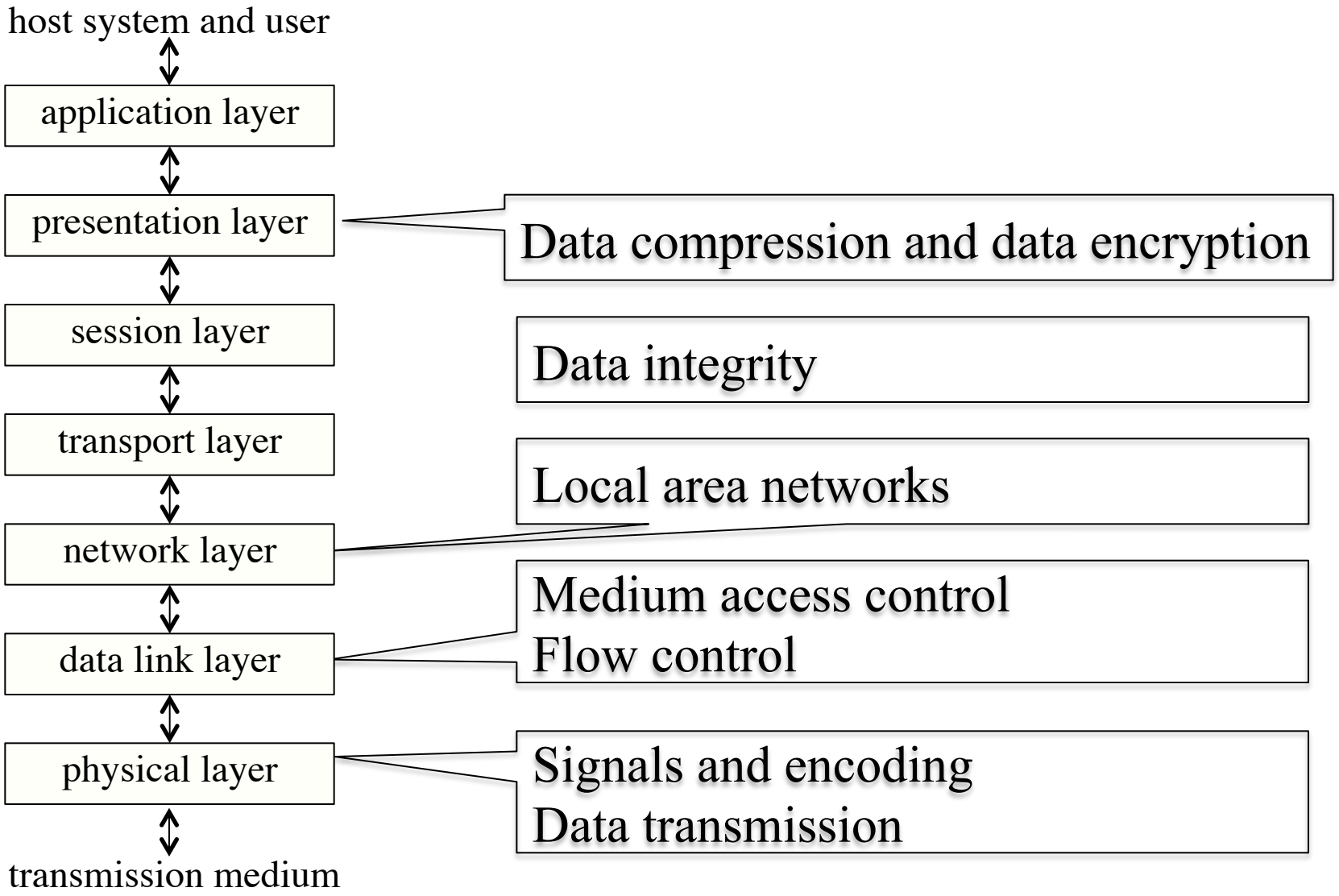
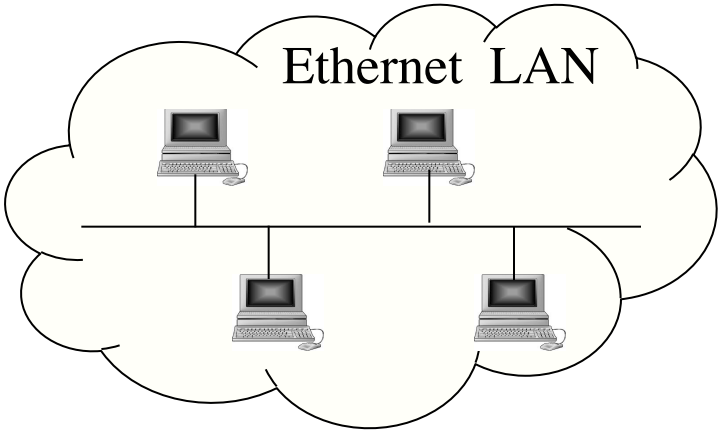
Lecture 15 Overview

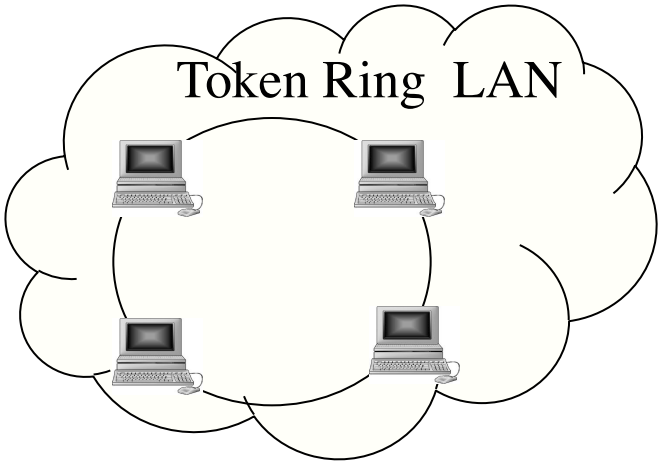
- Last Lecture
  - Local area networking
- This Lecture
  - Wide area networking 1
  - Source: chapters 8.1-8.3, 17.1, 18.1, 18.2
- Next Lecture
  - Wide area networking 2
  - Source: Chapter 20

Revision of Previous Lectures

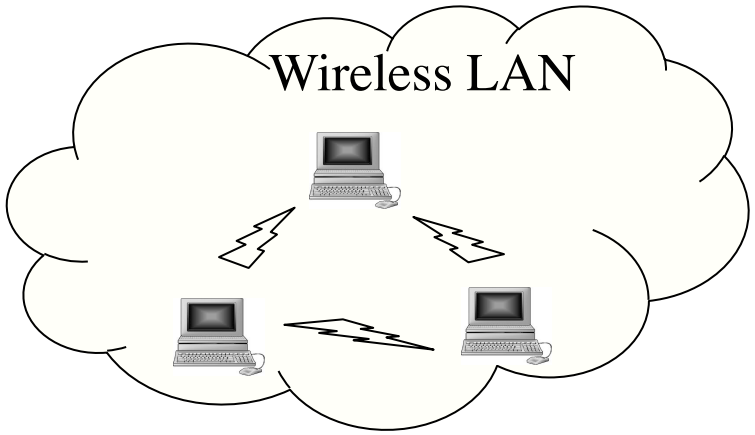


Today's Focus





- How to physically connect devices in different LANs?
- How to route packets between devices in different LANs?



Network Connecting Devices (1)

- Repeater/Hub - layer 1
  - A repeater is a regenerator (reconstruct the signal, send it on)
  - An active hub is a multiport repeater

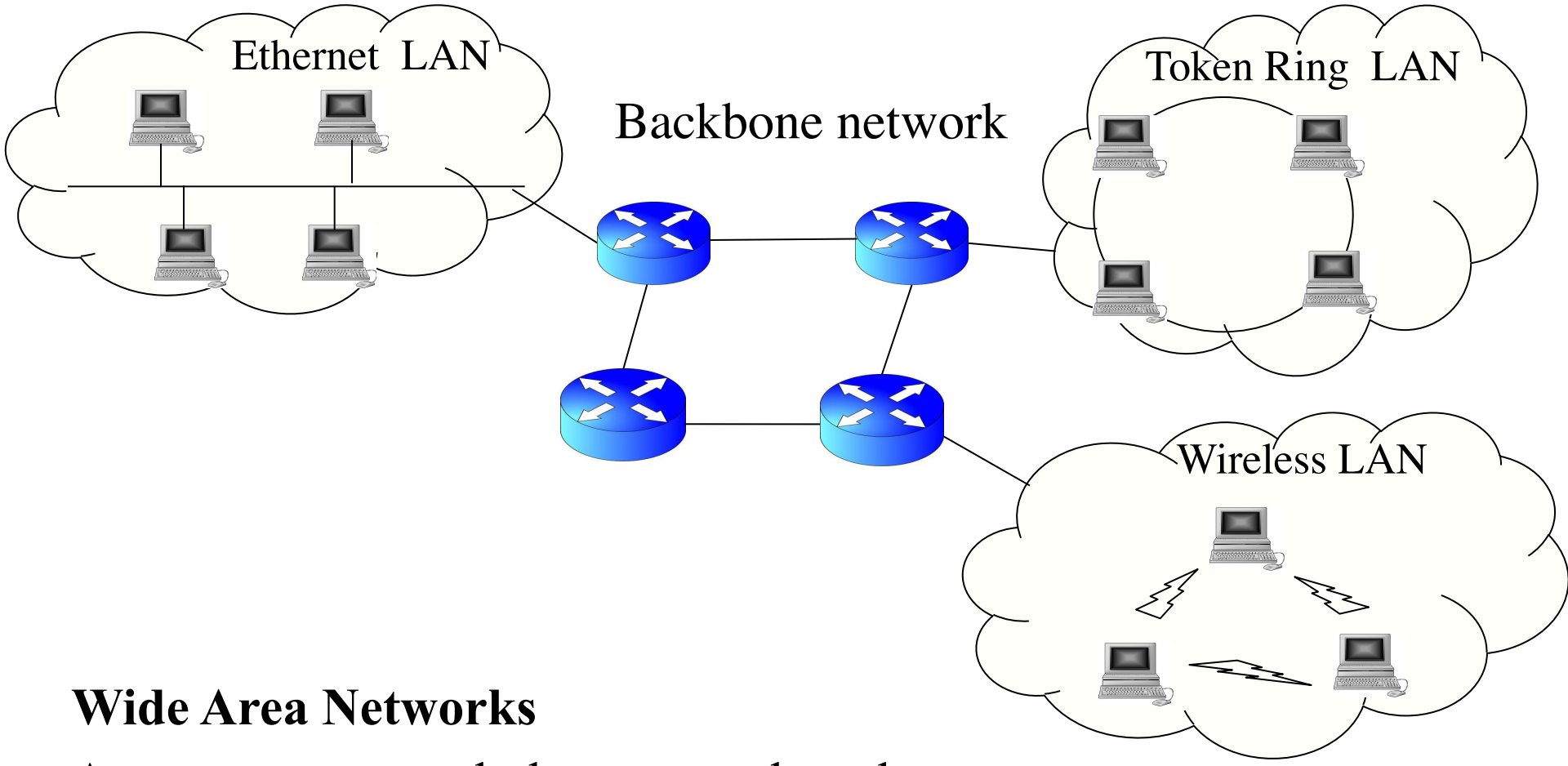
- Bridge – layer 2
  - Has a simple routing table used in **filtering** decisions
  - Filtering traffic using **MAC addresses**
  - Can be used to connect different LANs
  - Bridges connecting LANs are also called Layer 2 Switches
    - Protocol conversion
      - Frame format
      - Maximum data size
      - Date rate
      - Security

Network Connecting Devices (2)

- Router – layers 3
  - Connects different types of LAN's
  - Needs to know how to get to various networks
  - Maintains routing tables
  - Routing packets using **logical addresses** (IP address)
  - More complex routing algorithms

- Gateways - layer 7
  - Different character codes, encryption, compression
  - Different rules for establishing connections
  - Security

Wide Area Networks



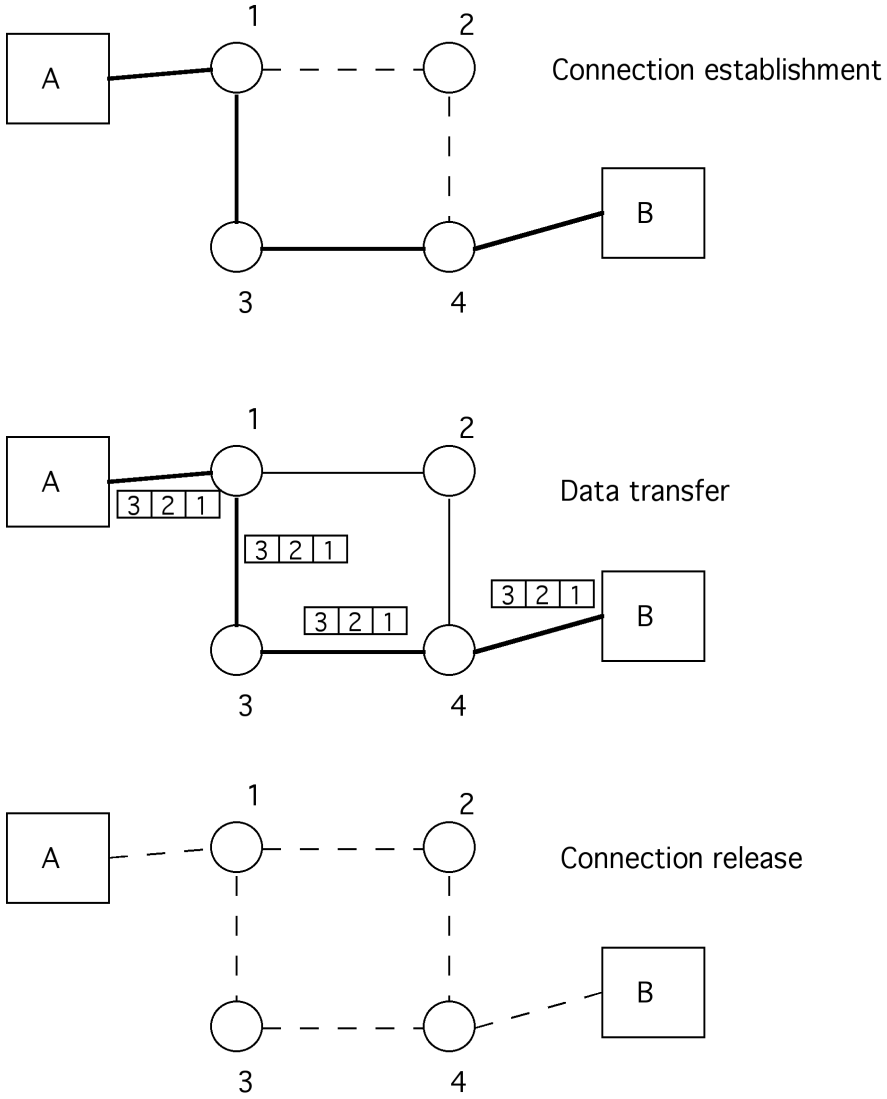
Wide Area Networks

A computer network that spans a broad area, often a country or a continent.

Connection Concepts (1)

- Service types
  - Connection-oriented service
  - Connectionless service
- Connection-Oriented Service
  - Modelled after the telephone system.
  - Establish a connection, use the connection, and then release the connection.
  - Acts like a tube - the sender pushes objects in at one end, and the receiver takes them out **in the same order** at the other end.

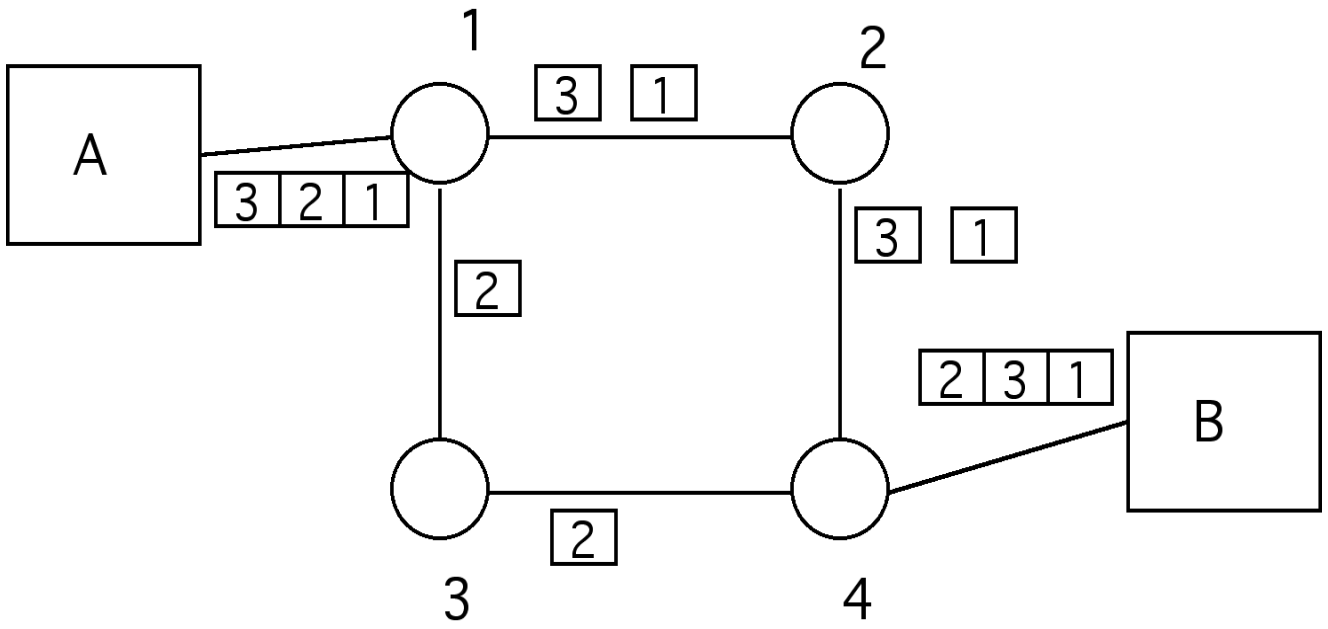
Connection-Oriented Service Example



Connection Concepts (2)

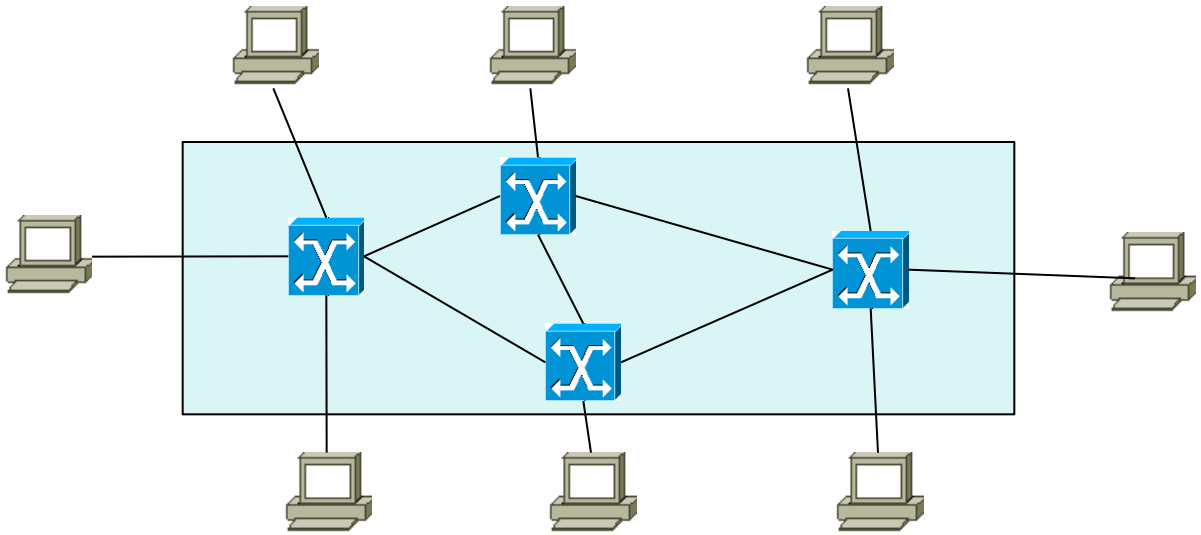
- Connectionless Service
  - Similar to the postal system.
  - Each message carries the full destination address.
  - Each message is routed through the network independent of the others.
  - Normally first message sent will be the first message to arrive.
  - But the order is not guaranteed.
  - An independent packet in connection-less service is called a *datagram*.

Connectionless Service Example



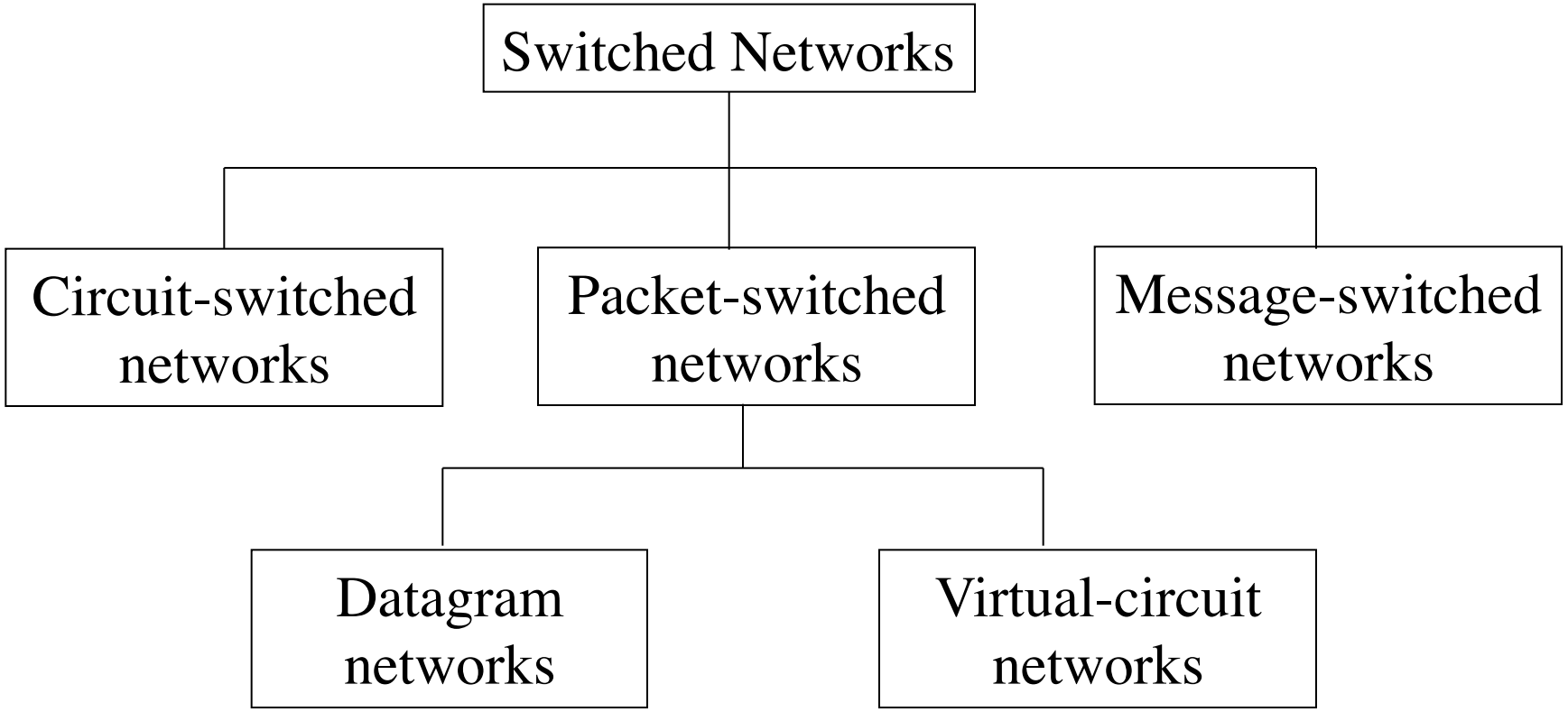
Switching Techniques

- Switched network
  - Switches: create temporary connection between linked devices



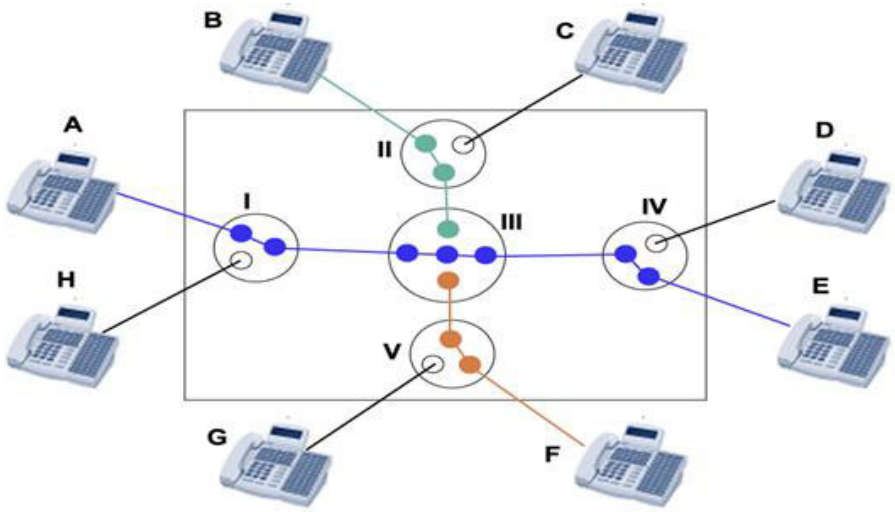
  - Switching can happen at several layers of the TCP/IP model
    - Physical layer
    - Data-link layer
    - Network layer
    - Application layer

Taxonomy of Switched Networks



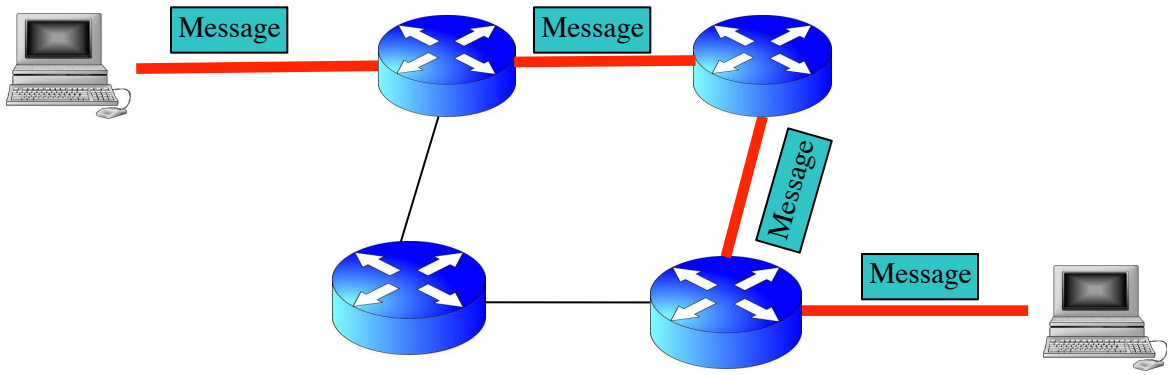
Circuit Switching

- Circuit switching
  - A physical connection (e.g. copper) is established before the start of communications.
  - Connection-oriented service: Connection is used solely by the communicating devices. Medium may be shared but not apparent.
  - Suitable for voice/video communication with constant bit rate.
  - Inflexible and low utilization
  - An example is the telephone system



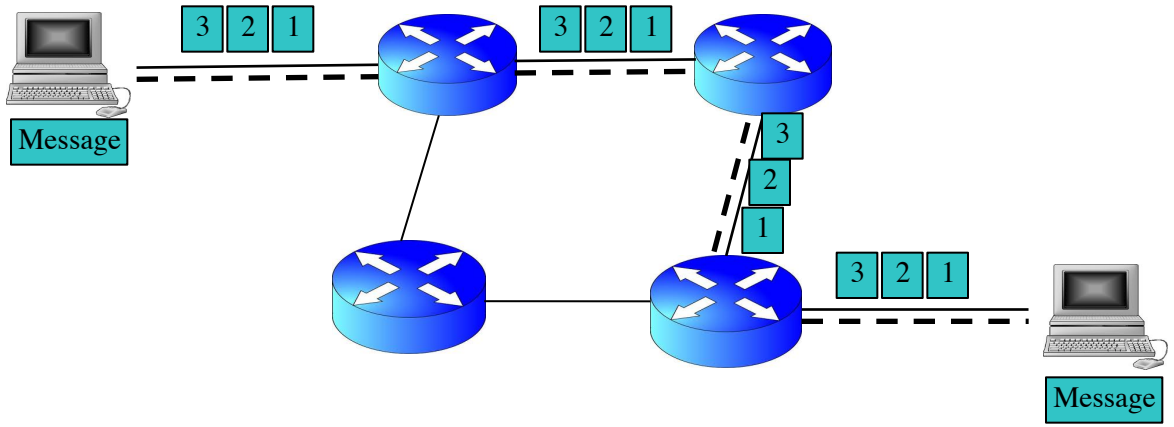
Message Switching

- Message Switching
  - Store and forward - the message is stored at each station until the route is available, then it is sent on its way.
  - Each switch stores the **whole** message and forward it to the next switch
  - Connectionless service, different message may travel over different routes.
  - Disadvantage - a long message may occupy the route for a long time



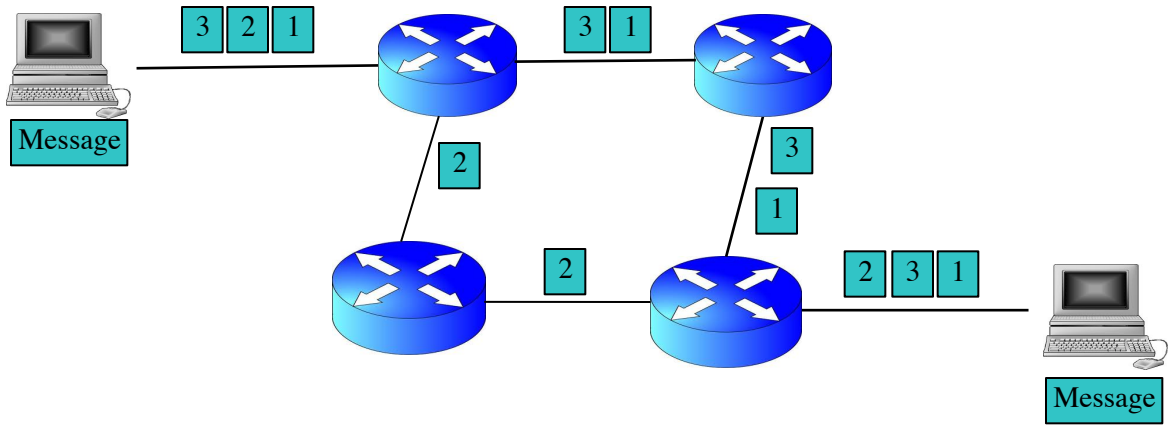
Packet Switching (1)

- Packet Switching
  - Message broken into pieces, called packets, sent independently
  - Packets are received and stored until forwarded to the next node in the route.
  - Support both connection-oriented and connectionless services
  - Routing methods
    - Virtual circuit – a logical connection established prior to data transfer. All packets associated with the connection travel through the same nodes.



Packet Switching (2)

- Packet Switching
  - Message broken into pieces, called packets, sent independently
  - Packets are received and stored until forwarded to the next node in the route.
  - Support both connection-oriented and connectionless services
  - Routing methods
    - Datagram - similar to letters delivery

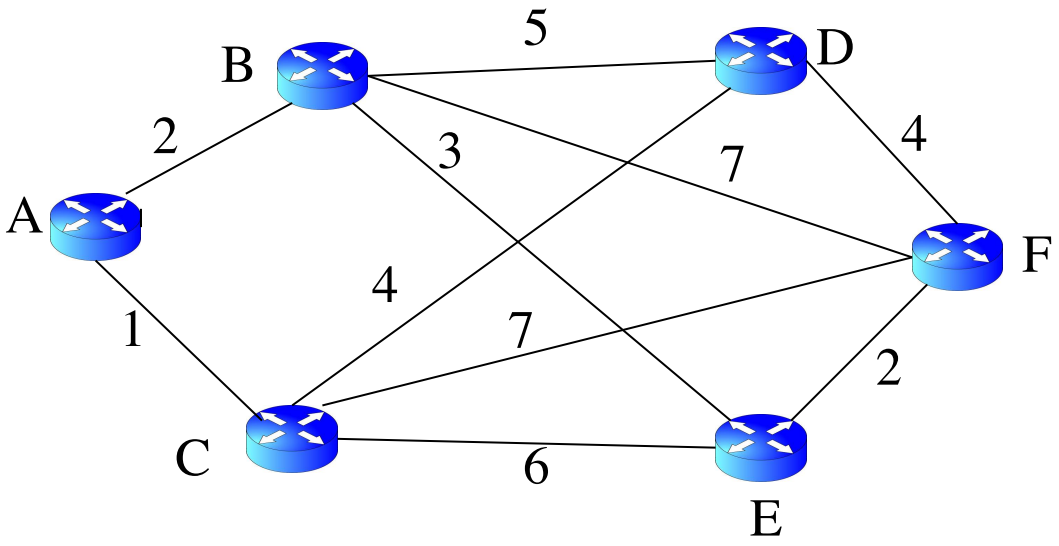


LANs vs. WANs

- Protocol conversion
  - Simple protocol conversion in LAN's bridges
  - Convert between different LAN protocols in WAN's routers
    - WAN's evolved by interconnecting networks
    - Many different protocols and equipments
- Routing
  - Simple routing in LAN's bridges according to LAN addresses, such as Ethernet addresses.
  - Complex routing in WAN's routers according to WAN addresses, such as IP addresses.
    - Require more complex strategies
    - Often many paths between nodes
    - Paths can experience failures
    - Congestion

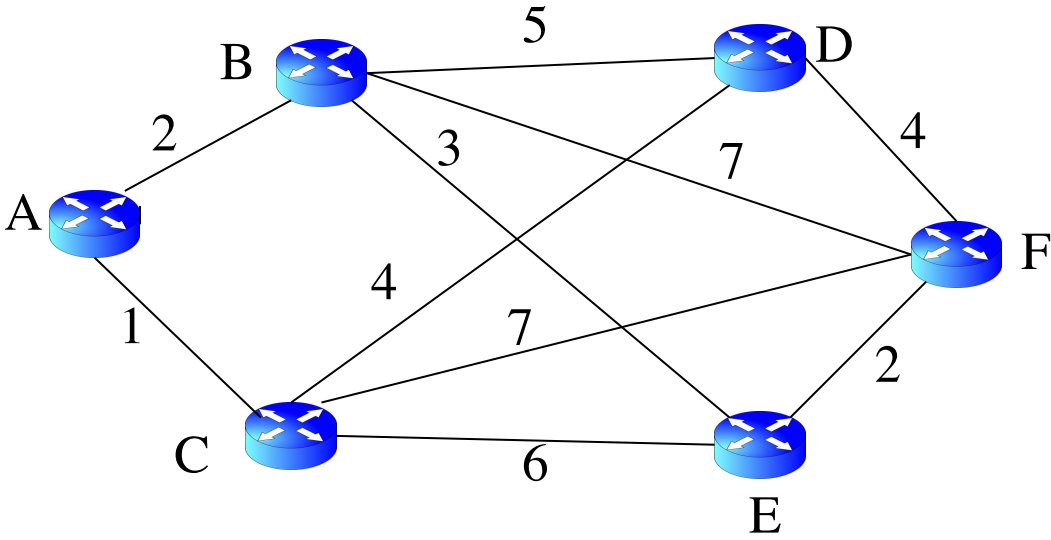
Introduction to Routing

- Routing metric: the major factor considered when routing
  - Length of path
  - Number of hops
  - Transport time
  - In-route delays



Introduction to Routing (cont.)

- Routing Tables
  - Do not store the entire end-to-end route
  - Specify the next-hop node and cost



Destination	Next-hop	Cost
B	B	2
C	C	1
D	C	5
E	B	5
F	B	7

Partial routing table for node A

Introduction to Routing (cont.)

- Types of routing
  - How are tables created and maintained?
    - **Centralised:** created and maintained by a central node
    - **Distributed:** created and maintained by individual nodes
  - How are the tables updated?
    - **Static:** created once and maintained manually
    - **Adaptive:** self-adaptive to network changes

Centralised Routing

- Global routing table is created and maintained by a central device.
- Global routing table is broadcast to network nodes so they can set up their own routing tables.
- Routing matrix:

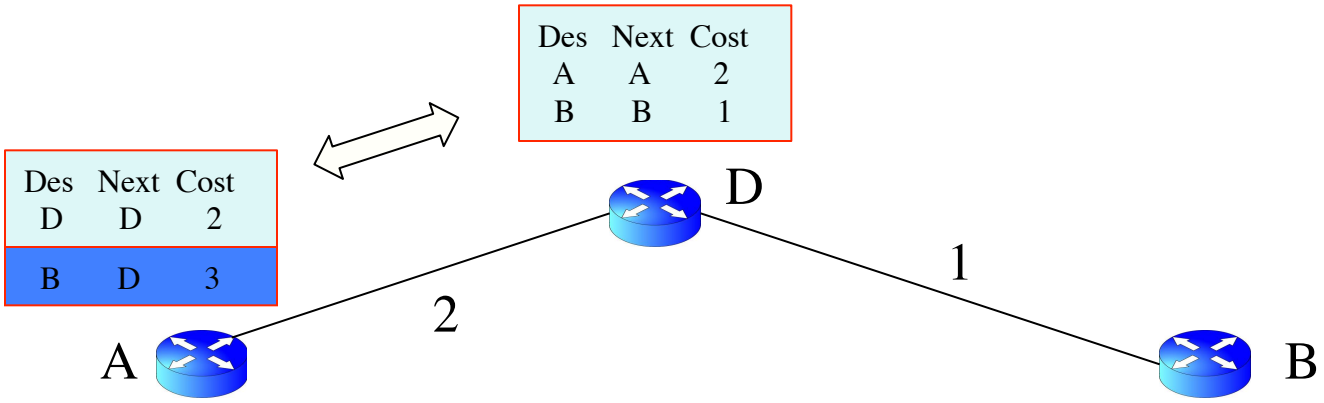
Destination nodes →

Source nodes ↓

	A	B	C	D	E	F
A	—	B	C	C	B	B
B	A	—	A	D	E	E
C	A	A	—	D	E	F
D	C	B	C	—	F	F
E	B	B	C	F	—	F
F	E	E	C	D	E	—

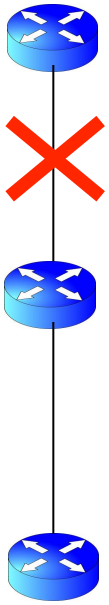
Distributed Routing

- No central control
- Each node must determine and maintain its own routing table.
  - Know the neighbours and cost of getting to them
  - Share routing table with neighbours via communication
  - Determine cost to send to a specific destination



Static Routing & Dynamic Routing

- Static routing
  - Assumes conditions do not change
  - Created once, but have to update manually
  - Reality
    - Nodes are added or removed
    - Cost changes
- Dynamic routing
  - Allows a routing node to respond to changes
  - Update routing tables in response to changes
  - Reality
    - Difficult to implement efficiently
    - Increases network traffic due to routing table updates
    - Can have packets shuttling between source and/or routers under some conditions



Comparison of Routing Types

Table 7.1 Types of Routing

Routing Type	Advantages	Disadvantages
Centralized routing	Simple method because one location assumes routing control.	The failure of the central location or any links connected to it has a severe effect on providing routing information to network nodes.
Distributed routing	Failure of a node or link has a small effect in providing accurate routing information.	Exchange of information is more complex. May also take longer for a node to learn of conditions in remote locations.
Static routing	Simple method because nodes do not have to execute routing algorithms repeatedly.	Insensitive to changing conditions. A good route may turn into a very bad one.
Adaptive routing	Provides the most current information regarding link costs.	High overhead because nodes must maintain current information. Transmitting information regarding changing conditions adds to network traffic.

Summary

- Concepts
  - Connection-oriented service
  - Connectionless service
  - Circuit switching
  - Message switching
  - Packet switching
- Connecting devices
  - Repeaters, Bridges, Routers, Gateways
- Routing classification
  - Centralised routing
  - Distributed routing
  - Static routing
  - Adaptive routing