP Cable Categories

- Cables rated based ANSI/TIA/EIA Standard (1991).
  - American National Standard Institute
  - Telecommunications Industries Association (TIA)
  - Electronic Industries Alliance (EIA)

Category	Bandwidth Specifications	Application
Cat. 1	voice only	telephone cabling
Cat. 2	up to 4 Mbps	not used any longer
Cat. 3	up to 10 Mbps (16 MHz)	10BaseT, 4 Mbps token ring, …
Cat. 4	up to 16 Mbps (20 MHz)	10BaseT, 16 Mbps token ring, …
Cat. 5	up to 100 Mbps (100 MHz)	100BaseT, ATM, token ring, ..
Cat. 5e	up to 1000 Mbps (100 MHz)	1000BaseT (Gigabit Ethernet), …
Cat. 6	up to 1000 Mbps (200 MHz)	1000BaseT (Gigabit Ethernet), …

Data Transport in Networks

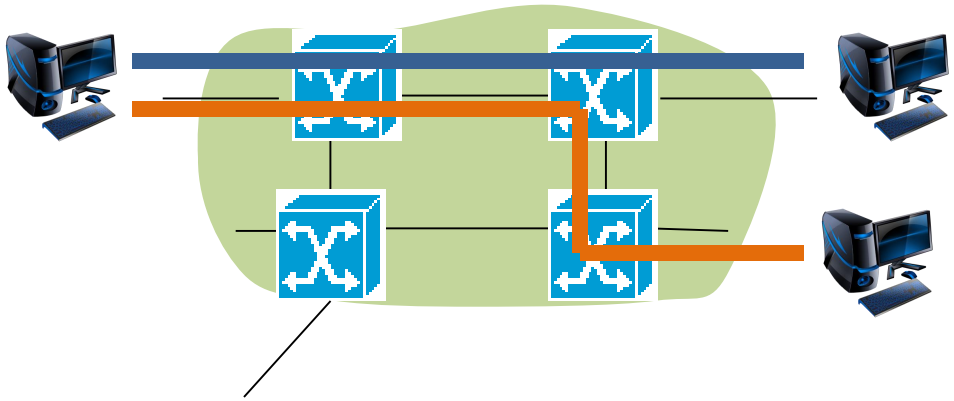


Two types of data transport:

- Packet-switched:
  - no dedicated path needed for sending data packages
  - Internet
- Circuit switched:
  - virtual circuit is established before data may be sent
  - telephone network or Asynchronous Transfer Mode (ATM) networks

Sharing Network Links

- For circuit-switched networks a temporary path is setup before data may be sent.
  - path must be shared by other senders
  - sharing can be done by multiplexing signals onto same link



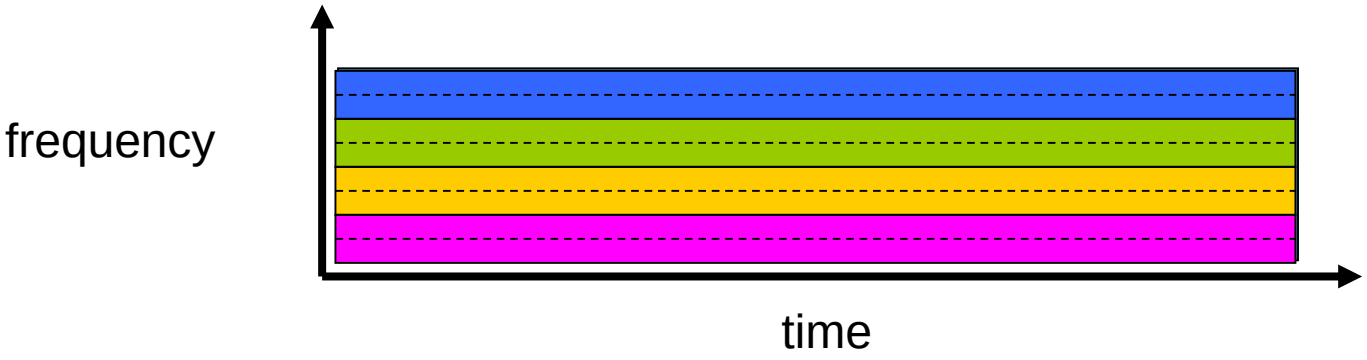
ATM Switch

Multiplexing in Network Links

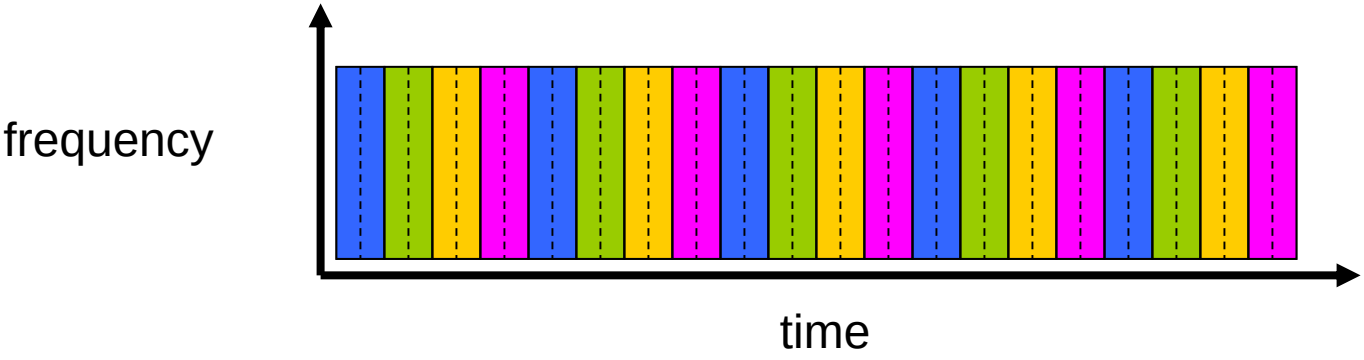
Example:

4 users

FDM



TDM



Summary Questions

- What equipment is needed to build computer networks?
- What type of networks are implemented for businesses, government agencies?
- What are WANs and how are they built?
- What is the topological of a typical LAN?
- What protocols are needed to transport data in a large-scale network?
- What type of data transport is available in the Internet?
- How can single-link networks be shared across multiple users?