National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 04

Chapter 1

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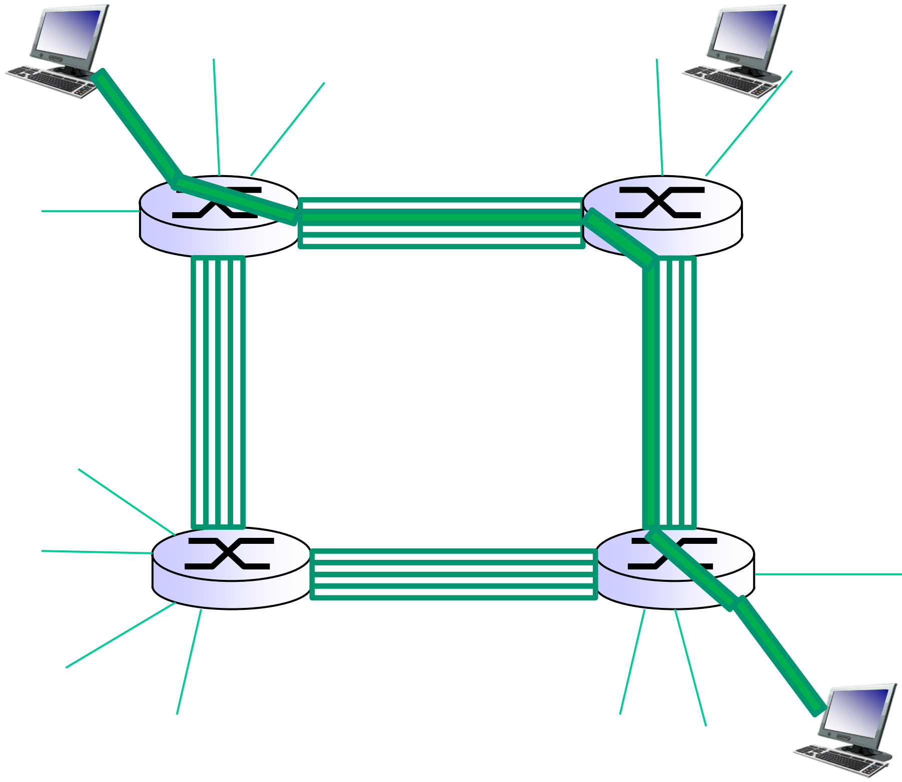
Office Hours: 02:30 pm till 06:00 pm (Every Tuesday & Thursday)

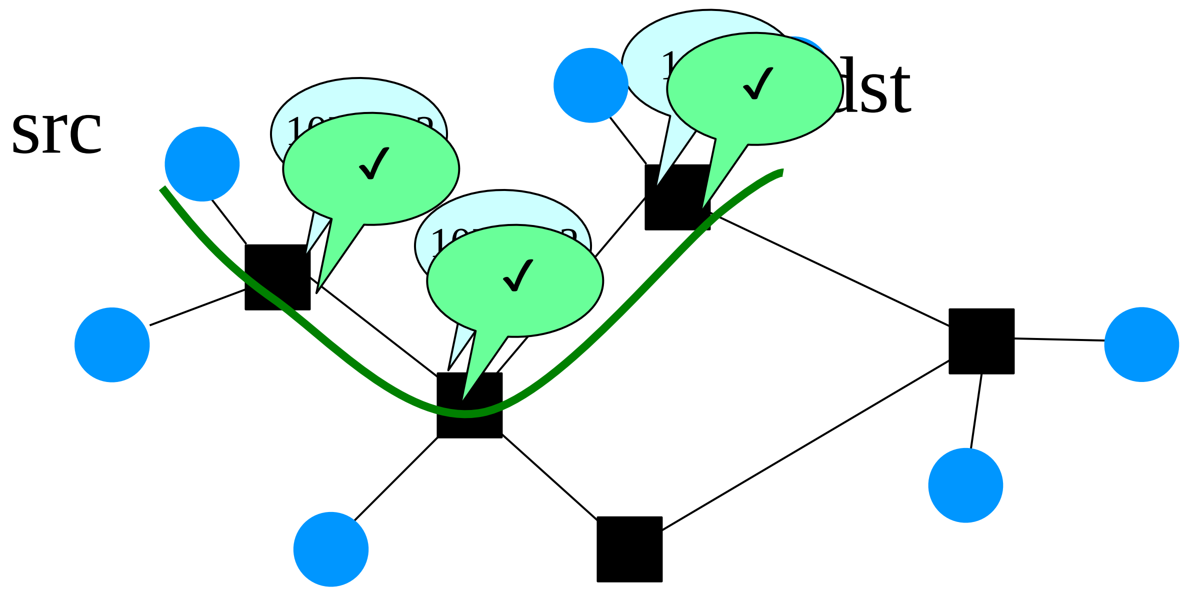
Circuit Switching

end-end resources allocated to, reserved for "call" between source & dest:

- In diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call *(no sharing)*
- Commonly used in traditional telephone networks

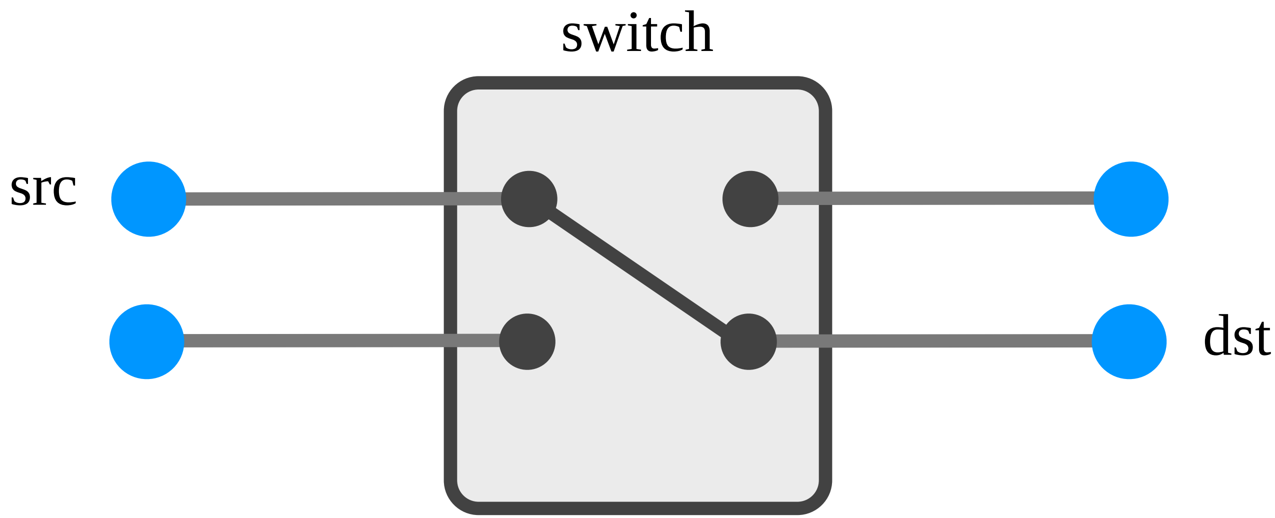


Circuit Switching



(1) src sends a reservation request to dst
(2) Switches "establish a circuit"
(3) src starts sending data
(4) src sends a "teardown circuit" message

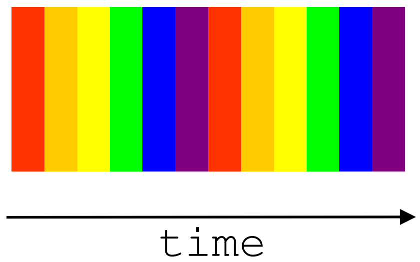
Circuit Switching



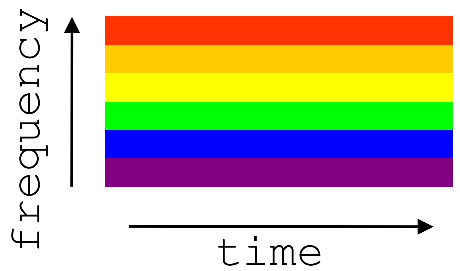
Reservation establishes a “circuit” within a switch

Many kinds of "circuits"

- **Time division multiplexing**
  - divide time in time slots
  - separate time slot per circuit



- **Frequency division multiplexing**
  - divide frequency spectrum in frequency bands
  - separate frequency band per circuit

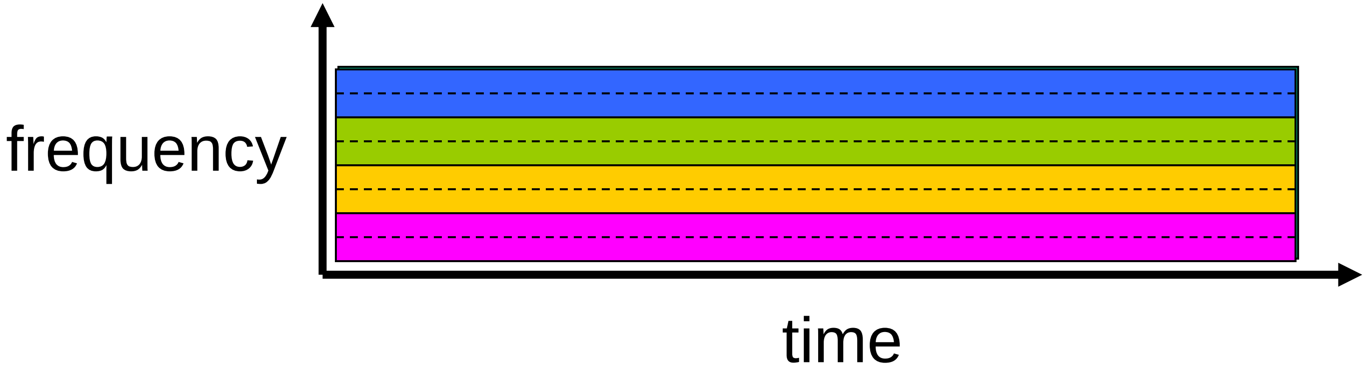


Circuit switching: FDM versus TDM

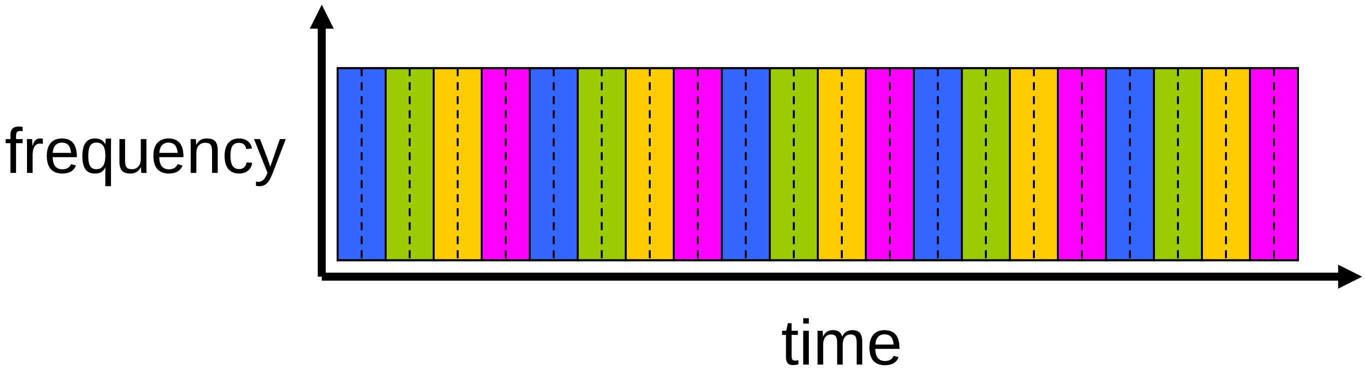
Example:

4 users

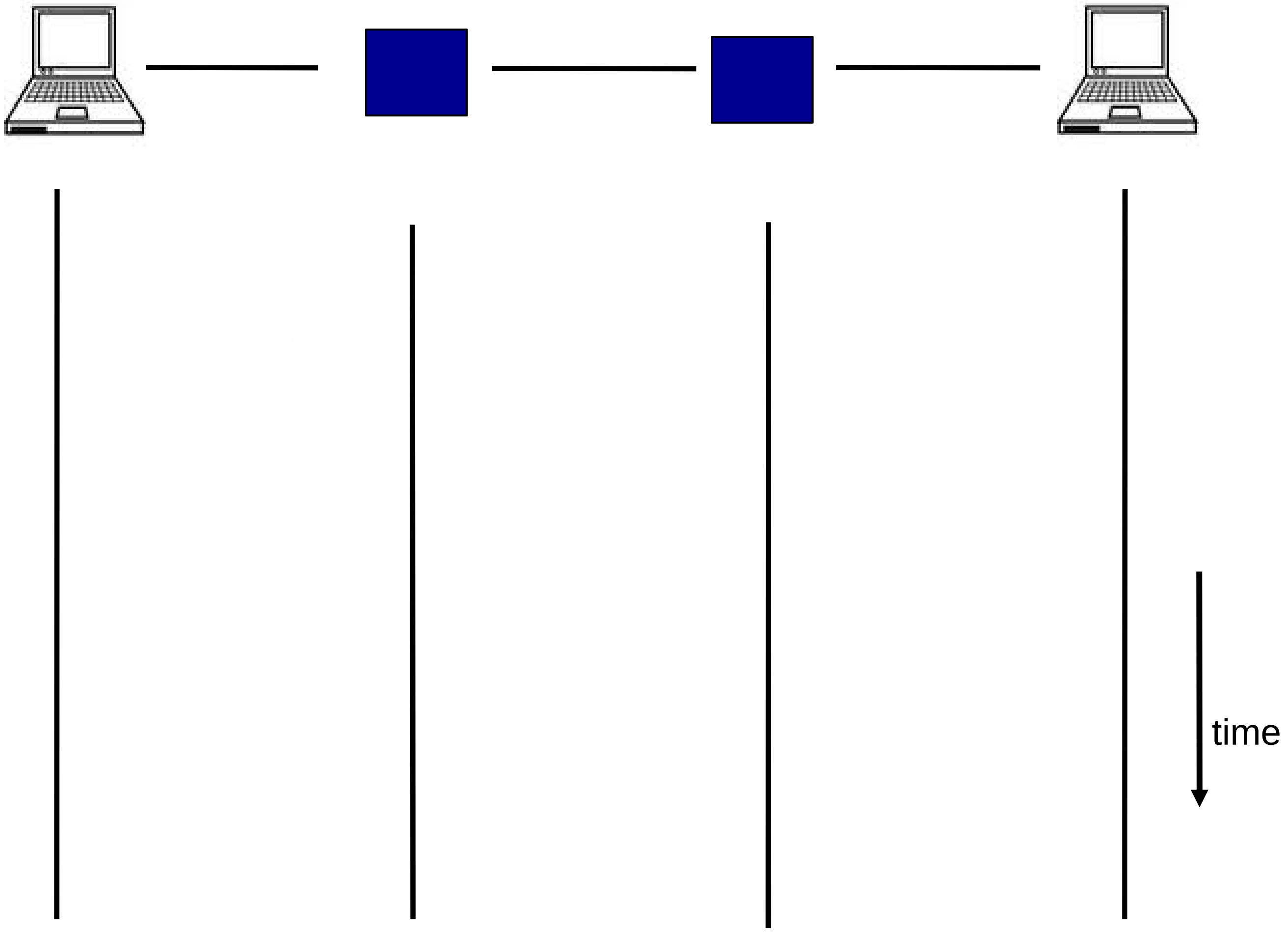
FDM



TDM



Timing in Circuit Switching



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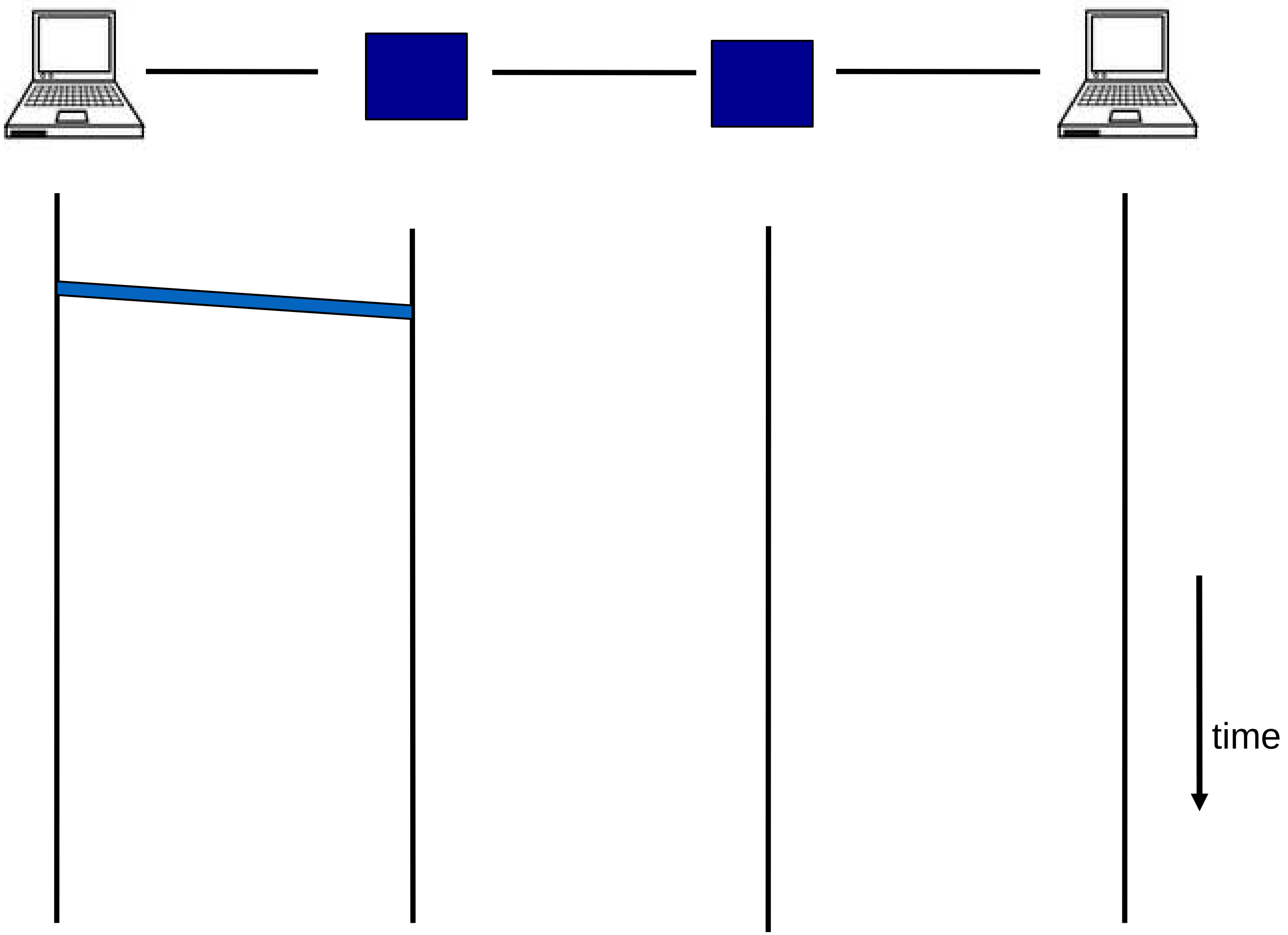

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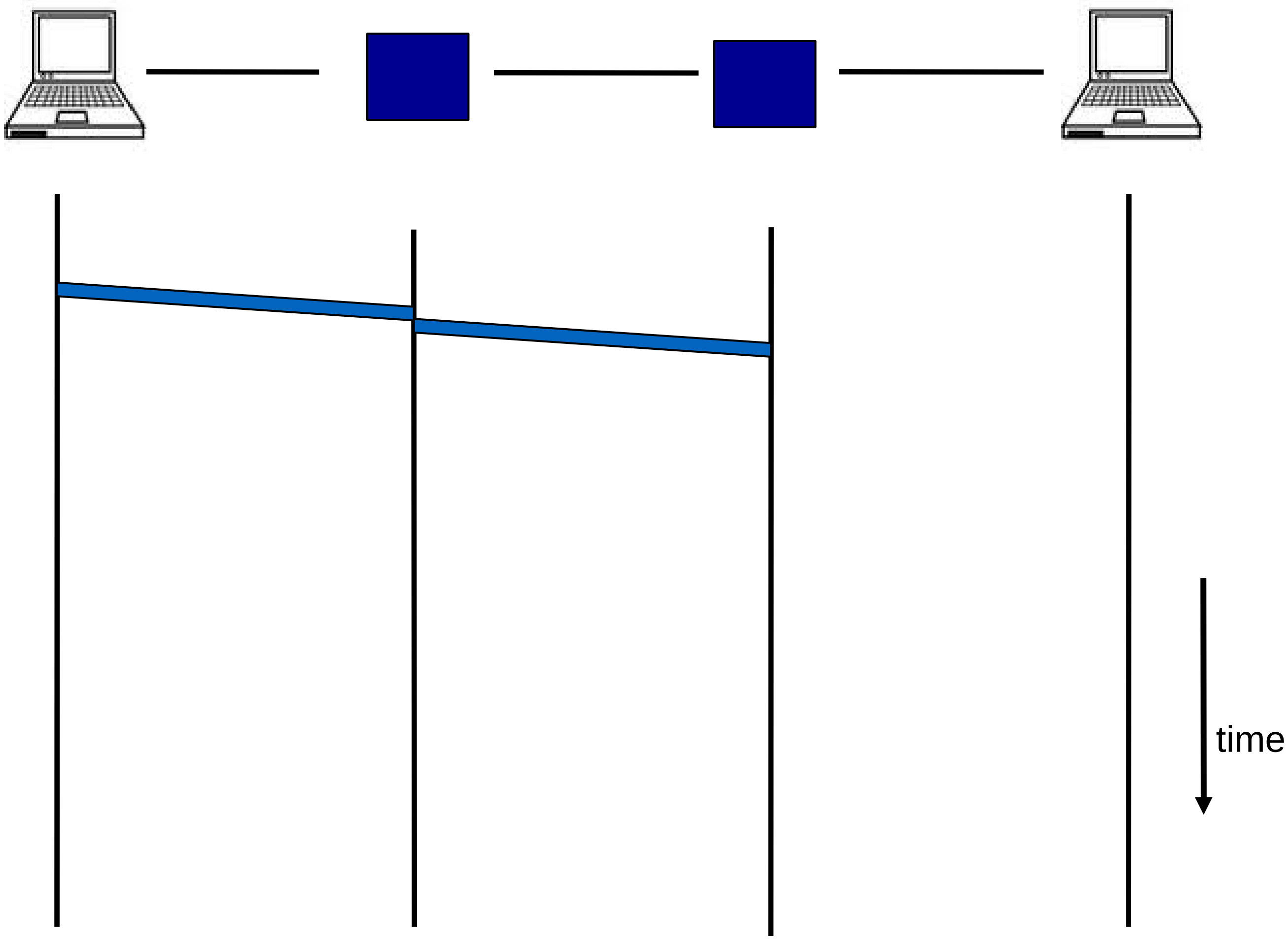
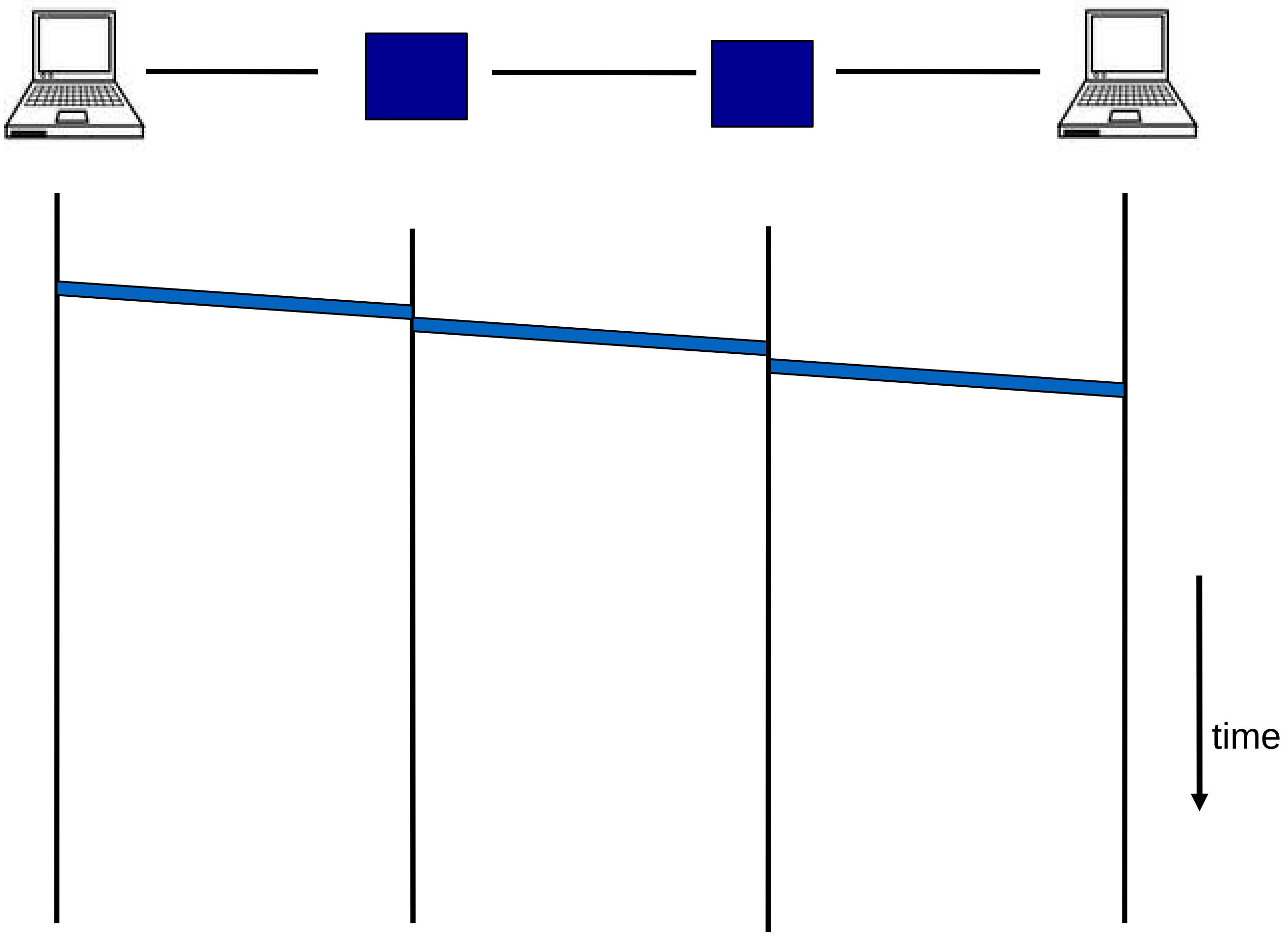
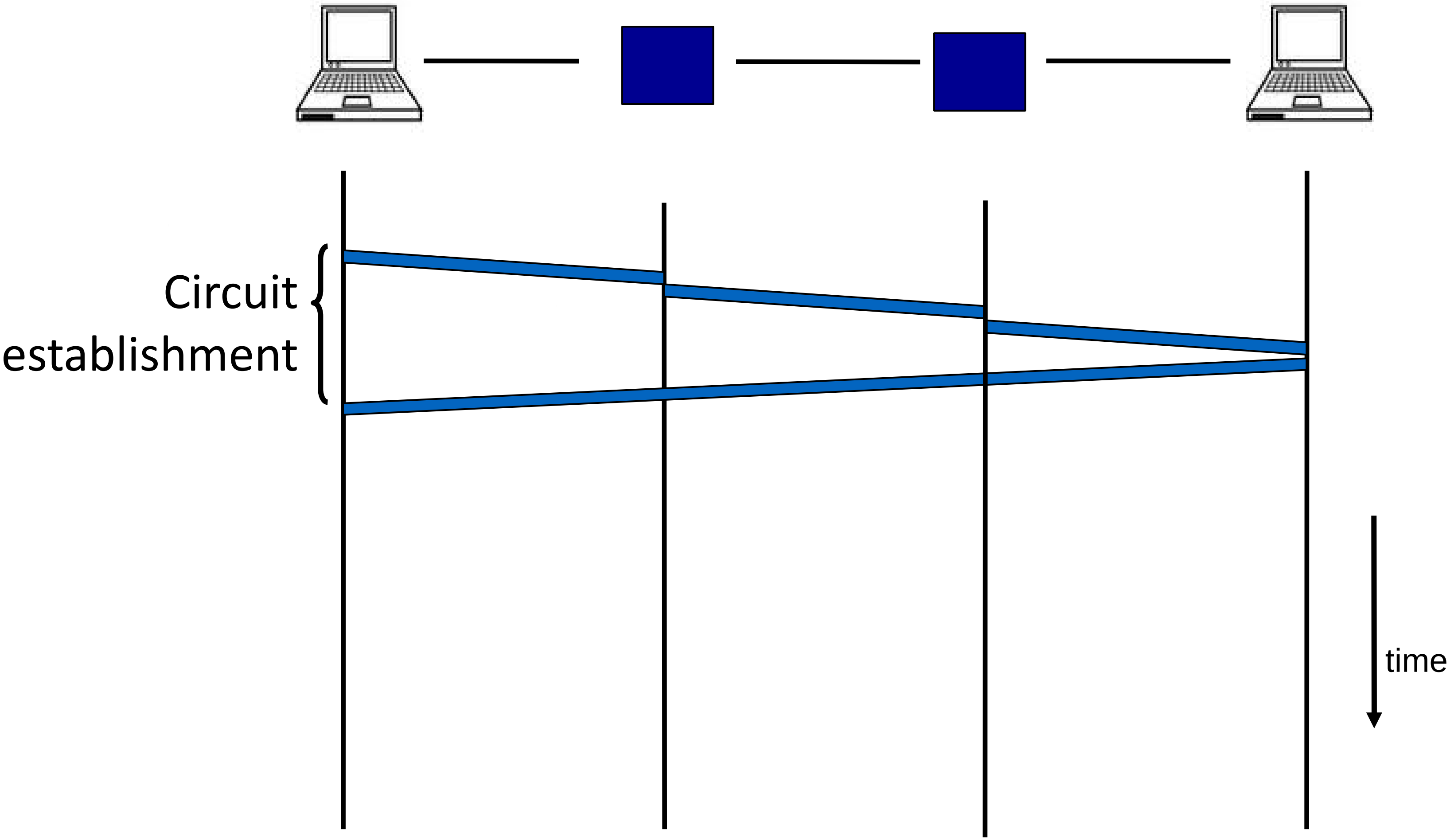


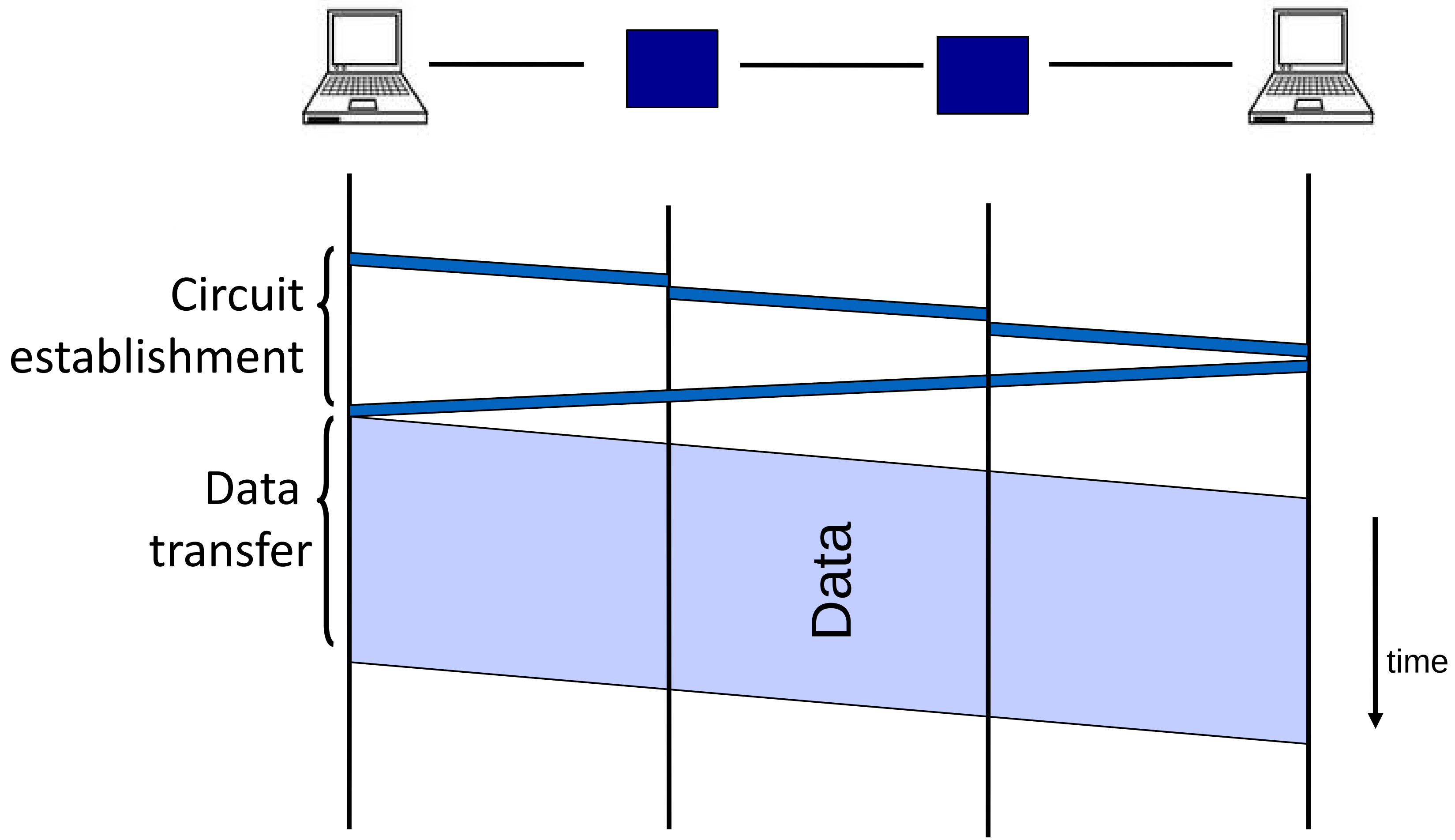
Timing in Circuit Switching



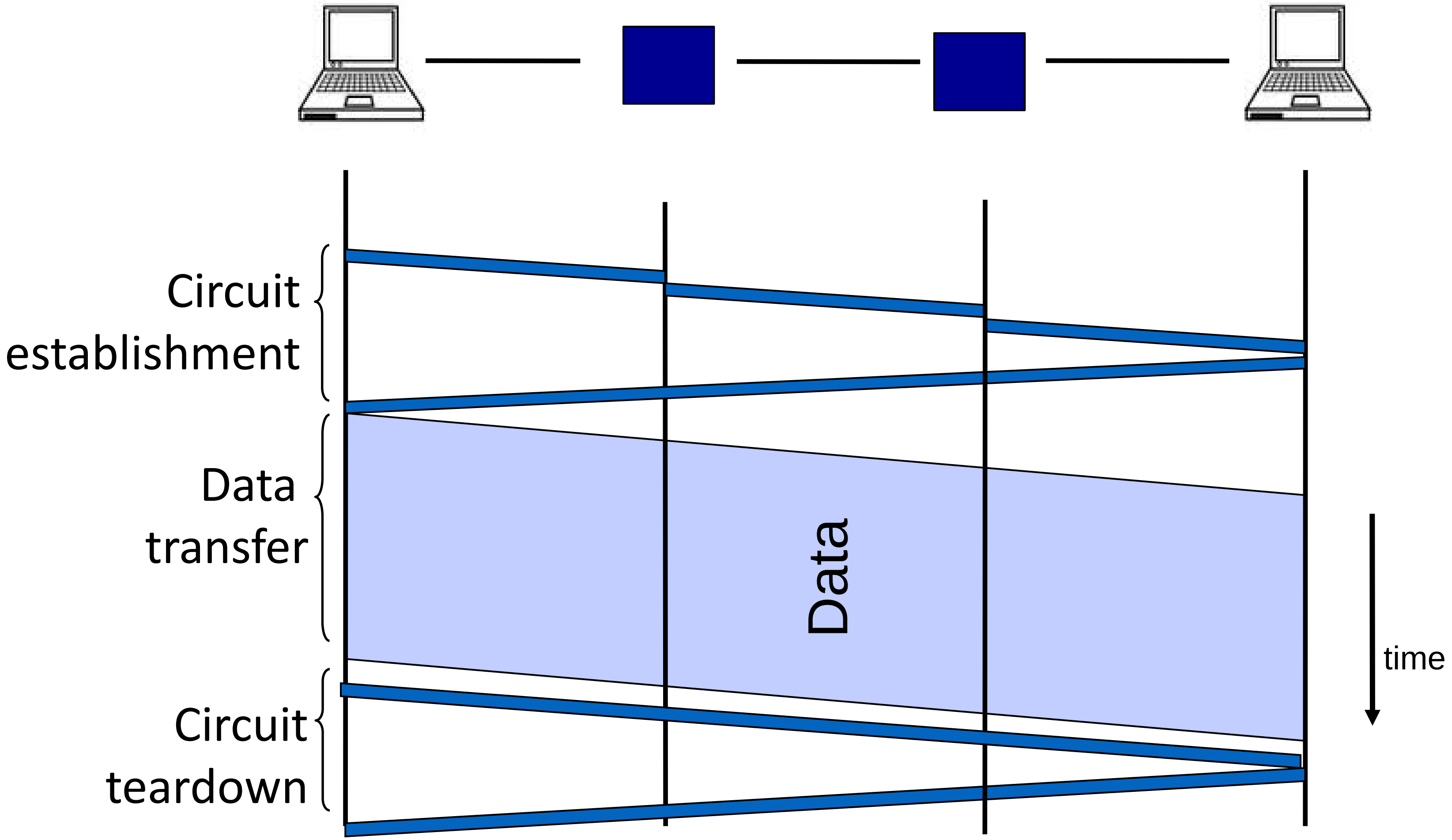
Timing in Circuit Switching



Timing in Circuit Switching



Timing in Circuit Switching



Numerical Example

• How long does it take to send a file of 80 Kbytes from host A to host B over a circuit-switched network?

- All links are 1.536 Mbps
- Each link uses TDM with 24 slots/sec
- Time to establish end-to-end circuit is 500 msec

Let's work it out!

Numerical Example: Solution

- 80 Kbytes is 640,000 bits

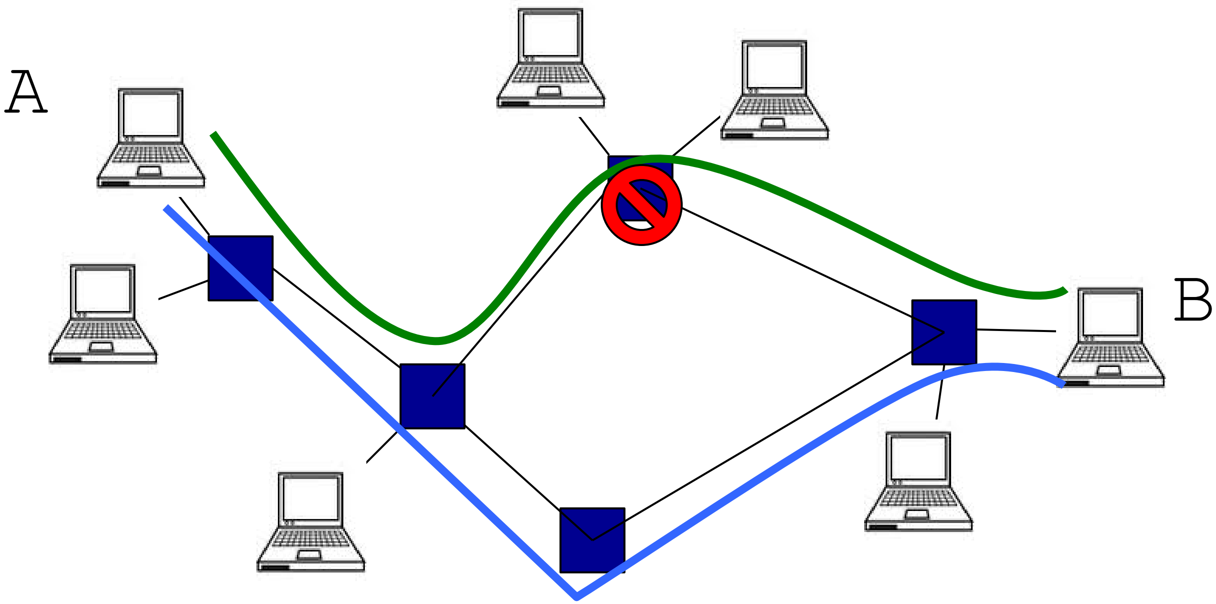
– NOTE: networks in bits, end systems in bytes
– NOTE: 8 bits to a byte

- Each circuit has a rate of 1.536Mbps / 24
  => 1536000/24 = 64000bps

- So, it takes 640000 bits / 64000 bps = 10 seconds to transmit the file

- Need to add the circuit establishment time ($\frac{1}{2}$ second)
- So, 10.5 seconds

Circuit Switching



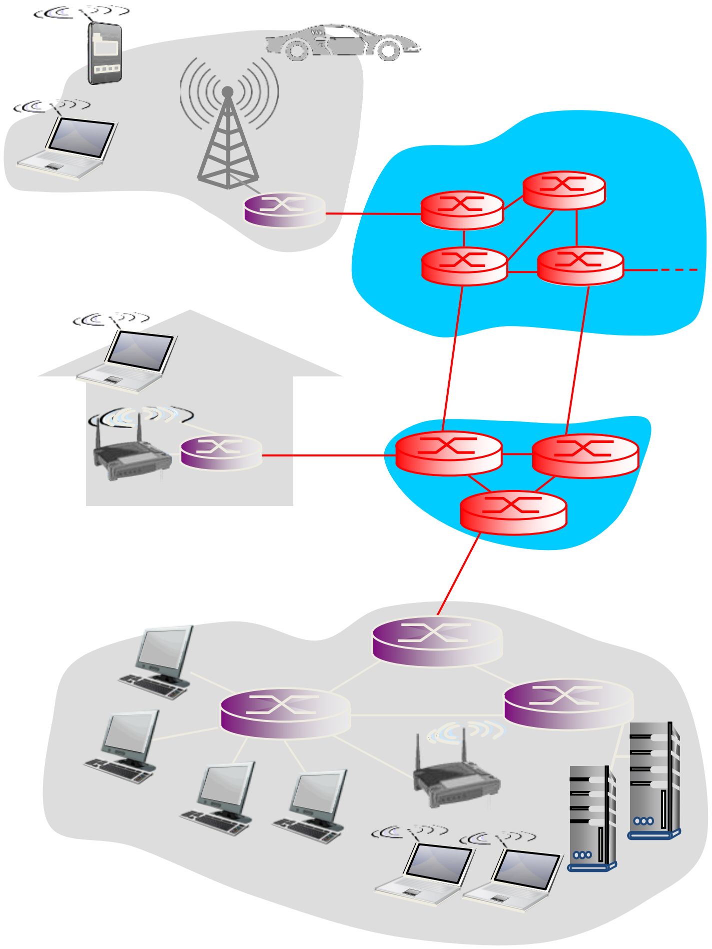
Circuit switching doesn’t “route around trouble”

Circuit Switching

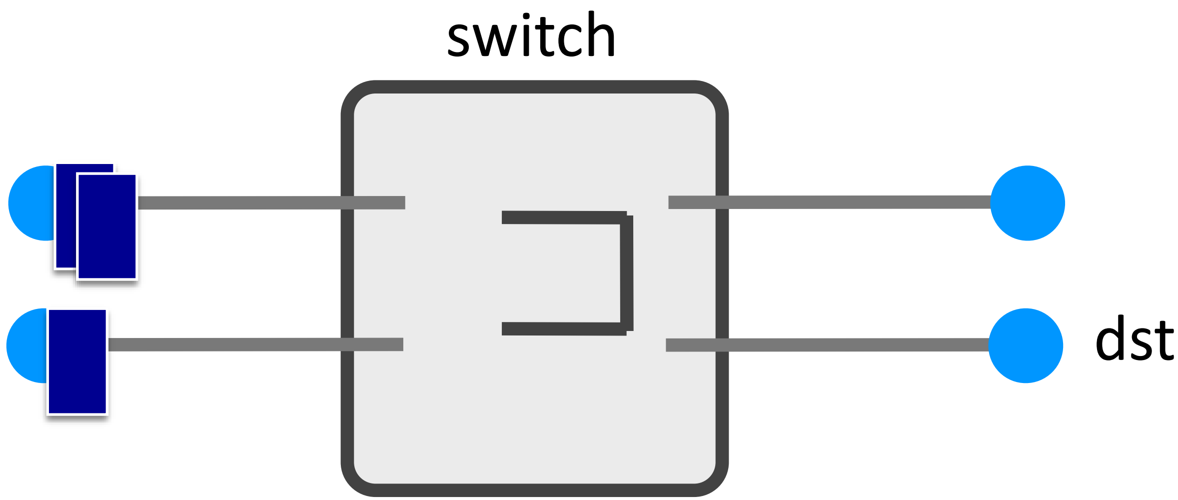
- **Pros**
  - predictable performance
  - simple/fast switching (once circuit established)
- **Cons**
  - complexity of circuit setup/teardown
  - inefficient when traffic is bursty
  - circuit setup adds delay
  - switch fails → its circuit(s) fails

Packet Switching

- mesh of interconnected routers
- packet-switching: hosts break application-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



Packet switching



Each packet contains destination (dst)
Each packet treated independently

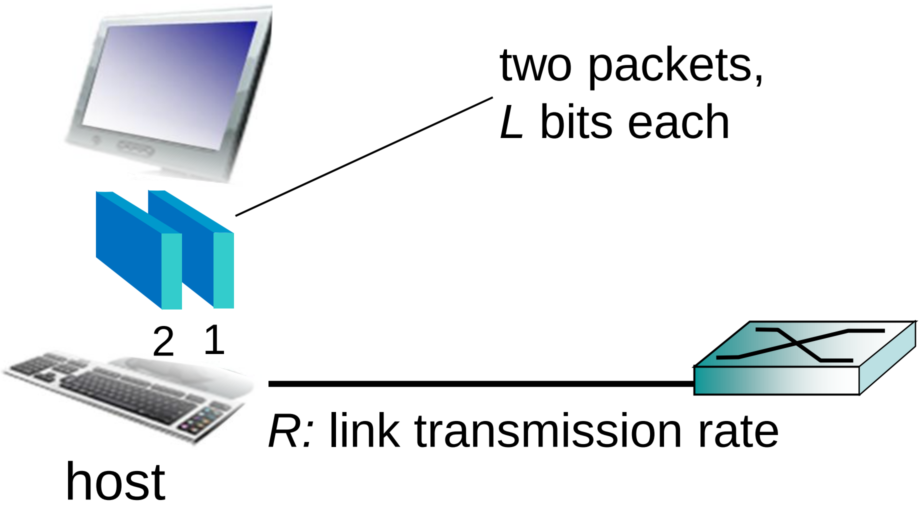
With buffers to absorb transient overloads

Host: sends *packets* of data

host sending function:

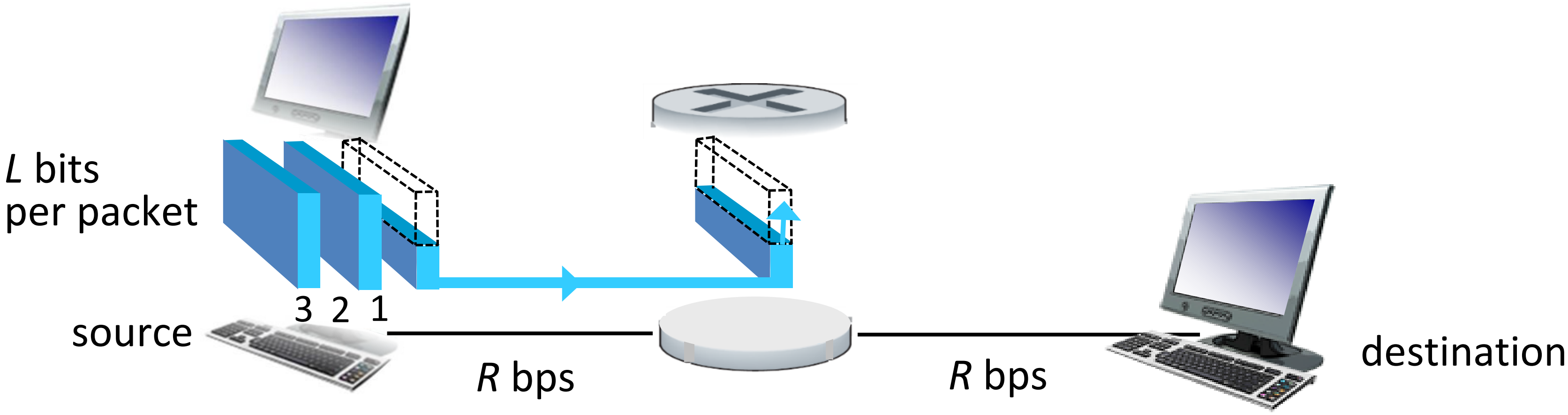
- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate, aka

Link capacity, aka link bandwidth



$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

Packet-switching: store-and-forward



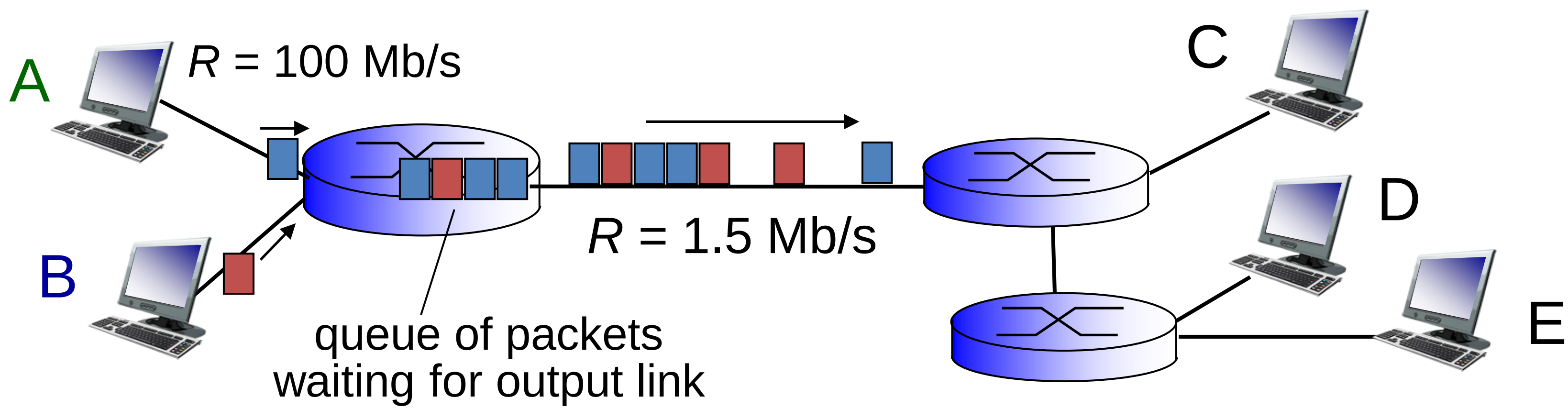
- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link

❖ end-end delay = 2*L*/*R* (assuming zero propagation delay)

one-hop numerical example:

- *L* = 7.5 Mbits
- *R* = 1.5 Mbps
- one-hop transmission delay = 5 sec
- How much delay till dest.?
- How much delay till dest. and back to source?

Packet Switching: queueing delay, loss



queuing and loss:

- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

Packet Switching

- **Pros**
  - efficient use of network resources
  - simpler to implement
  - robust: can “route around trouble”
- **Cons**
  - unpredictable performance
  - requires buffer management and congestion control

On-demand or reserve?

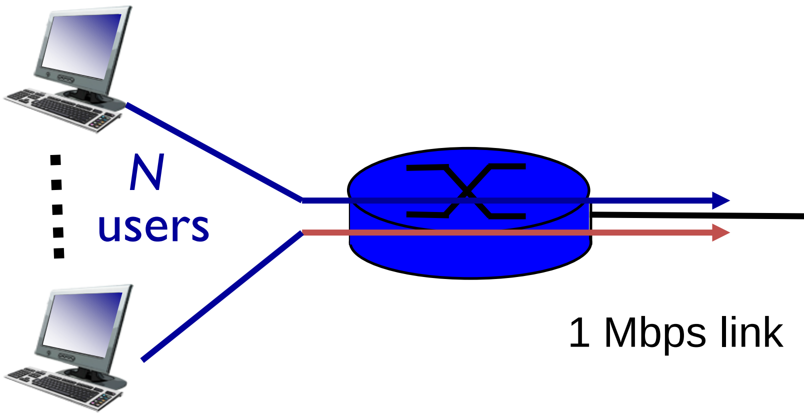
Packet switching versus circuit switching

packet switching allows more users to use network!

example:

- 1 Mbps link
- 10 total users
- 9 users silent
- Only one active user generates:
  - One thousand 1000-bit packets (1 Million bits)

- *circuit-switching:*
  - Will take one user 10 seconds to transmit complete 1 Million bits
  - Only 10 users can be serviced via this model simultaneously
  - Thus if only 1 active, remaining 9 slots wasted
  - But guaranteed service and quality to 10 users
- *packet switching:*
  - Only 1 active user will transmit complete 1 Million bits in 1 sec (@ the full capacity of the link i.e. 1 Mbps)
  - Depending on probability of simultaneously active users (if they are less or equal to 10), and arrival rate of data <= 1 Mbps (Capacity of the link), packets flow without delay. When users > 10, arrival rate of data increases > 1 Mbps and packets queue, causing delays
  - If probability of simultaneously active users > 10 is miniscule, packet switching provides the same performance (quality) as circuit switching but serving more users



Packet switching versus circuit switching

is packet switching a "slam dunk winner?"

- great for bursty data
  - resource sharing
  - simpler, no call setup
- excessive congestion possible: packet delay and loss
  - protocols needed for reliable data transfer, congestion control
- *Q:* How to provide circuit-like behavior?
  - bandwidth guarantees needed for audio/video apps
  - still an unsolved problem (chapter 7)

Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet-switching)?