Computer Networks Foundations: Requirements

Hui Chen

Department of Computer & Information Science

CUNY Brooklyn College

What is the Class about?

- A single focus
  - Design networked system
- Two thrusts:
  - Design of future computer network products and protocols
  - Design network applications using existing networks and protocols
- Which requires us to understand underlying principles of networking

What is a ***Computer*** Network?

- Built primarily from ***general-purpose*** programmable hardware
- Optimized for carrying many ***different types of data***
- Support a wide, and ever-growing, range of ***applications***.

Design Networked System?

- Primary concerns:
  - Connectivity
    - What are the ways that a user can get connected to a larger network?
  - Scalability
    - How do we grow networks in size?
  - Heterogeneity
    - What are the ways to allow different network products and protocols to coexist on the same network?
  - Resource management and congestion control
    - How do we manager resources on the network and satisfy requirements of different users?
  - Network security
    - How do we keep data transmitted over networks secure?

Learn to Build Networked System?

- Building and designing networks from the ground up
  - Foundation: basic concepts
  - Direct link network
    - Nodes and links
  - Grow network
    - Direct link network → switched network → internetworks
      - The Internet is an internetwork
  - Network applications and security

Connectivity

- Nodes and links

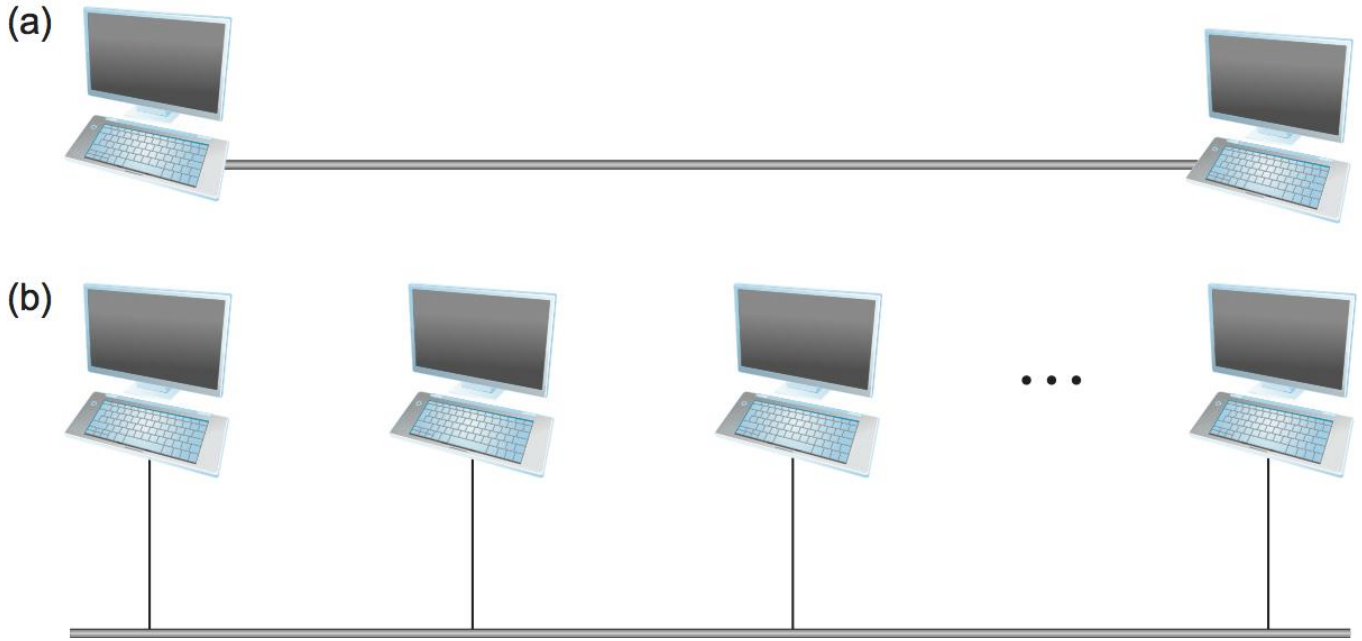
Nodes and Links

- Nodes: personal computers, server computers, special-purpose hardware …
- Links:
  - Physical media
    - Coax cable, optical fiber, twisted-pair network cable, wireless (EM radiation, acoustic waves, …) …
  - Connection type
    - Point-to-point
    - Multiple access

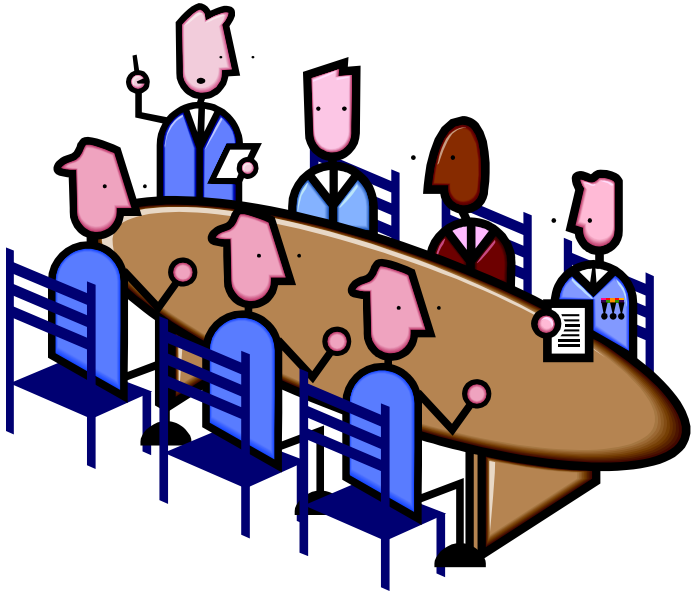
Direct Link Networks

(a) Point-to-point networks

(b) Multiple access networks



Direct Link Networks: Two Types of Links

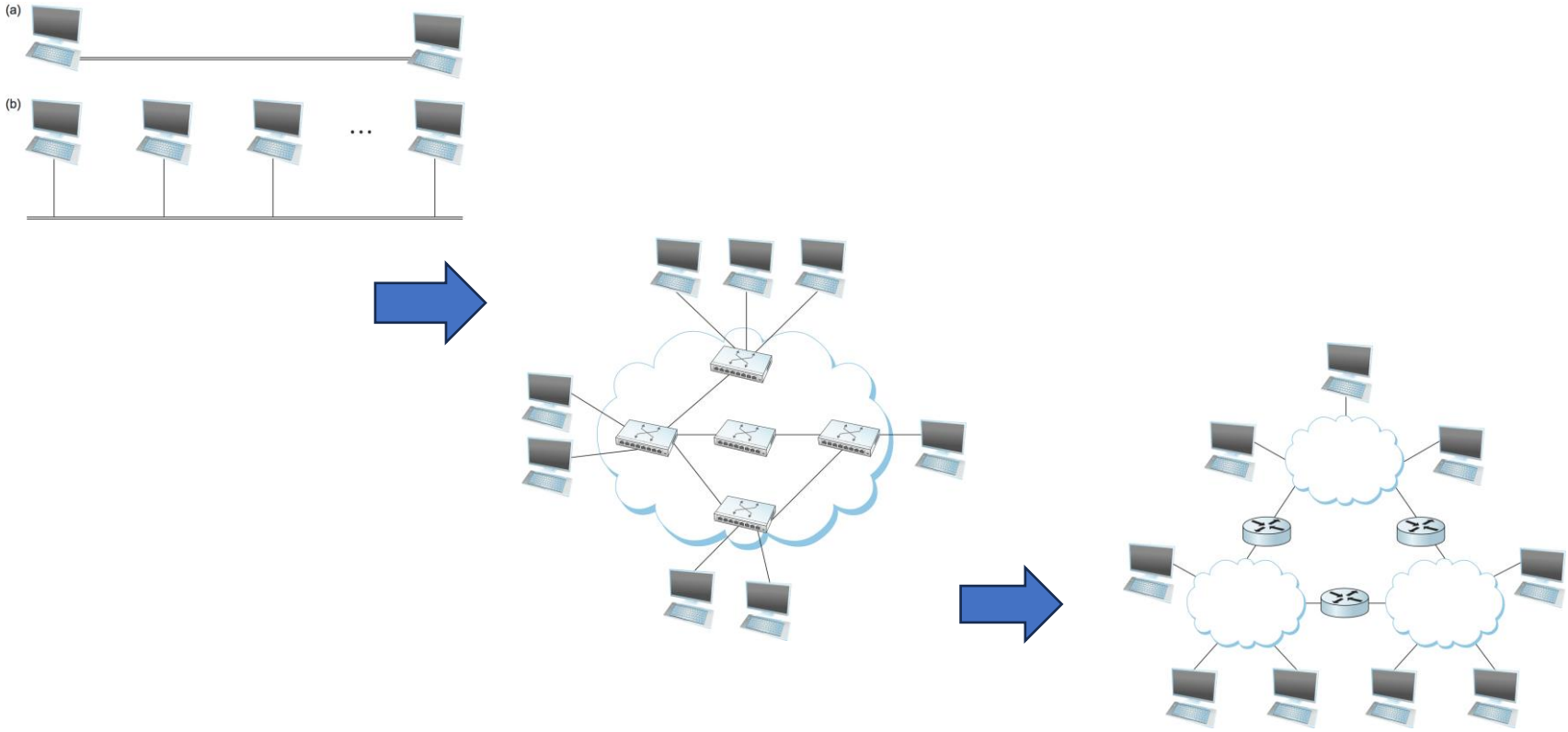


Direct Link Networks: Advantage and Disadvantages

- What are their *advantage and disadvantage* between point-to-point and multiple access networks?

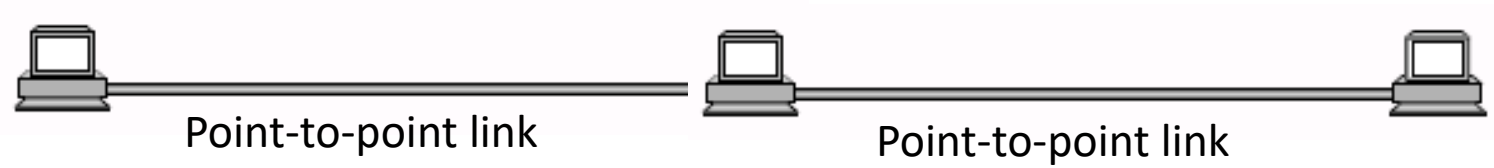
Scalable Connectivity

- How to grow networks in size? The big picture:

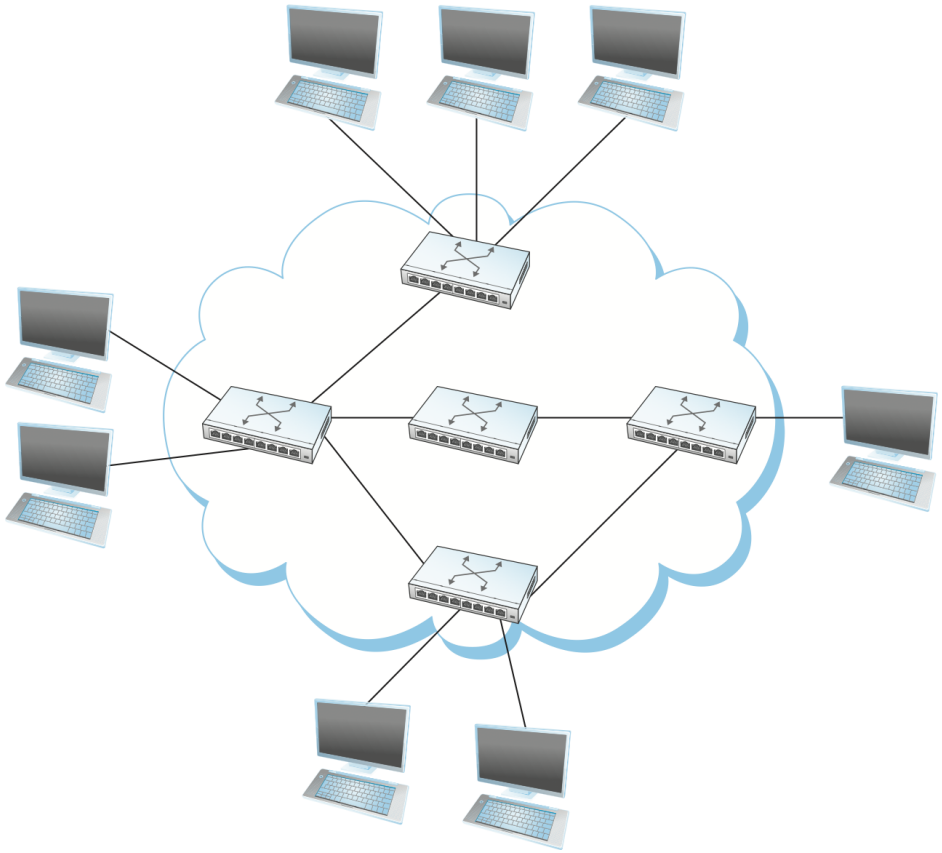


Grow Network in Size

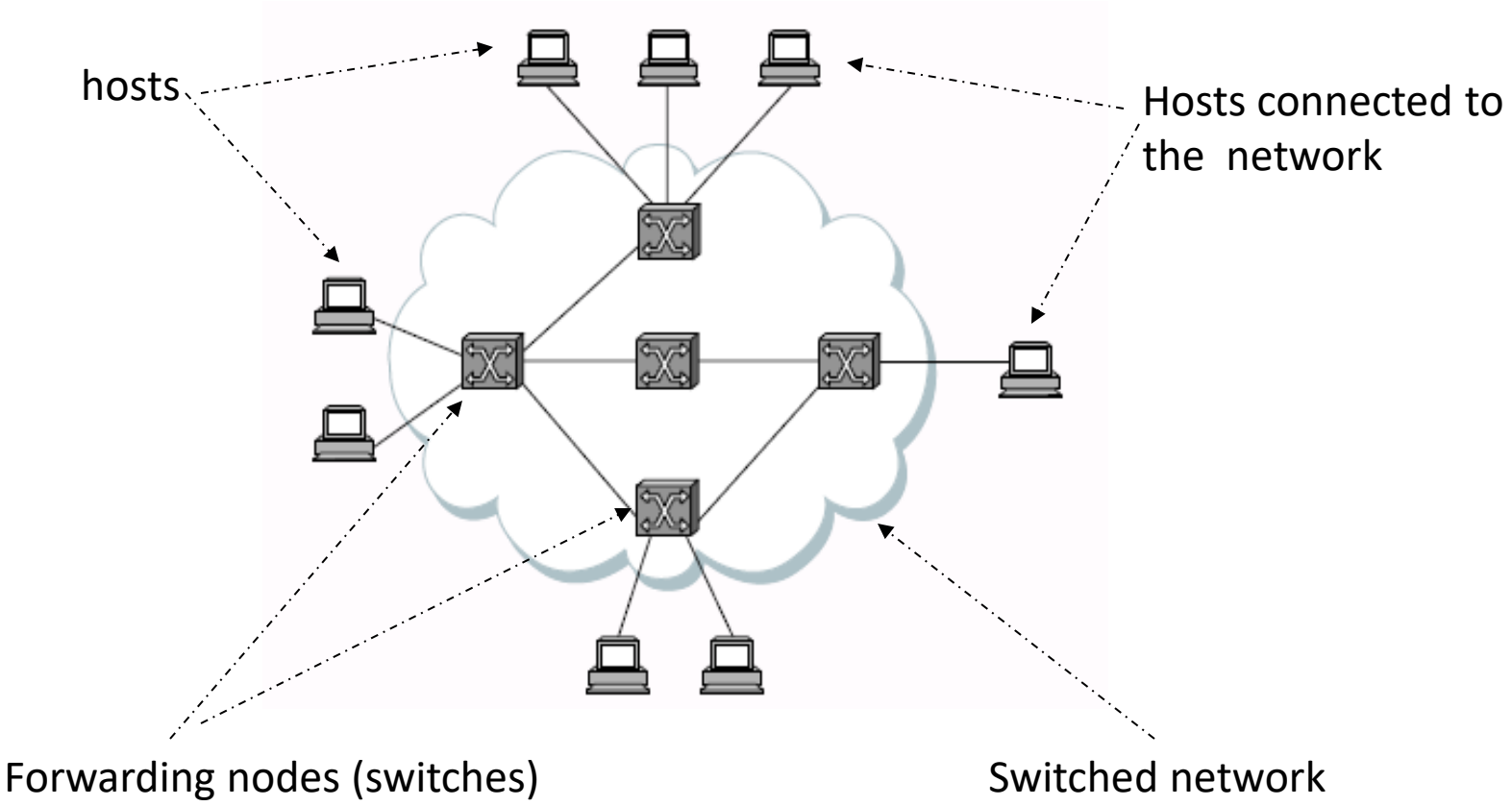
- Direct link networks are small
- How to grow networks in size?
  - Switched networks: a network of networks connected by network switches
  - A network switch (forwarding node) is a node with two or more links
    - Forward messages from one network to other networks



Switched Network



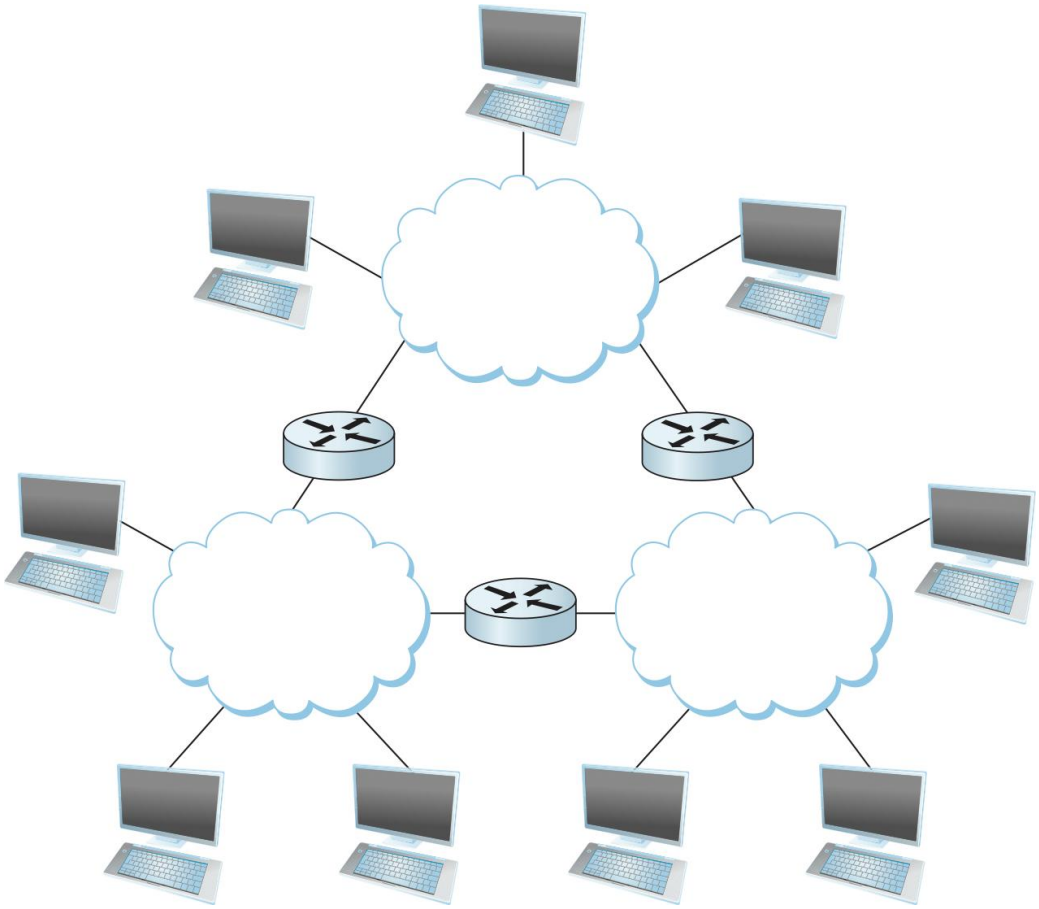
Switched Network



Types of Switched Networks

- Circuit-switched networks
  - Carry bit-streams
    - Establishes a dedicated circuit across a sequence of links between source node and destination node
    - Allows the source node to send a stream of bits across this circuit to a destination node.
  - e.g.: original telephone network
- Packet-switched networks
  - Store-and-forward messages
    - Receive: each node in a store-and-forward network first receives a complete packet over some link
    - Store: stores the packet in its internal memory
    - Forward: forwards the complete packet to the next node.
  - e.g.: Internet

Internetworks



Identifying Nodes and Networks

- When networks grow, there is a need to identify and differentiate different nodes and to forward messages to a or a set of nodes
- When networks grow to become an internetworks, there is also a need to identify networks.
- Relevant problems: addressing and routing

Addressing and Routing

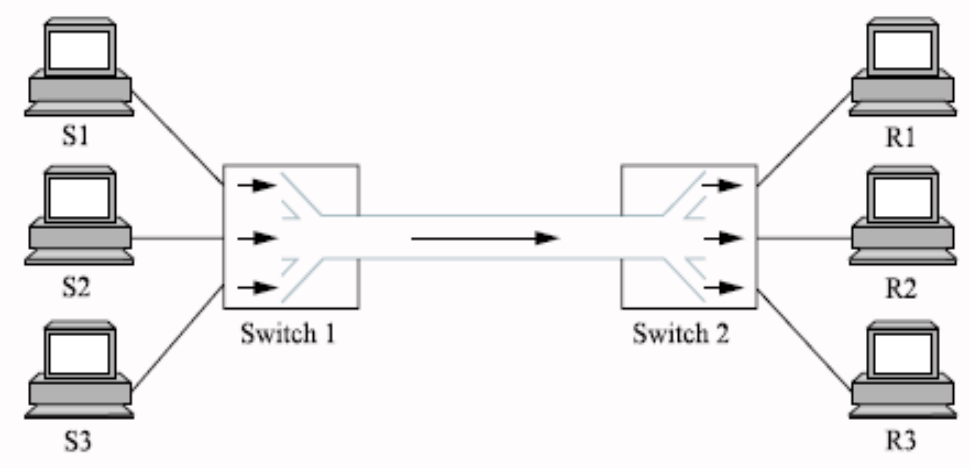
- Address: byte-string that identifies a node
  - Usually unique
- Routing: process of finding ways to forward messages to the destination nodes based on its address
- Type of addresses
  - Unicast: node-specific
  - Broadcast: all nodes on the network
  - Multicast: some subset of nodes on the network

Cost-Effective Resource Sharing

- How do all the hosts that want to communicate share the network, especially if they want to use it at the same time?

Multiplexing

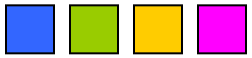
- A system resource is shared among multiple users
- Examples:
  - Time-division multiplexing (TDM)
  - Frequency-division multiplexing (FDM)



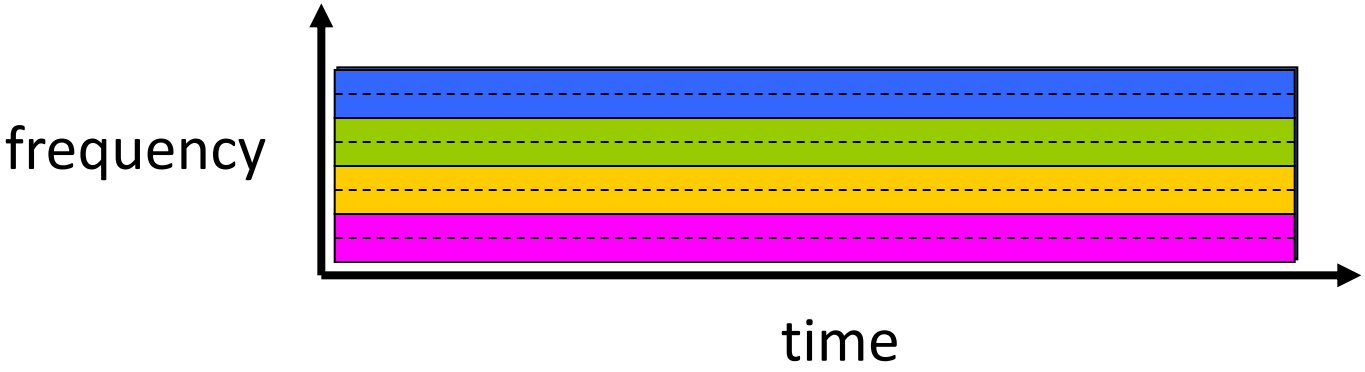
FDM and TDM

Example:

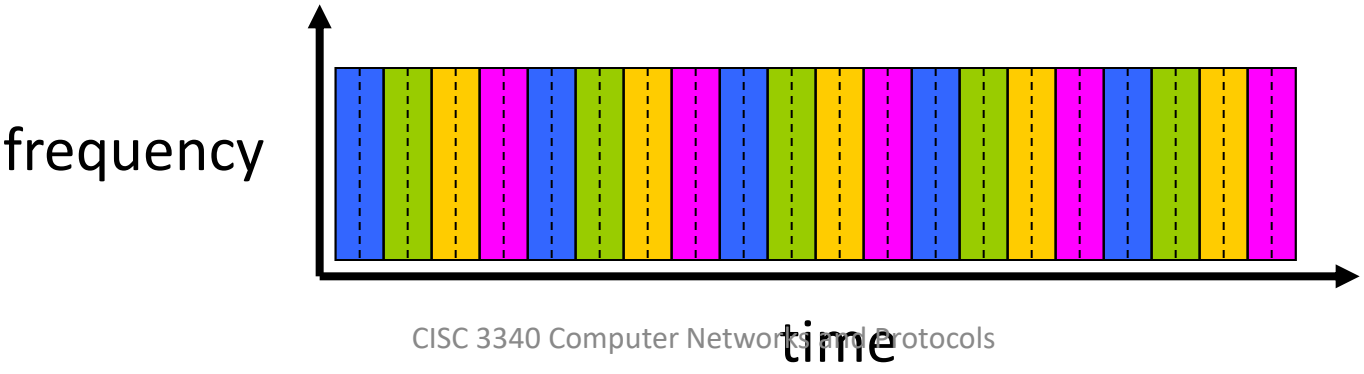
4 users



FDM



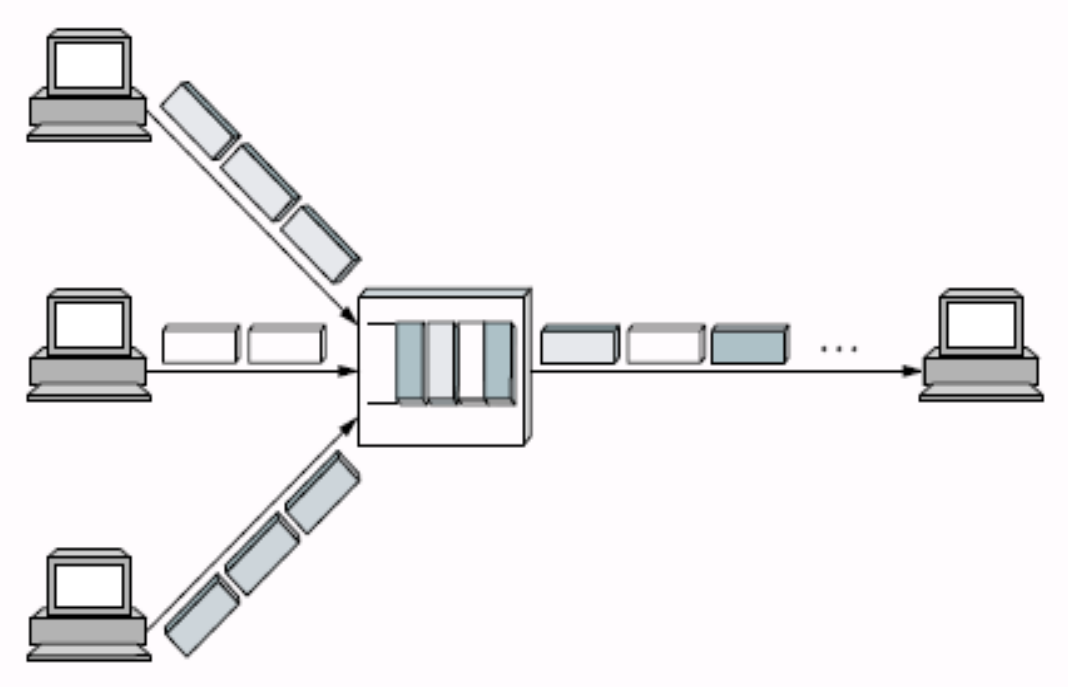
TDM



Static and Statistical Multiplexing

- Static Multiplexing
  - Examples: TDM and FDM
  - Limitations
    - If one flow does not have any data to send, its share of physical link (time quantum or frequency) remains idle
    - The maximum number of flows is fixed and known ahead of time
- Statistical Multiplexing
  - On-demand time-division
  - Schedule link on a per-packet basis
  - Packages from different sources interleaved on link
  - Buffer packets that are contending for the link
  - Congestion: Buffer (queue) overflow

An Example of Multiplexing



A switch multiplexing packets from multiple sources onto one shared link.

Statistical Multiplexing: Challenges

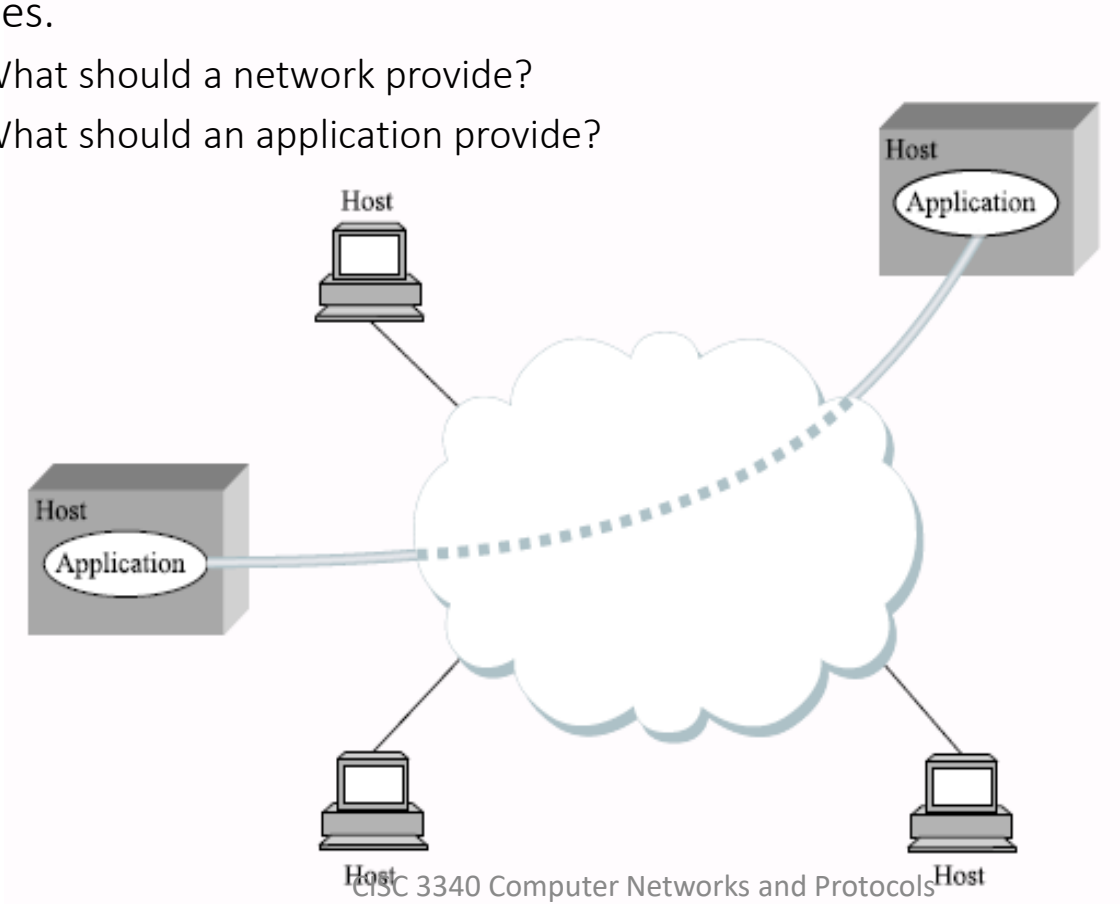
- Fairly allocating link capacity to different flows
- Dealing with congestion
- Ensuring quality of service

Support for Common Services

- Computer networks are to support computer applications.
- The application programs running on the hosts connected to the network must be able to communicate in a meaningful way.
- How do we design the network to ease the development of application programs?

Inter-Process Communication

- Turn host-to-host connectivity into process-to-process communication
- Fill gap between what applications expect and what the underlying technology provides.
  - What should a network provide?
  - What should an application provide?



Identify Common Communication Patterns

- Extracting common communication requirements
- Incorporating the functionality that meets these requirements in the network.

Common Communication Patterns of Example Applications

- File Transfer Protocol
- Network File System
- The World-Wide Web
- …

Common Communication Patterns of Example Applications

- Request/reply-based
  - Distributed file systems
  - Web access
- Stream-based
  - Video: sequence of frames
  - Video application
    - On-demand video
    - Video conference

Reliable Message Delivery

- Things can go wrong
  - Network failures:
    - Bit-level errors (electrical interference, e.g., lightning)
    - Packet-level errors (congestion)
    - Link and node failures (cable is cut, computers crashes)
  - Other related issues
    - Messages/packets are delayed
    - Messages/packets are delivered out of order
    - Third parties eavesdrop

Things can go wrong!

- Network failures:
  - Bit-level errors (electrical interference, e.g., lightning)
  - Packet-level errors (congestion)
  - Link and node failures (cable is cut, computers crashes)
- Other related issues
  - Messages/packets are delayed
  - Messages/packets are delivered out of order
  - Third parties eavesdrop

Manageability

- Upgrading equipment as the network grows to carry more traffic or reach more users
- Troubleshooting the network when things go wrong or performance isn't as desired
- Adding new features in support of new applications.
- ……

Summary

- Requirements for computer networks