Computer Networks
COL 334/672

To Packet Switch or Not

Slides adapted from K&R book

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Sem 1, 2024-25

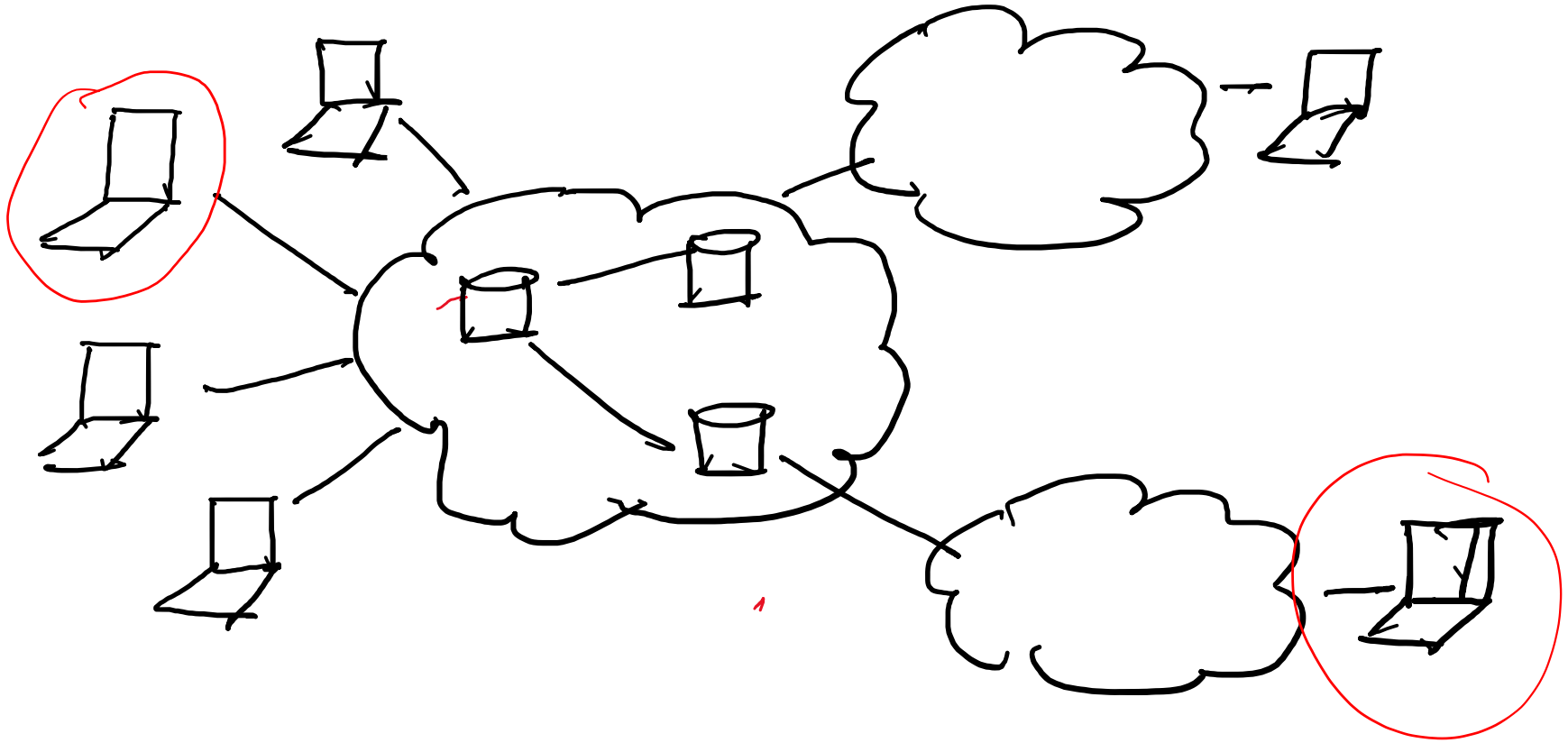
Recap

- Evolution of the Internet structure

Quiz 1

How To Send Data over the Internet?

① Addressing

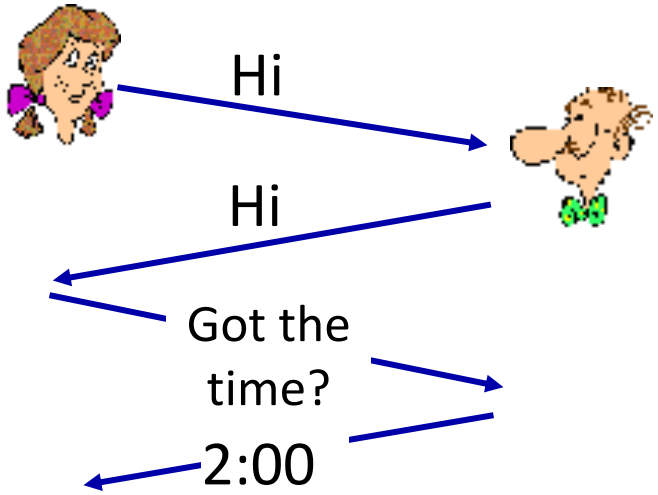


What's a human protocol?

Rules for:

… specific messages sent

… specific actions taken
when message received,
or other events

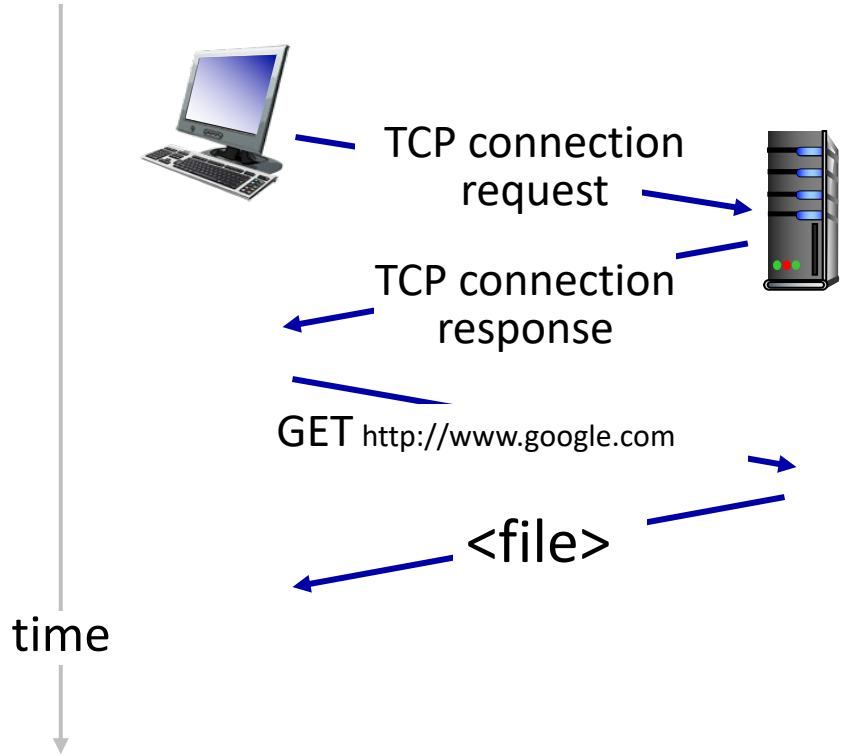


Q: other human protocols?

What's a network protocol?

Network protocols:

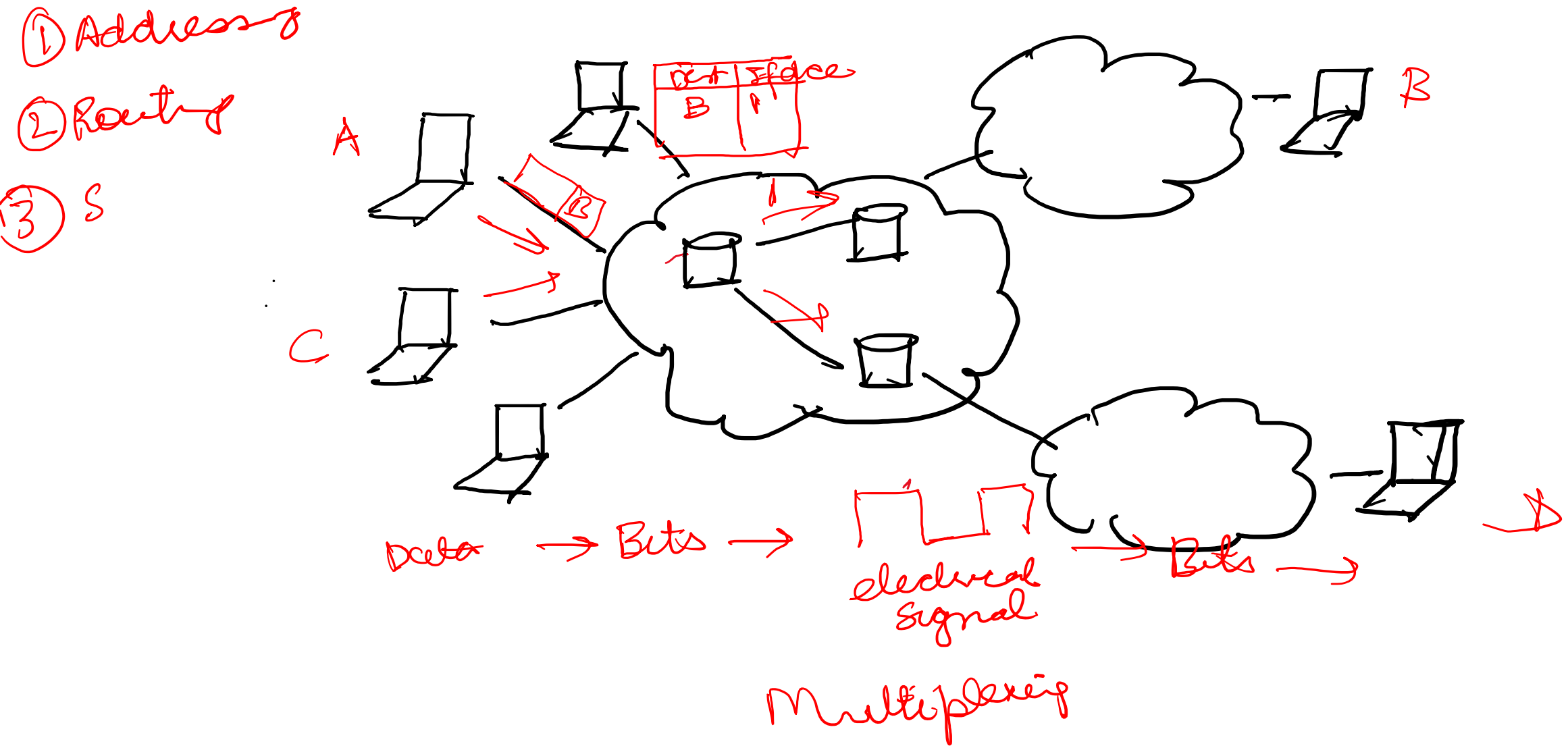
- computers (devices) rather than humans
- all communication activity in Internet governed by protocols



Protocols define the format, order of messages sent and received among network entities, and actions taken on message transmission, receipt

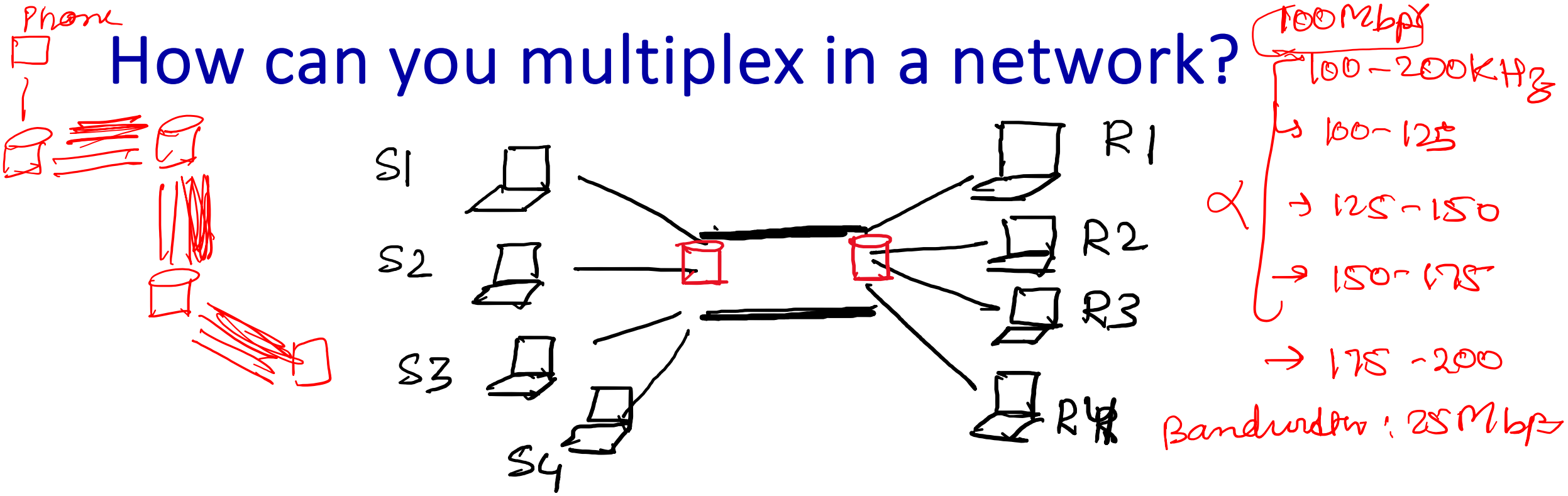
- Request For Comments (RFCs) specifying the protocols
- Standardization bodies: IETF, IAB etc.

How To Send Data over the Internet?



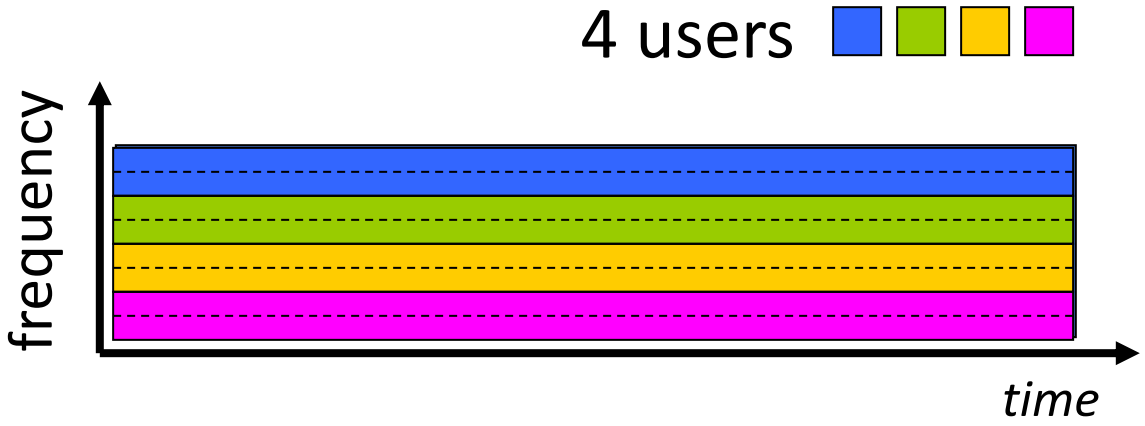
How do we share the network resources?

How can you multiplex in a network?

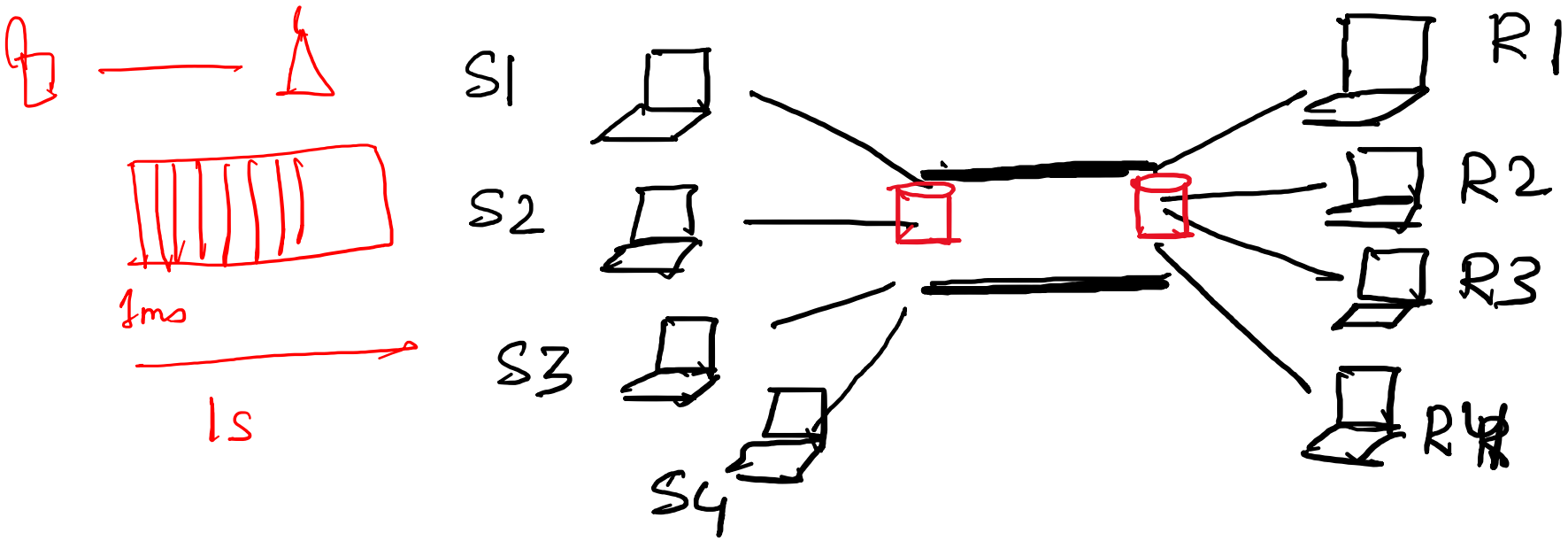


Frequency Division Multiplexing (FDM)

- optical, electromagnetic frequencies divided into (narrow) frequency bands
- each call allocated its own band, can transmit at max rate of that narrow band



Multiplexing in the Network: Another Option

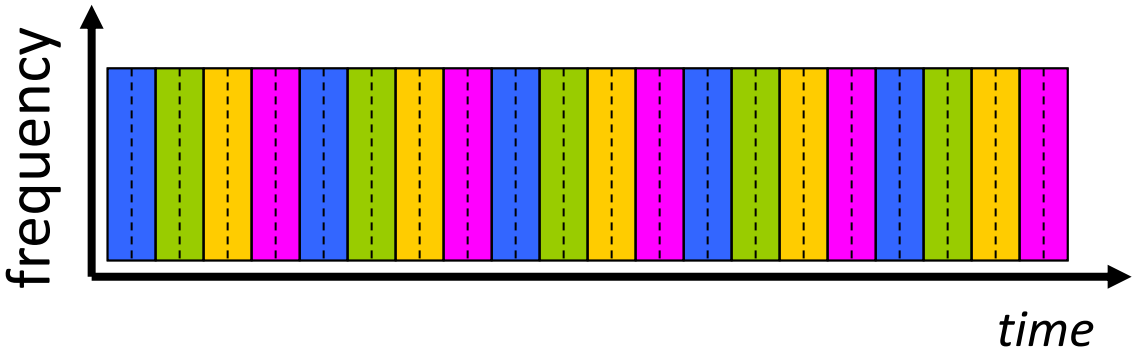


Numberical example:

- L = 10 Kbits
- R = 100 Mbps
- transmission delay?

Time Division Multiplexing (TDM)

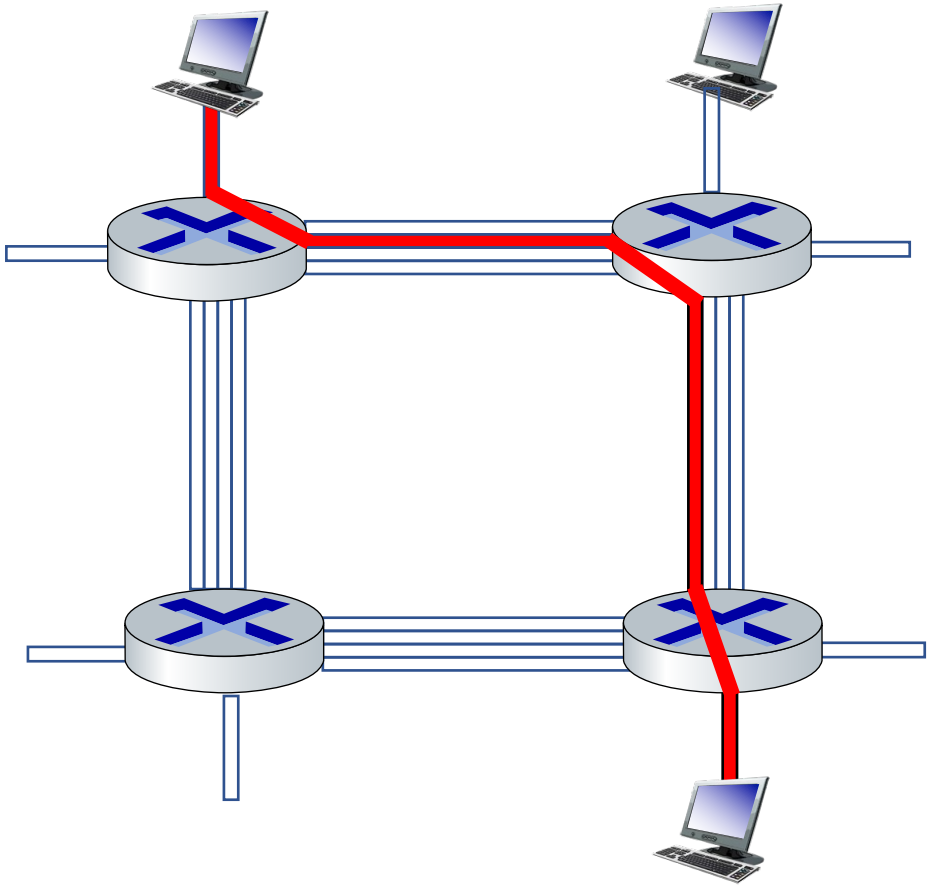
- time divided into slots
- each call allocated periodic slot(s), can transmit at maximum rate of (wider) frequency band (only) during its time slot(s)



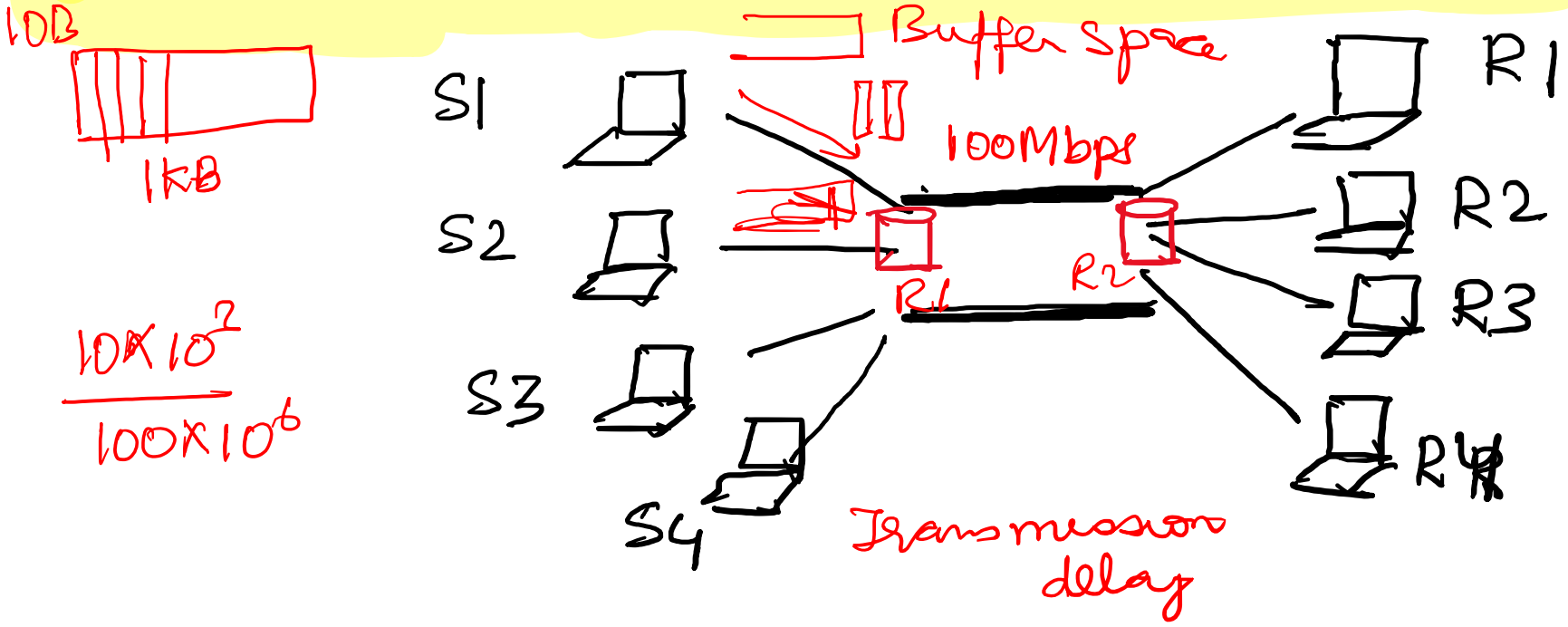
Circuit Switching

Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM) are examples of Circuit Switching

- end-end resources allocated to, reserved for "call" between source and destination
- in diagram, each link has four circuits.
  - Signalling for resource reservation
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance



Alternate option: Packet switching



$\frac{10 \times 10^2}{100 \times 10^6}$

$\frac{10 \cdot 10^3}{100 \cdot 10^6} = 10^{-4}$ sec

$= 0.1 \times 10^{-3}$ sec

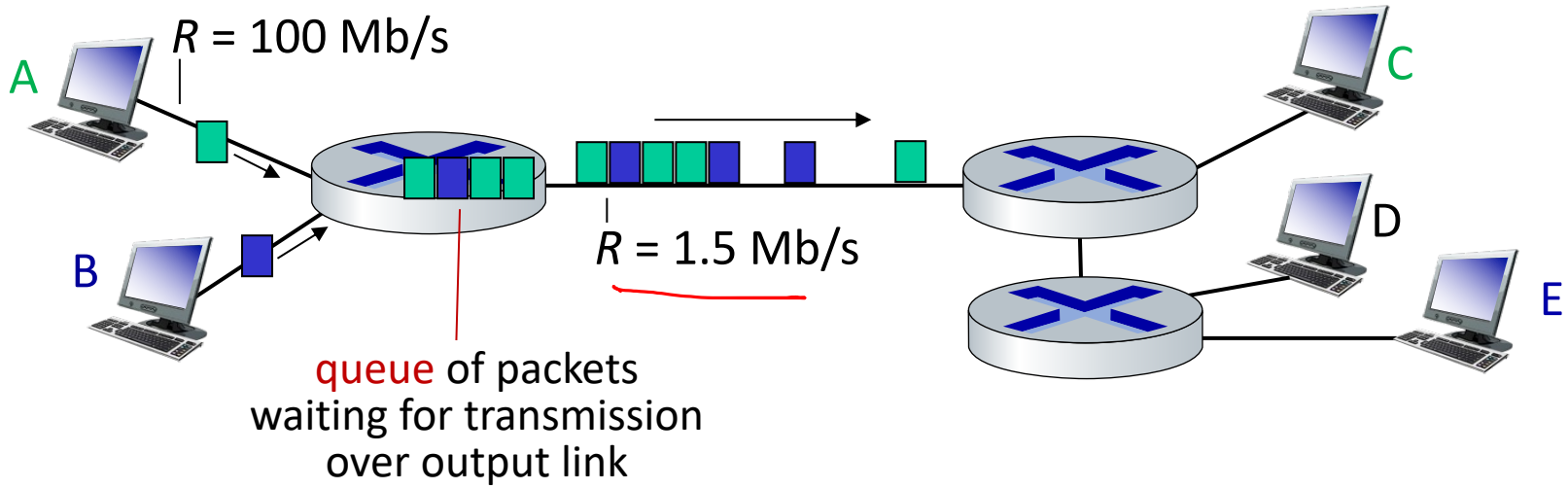
$= 0.1$ msec

- Divide the data into packets of size L bits
- Each packet is transmitted at link bandwidth
- Store and forward approach

One-hop numerical example:

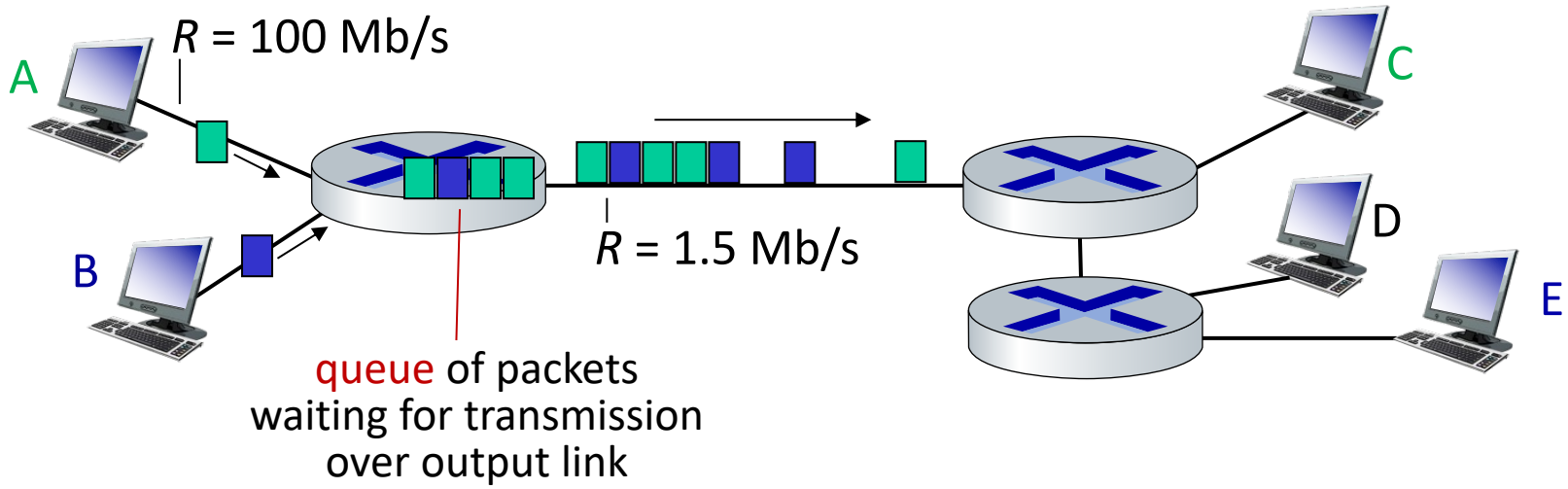
- L = 10 Kbits
- R = 100 Mbps
- one-hop transmission delay = 0.1 msec

Packet-switching: queueing



Queueing occurs when work arrives faster than it can be serviced:

Packet-switching: queueing



Packet queuing and loss: if arrival rate (in bps) to link exceeds transmission rate (bps) of link for some period of time: Congestion

- packets will queue, waiting to be transmitted on output link
- packets can be dropped (lost) if memory (buffer) in router fills up

Packet-switching versus circuit switching

- reserved resources (circuit switching) versus on-demand allocation (packet switching). Human analogy?
- Which option did the Internet chose? [Coming up in Next Class]