CS 372 Lecture #3 (Part 1)

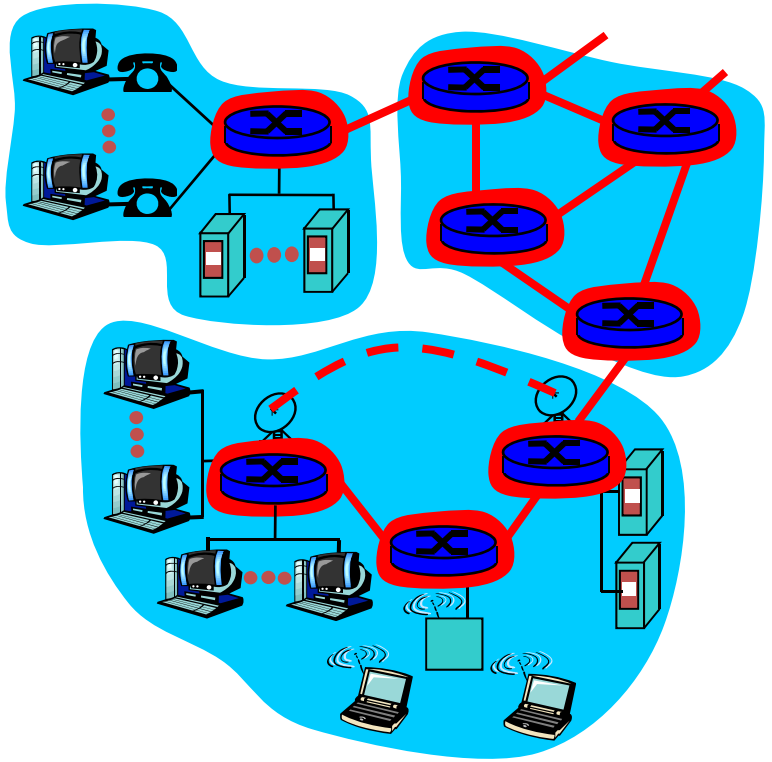
Overview of Networking:

- Network core
  - circuit switching
    - frequency-division multiplexing
    - time-division multiplexing
  - packet switching
    - statistical multiplexing
- Utilization

Note: Many of the lecture slides are based on presentations that accompany *Computer Networking: A Top Down Approach,* 6th edition, by Jim Kurose & Keith Ross, Addison-Wesley, 2013.

The network core:

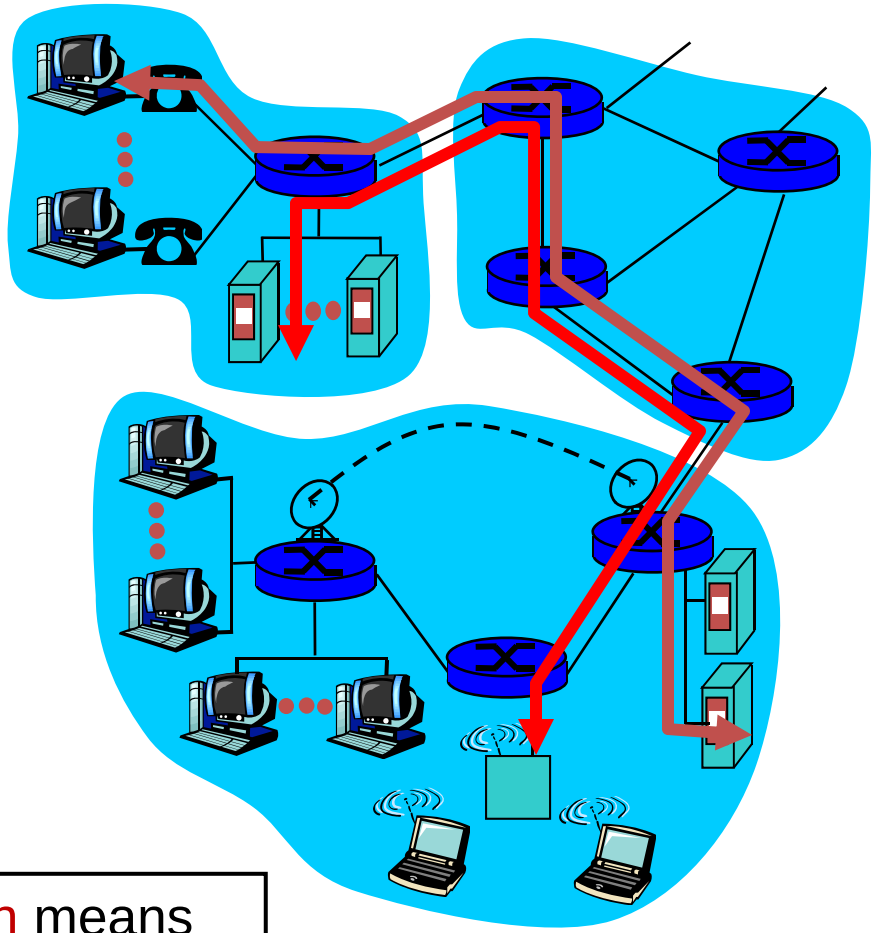
- mesh of interconnected routers
- *the* fundamental question: how is data transferred through the network?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent through net in discrete "chunks" (packets) on shared media



The network core: Circuit Switching

End-to-end resources reserved for "call"

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required



For our purposes, bandwidth means transmission rate, usually expressed in bits per second (bps)

The network core: Circuit Switching

network resources (e.g., bandwidth) divided into "pieces"

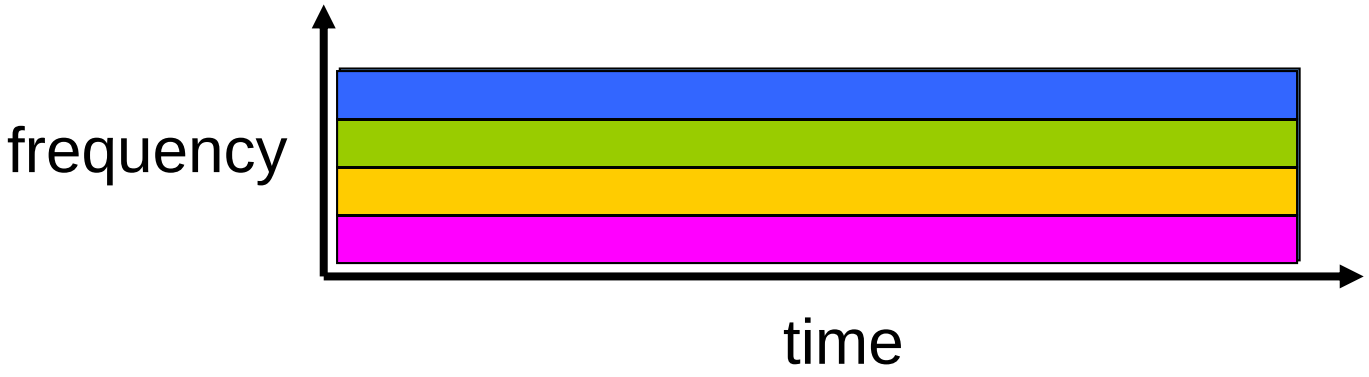
- pieces allocated to calls
- resource piece *idle* if not used by owning call *(no sharing)*
- Consumers are charged on a per-minute basis
- 2 ways of dividing the link bandwidth into "pieces"
  - frequency division multiplexing (FDM)
  - time division multiplexing (TDM)

Circuit Switching: FDM and TDM

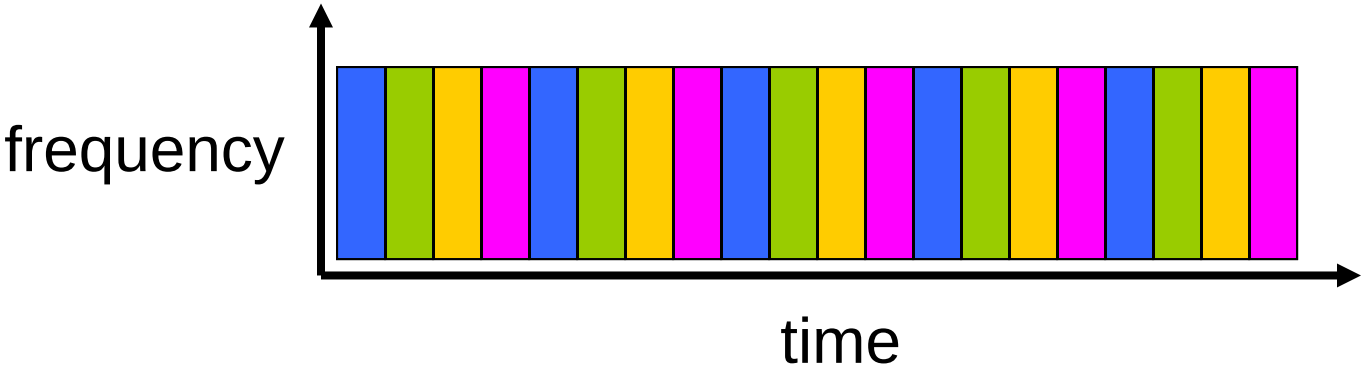
Example:

4 users

Frequency Division Multiplexing (FDM)



Time Division Multiplexing. (TDM)



Numerical example

- How long does it take to send a file of 80 KiB from host A to host B over a circuit-switched network?
  - The link's transmission rate = 1.5 Mbps
  - Each link uses TDM with 24 slots/sec
  - 500 ms to establish end-to-end circuit

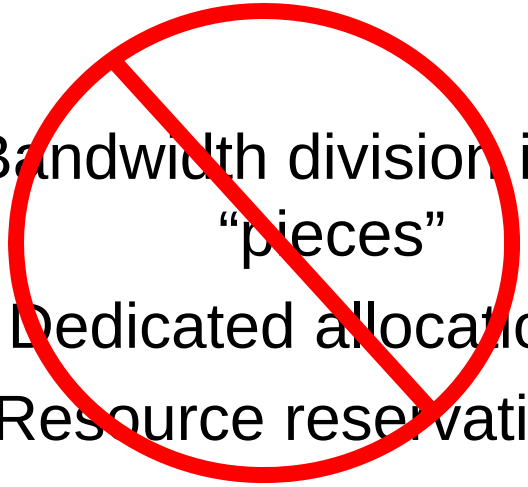
Figure it out … (watch the K, Ki and s, ms)

- Solution:
  - 80 KiB = (80 x 2^{10} Bytes) x (8 bits per Byte) = 640 Kib = 655.36 Kb
  - Bandwidth of one circuit = (1.5 Mbps)/24 = 62.5 Kbps
  - Time to send: (655.36 Kb)/(62.5 Kbps) + 0.5s
    = ~10.5 s + 0.5 s = ~ 11 s

Discussion question: What would be different if we use FDM instead of TDM?

The network core: Packet Switching

- all streams *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*



Resource contention:

- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link

Packet Switching

- Data transmitted in small, independent pieces
  - Source divides outgoing messages into *packets*
  - Destination recovers original data
- Each packet travels independently
  - Includes enough information for delivery
  - May follow different paths
  - Can be retransmitted if lost

Packet Switching

Functions of packet-switching networks

- Source host (edge): Packet construction
  - encode/package data at source
- Routers (core): Packet transmission
  - send packet from source to destination
- Destination (edge): Packet interpretation
  - unpack/decode data from packet at destination
  - acknowledge receipt

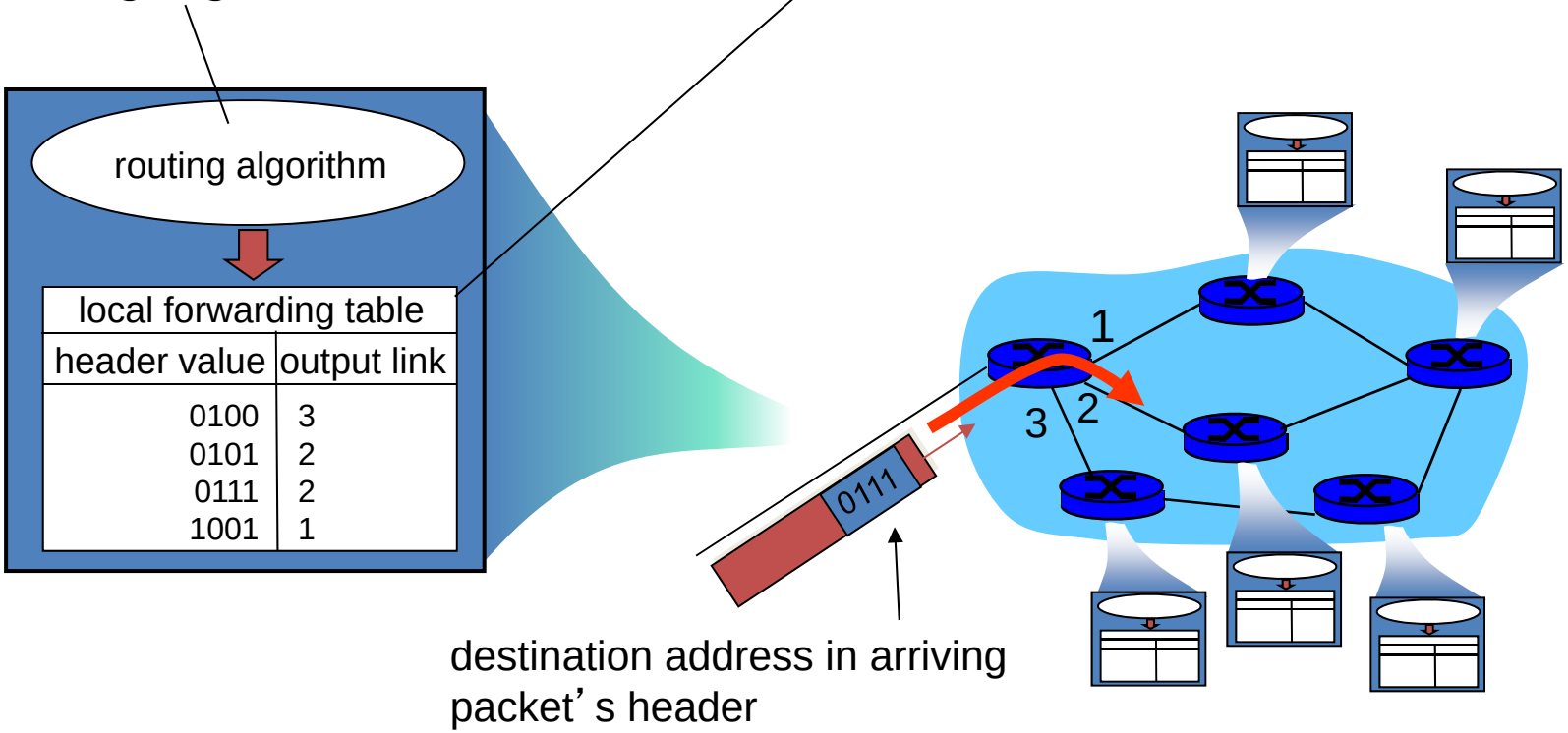
The network core: Packet Switching

Two key functions

routing: determines source-destination route taken by packets

- *routing algorithms*

forwarding: move packets from router's input to appropriate router output



The network core: Packet Switching

Other functions

- Queuing
- Route discovery
- Traffic/congestion control
- Retransmitting lost packets
- Determining type of data
  - messages
  - service requests/responses
  - files
  - audio/video
  - etc.
- etc.

Summary Lecture #3 (End of Part 1)

- Definitions:
  - network core
  - circuit-switching, packet-switching
  - multiplexing
- Network core
  - composition (interconnected routers)
  - functions
- FDM, TDM