Introduction

CS5700 Fall 2019

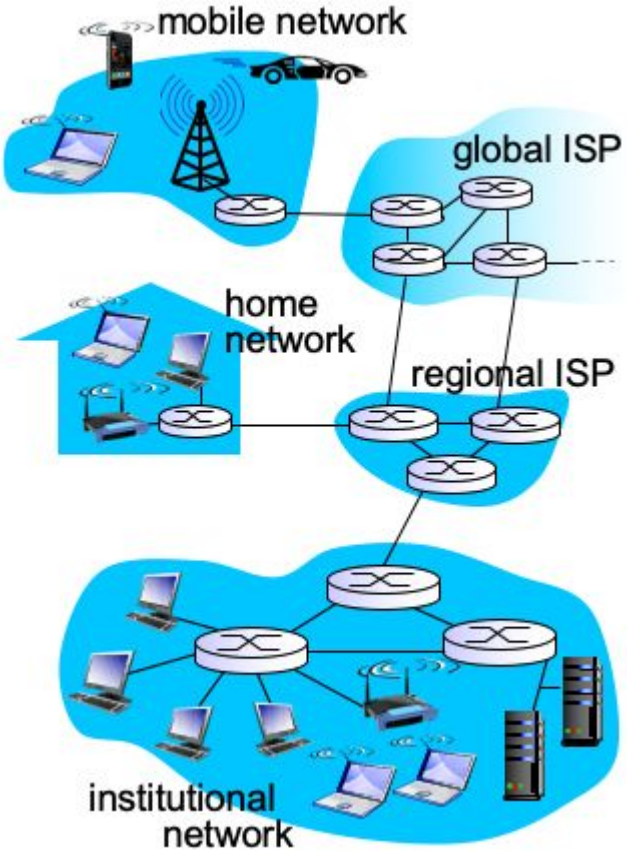
Agenda

- What is the Internet?
  - Network edge
  - Network core
- Protocol layers
- Key metrics
  - Latency, throughput, loss

What is the Internet?

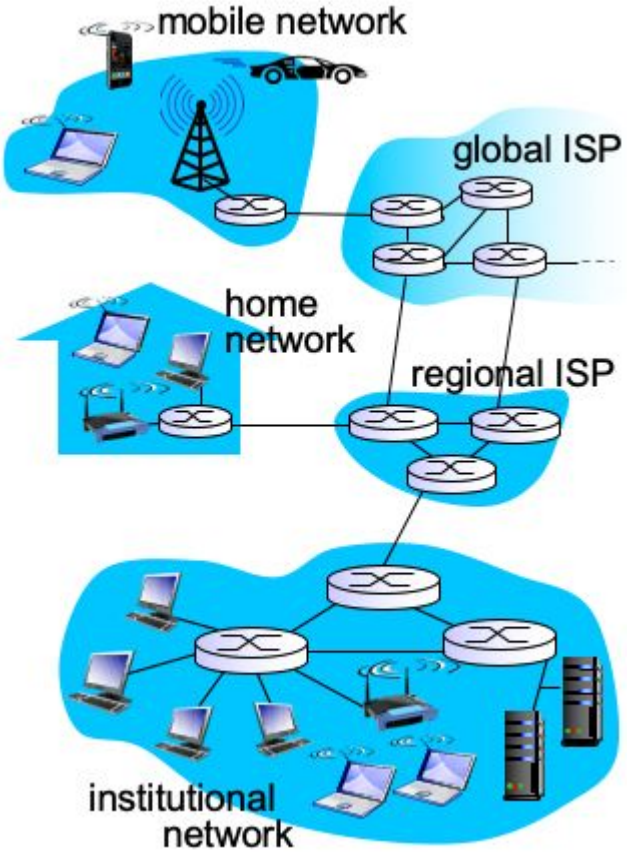
Components

- Hosts
  - Running network applications
- Communication links
  - Fiber, copper, radio
- Packet switches
  - Routers and switches



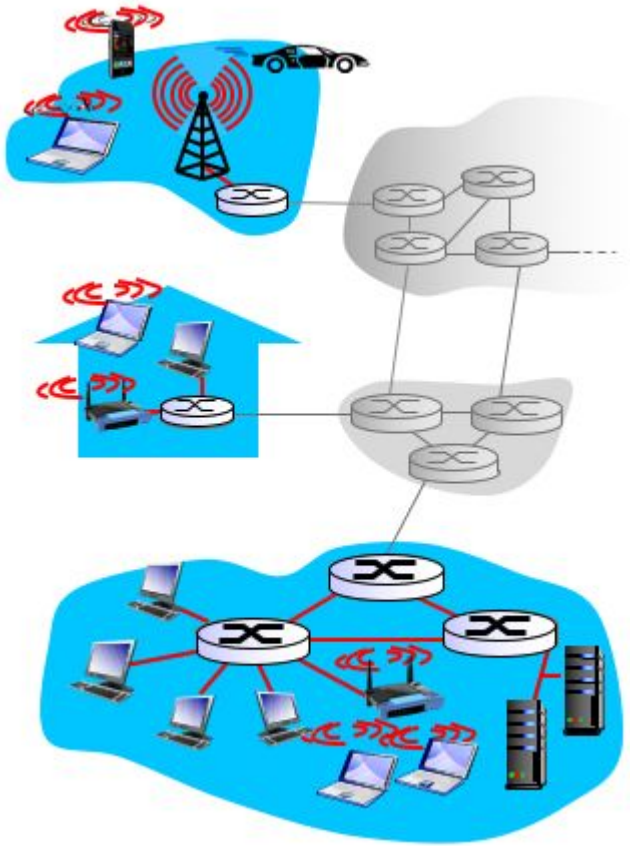
Structure

- Network edge
  - Hosts: clients and servers
  - Access network
- Network core
  - Interconnected routers
  - Network of networks



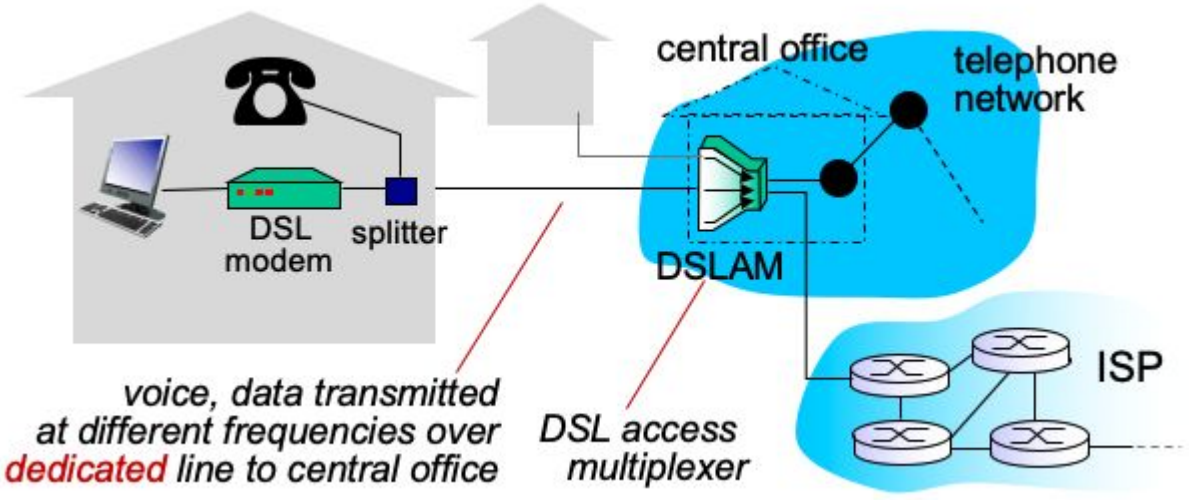
Network edge - access network

- Connect end systems to edge router
  - Residential access
  - Institutional access (school, company)
  - Mobile access



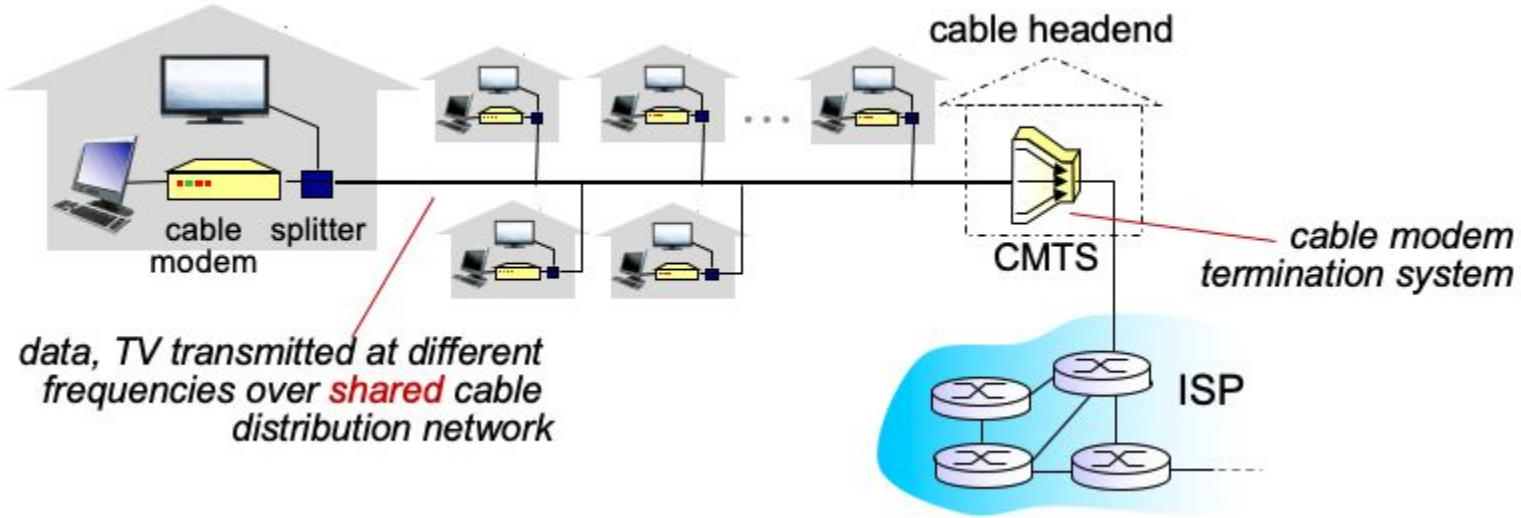
Network edge - access network

- DSL: digital subscriber line [~10Mbps]
- Frequency division multiplexing

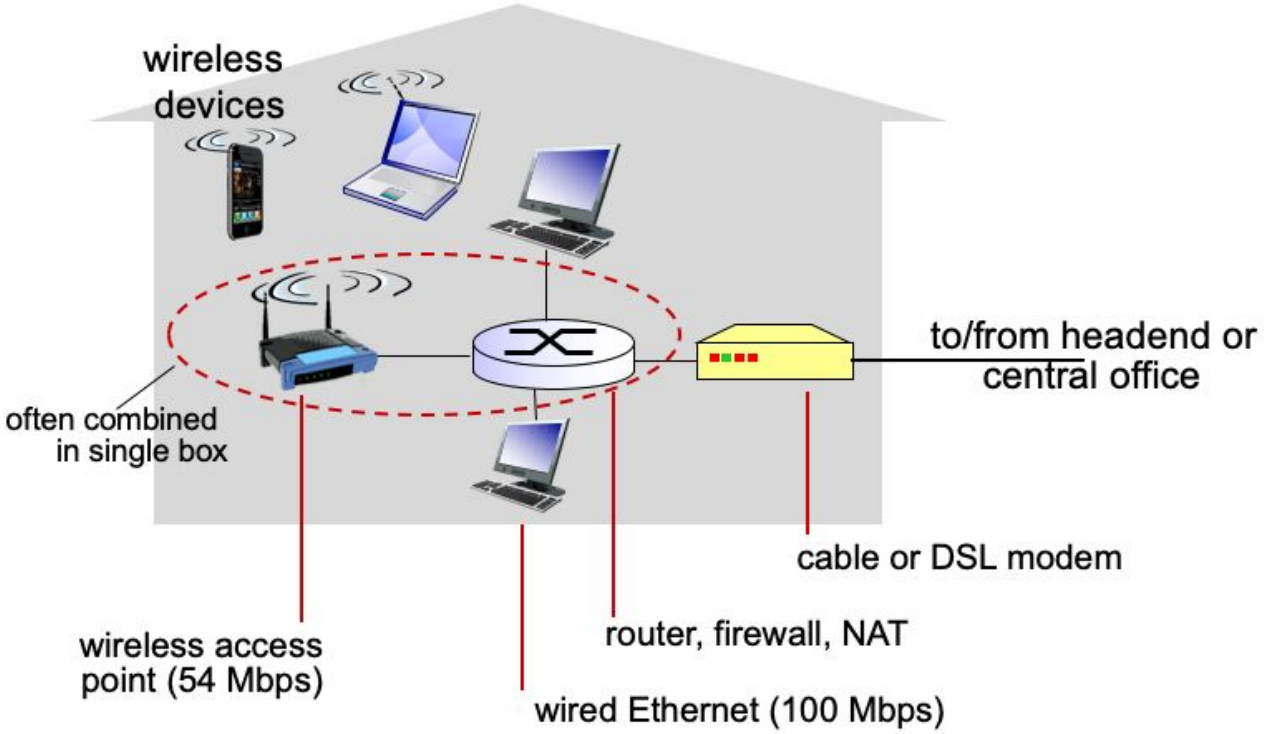


Network edge - access network

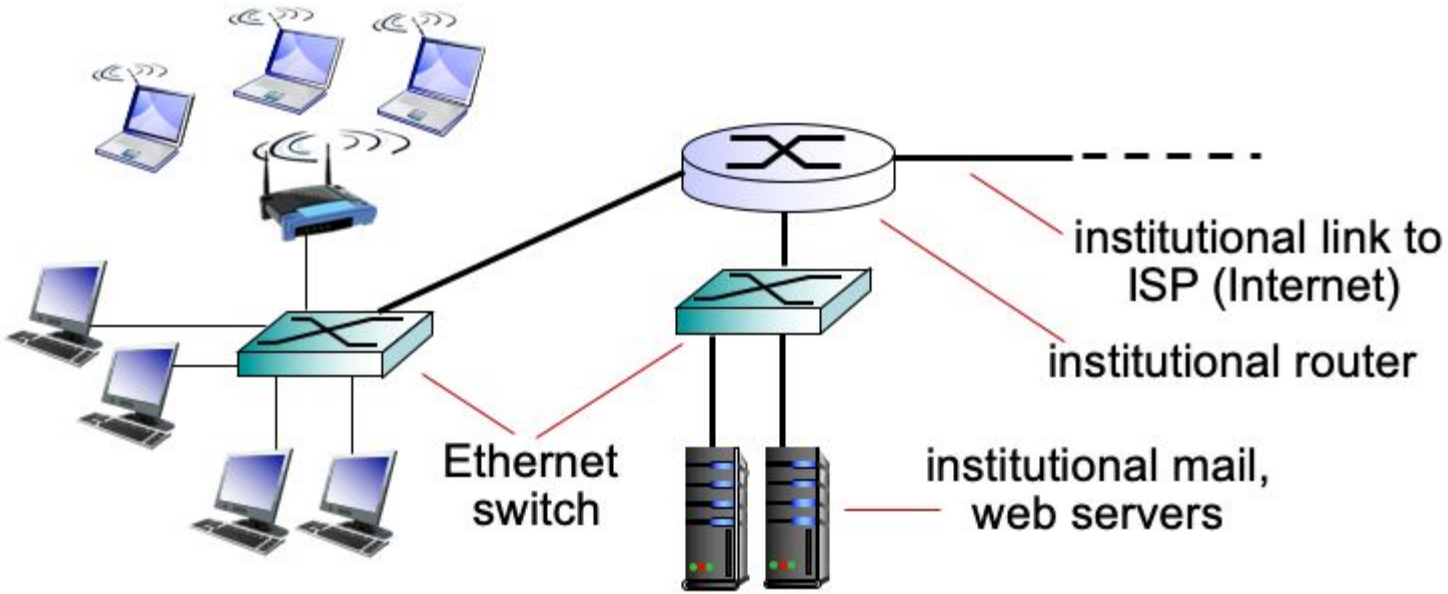
- Cable network [~30Mbps]
- Frequency division multiplexing



Network edge - access network

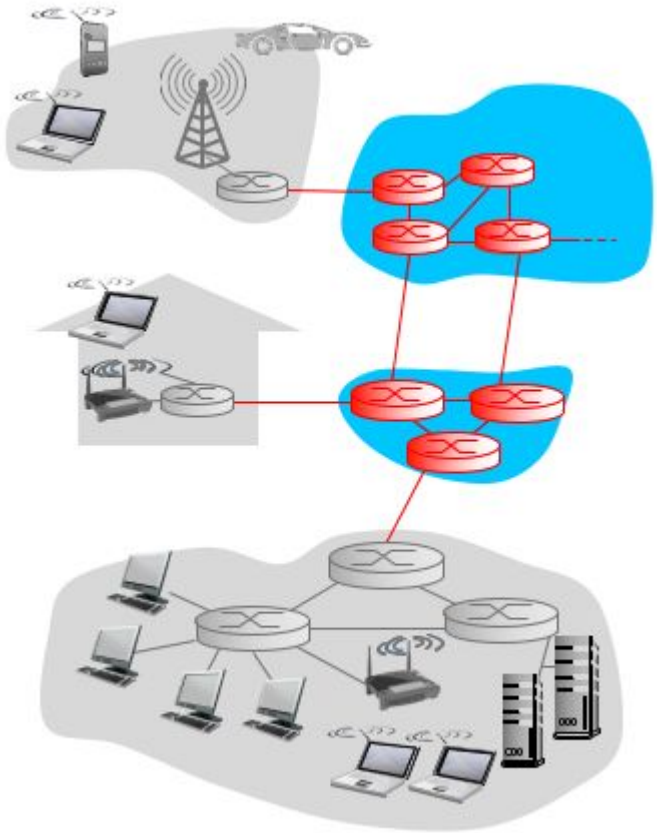


Network edge - access network



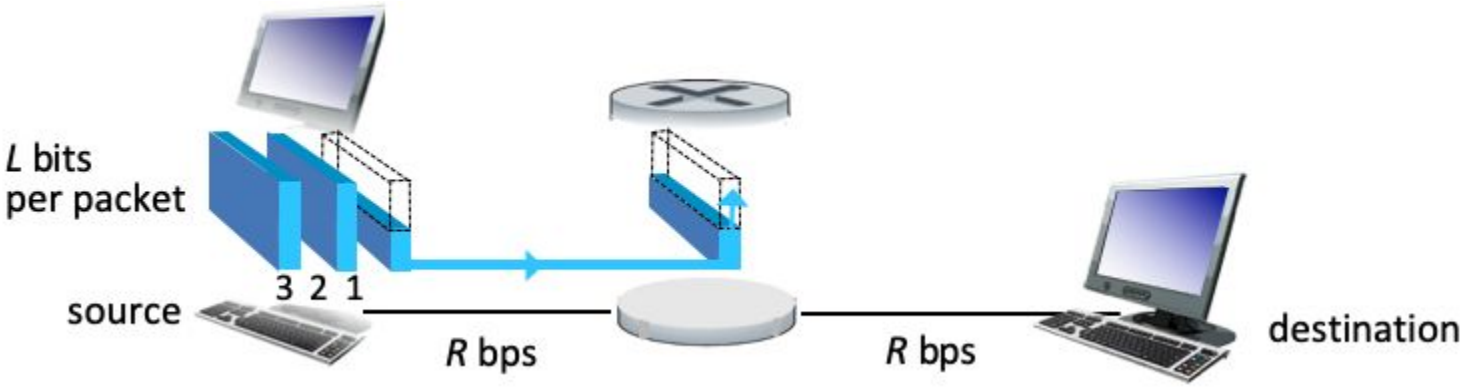
Network core

- Interconnected routers
- Packet switching
  - Hosts break application-layer messages into packets
  - Fwd packets from one router to the next
  - Each packet transmitted at full link capacity



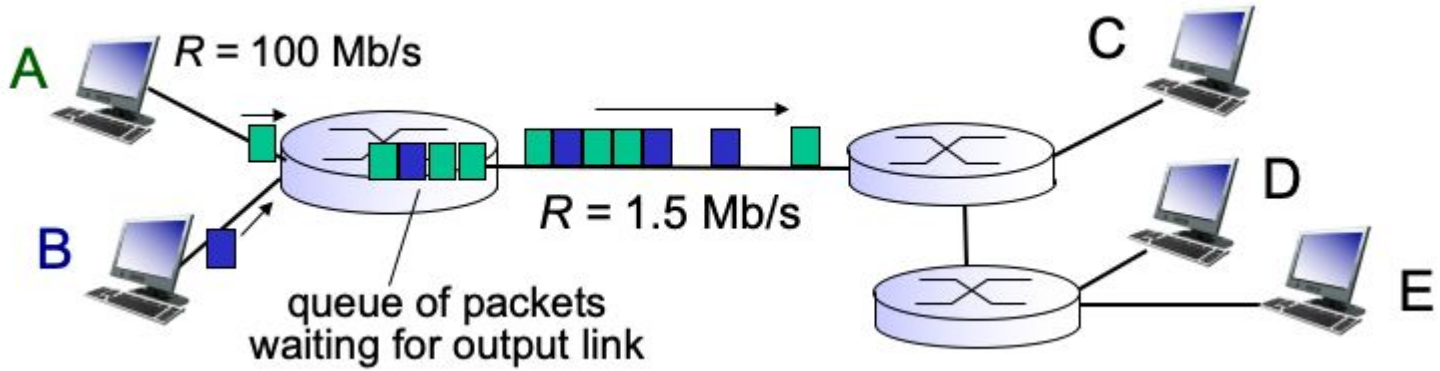
Network core - packet switching

- Each router store-and-forward
- What’s the end-to-end delay?



Network core - packet switching

- Queuing and packet loss
- Arrival rate (in bits) exceeds outgoing rate

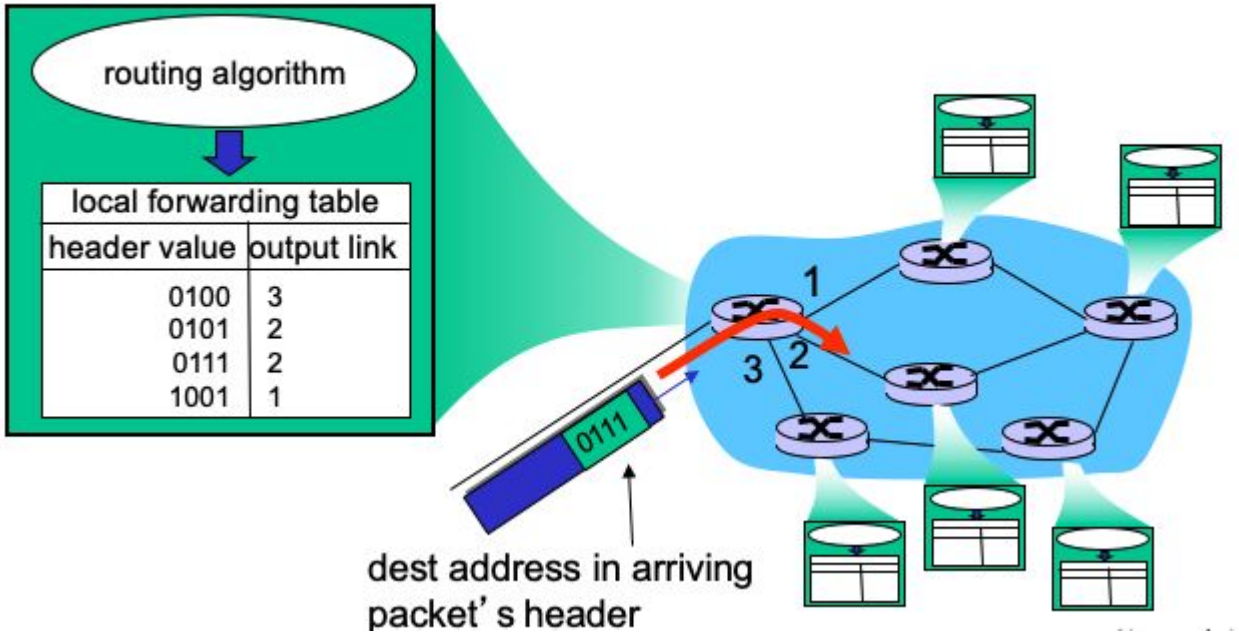


Network core - packet switching

Two key functions in each router

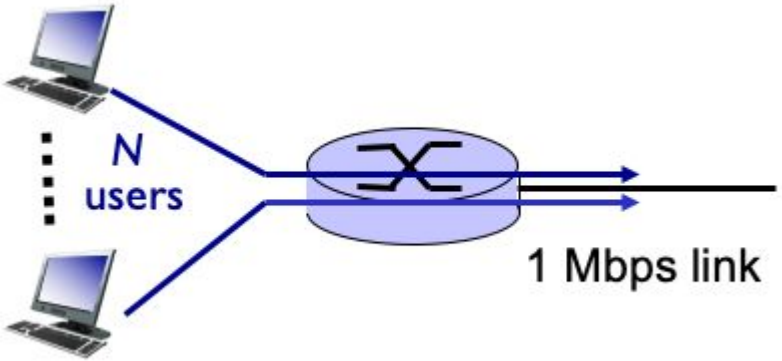
- Routing: determines source to destination route taken by packets
  - Routing algorithms to learn global topology
- Forwarding: move packets from router's input port to appropriate output port

Network core - packet switching



Network core - packet switching

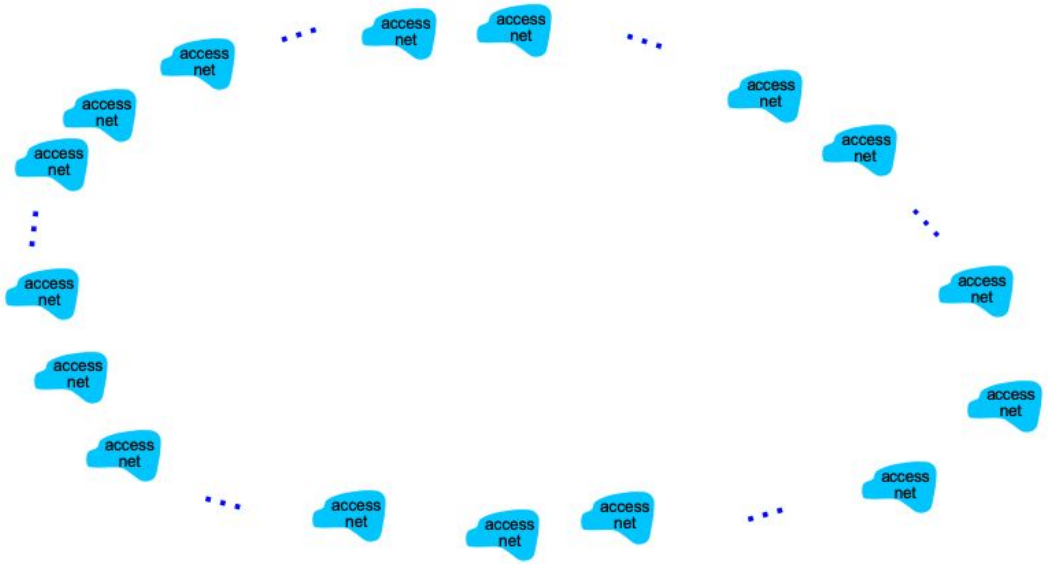
Resource utilization



- 1 Mbps link
- Each user
  - 100 Kbps when active
  - Active 10% of the time
- With 35 users, probability > 10 active users at the same time is < 0.0004

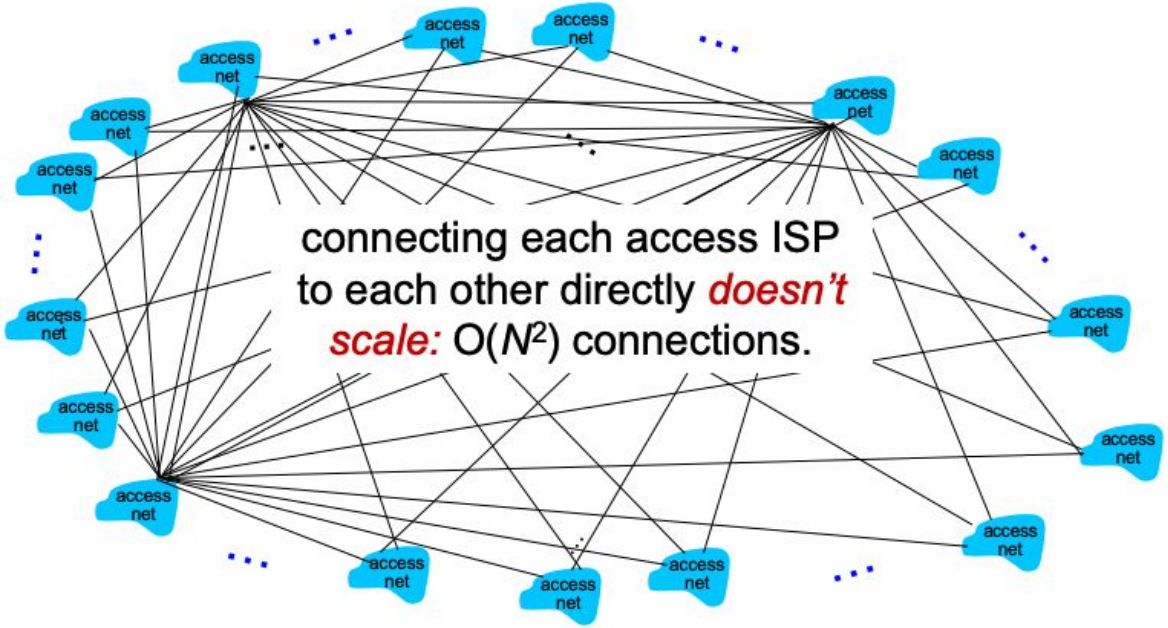
Internet structure

- End systems connect to the Internet via access ISPs
- Access ISPs in turn must be connected! But how?



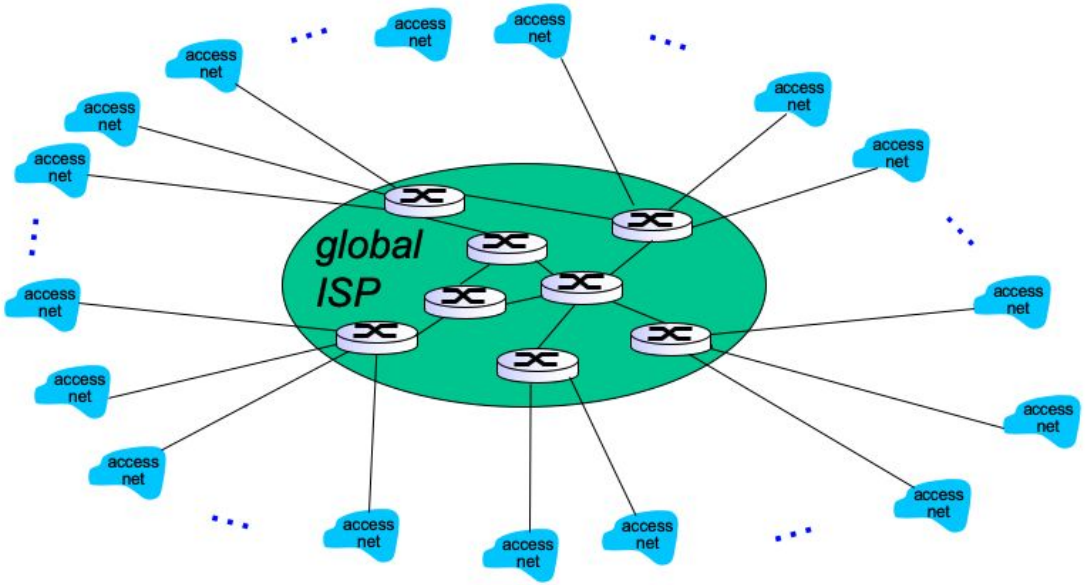
Internet structure

Option: connect each access ISP to every other access ISP?

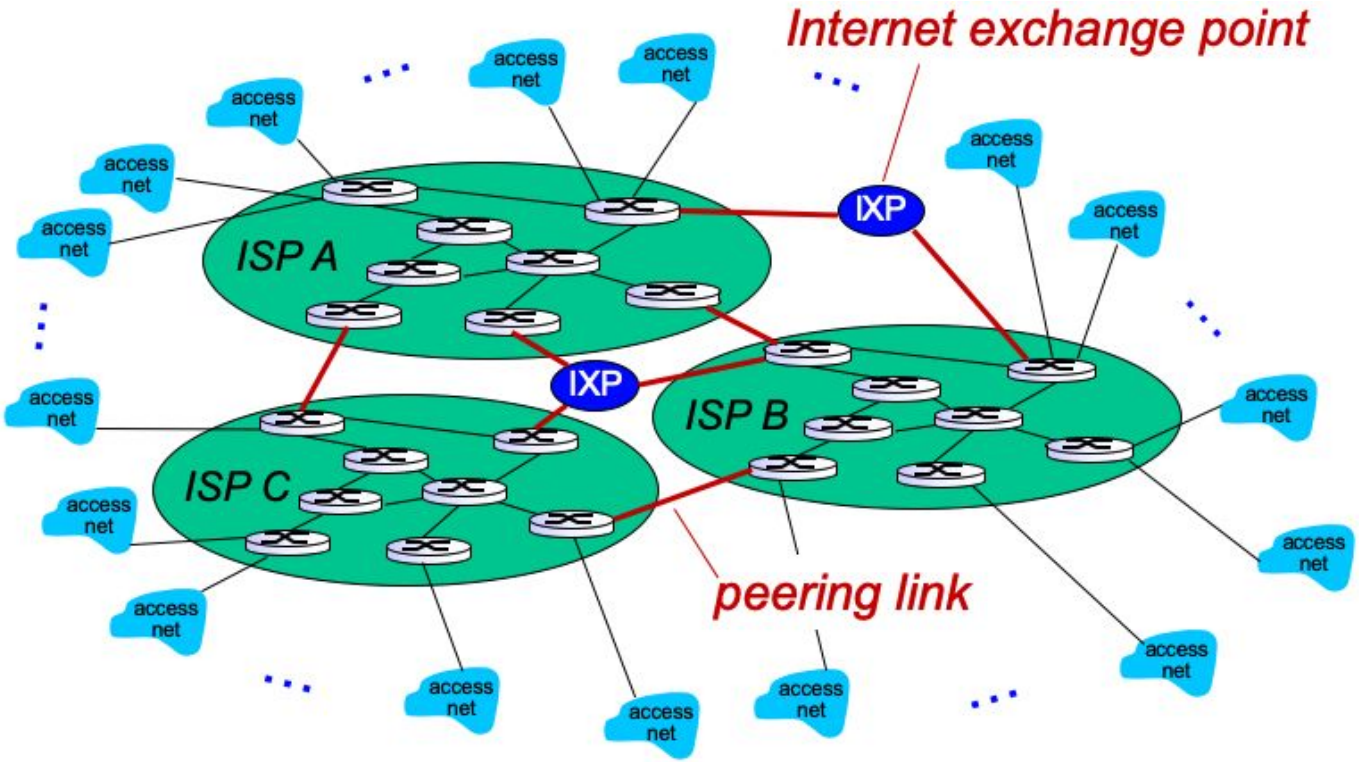


Internet structure

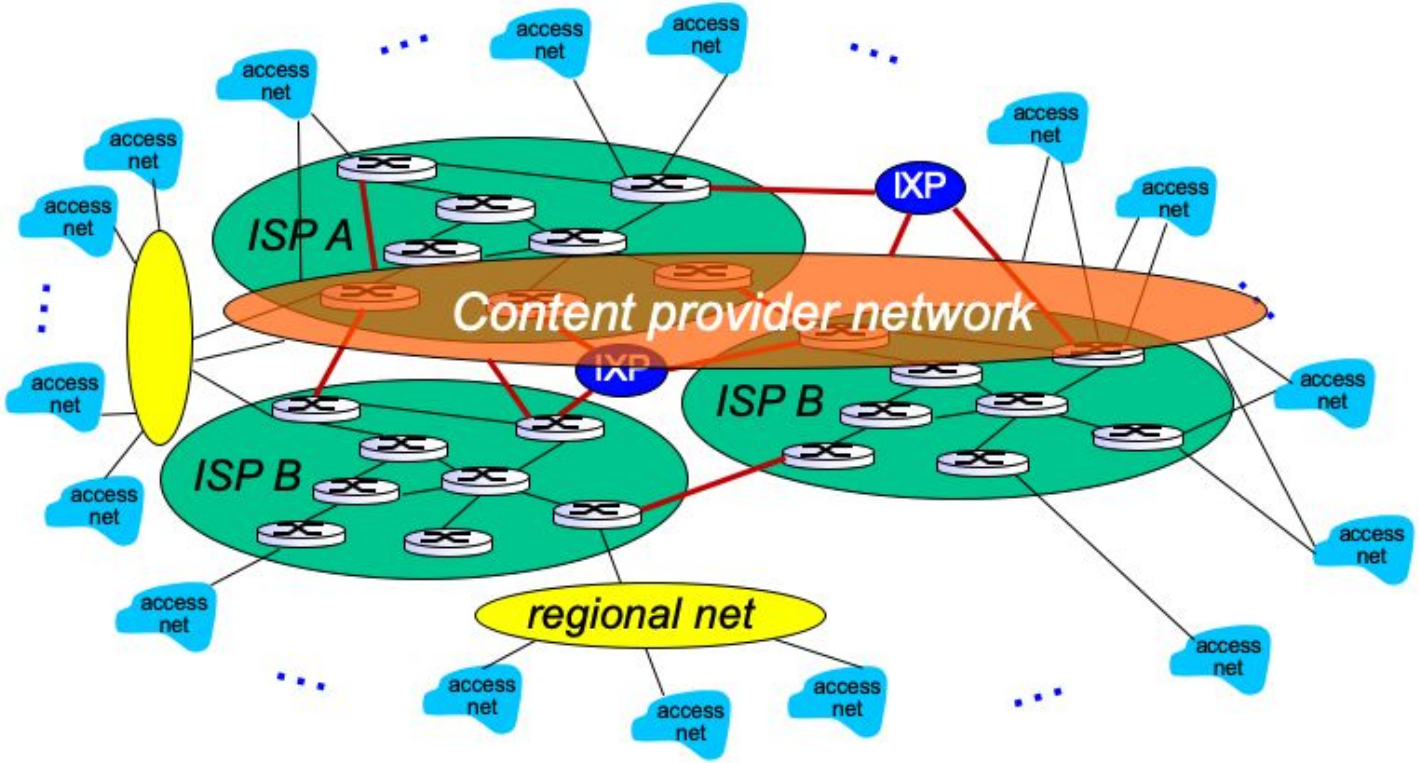
Option: connect each access ISP to a global transit ISP?



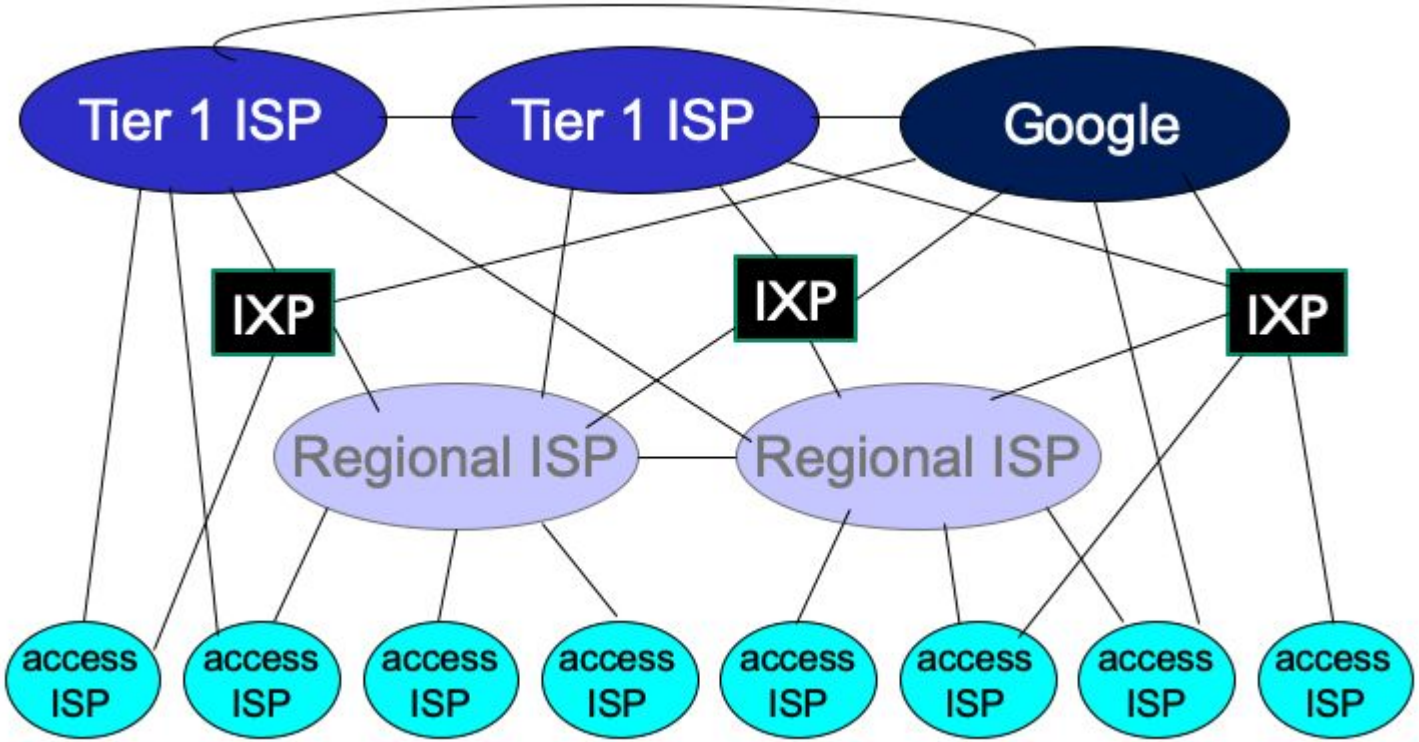
Internet structure



Internet structure



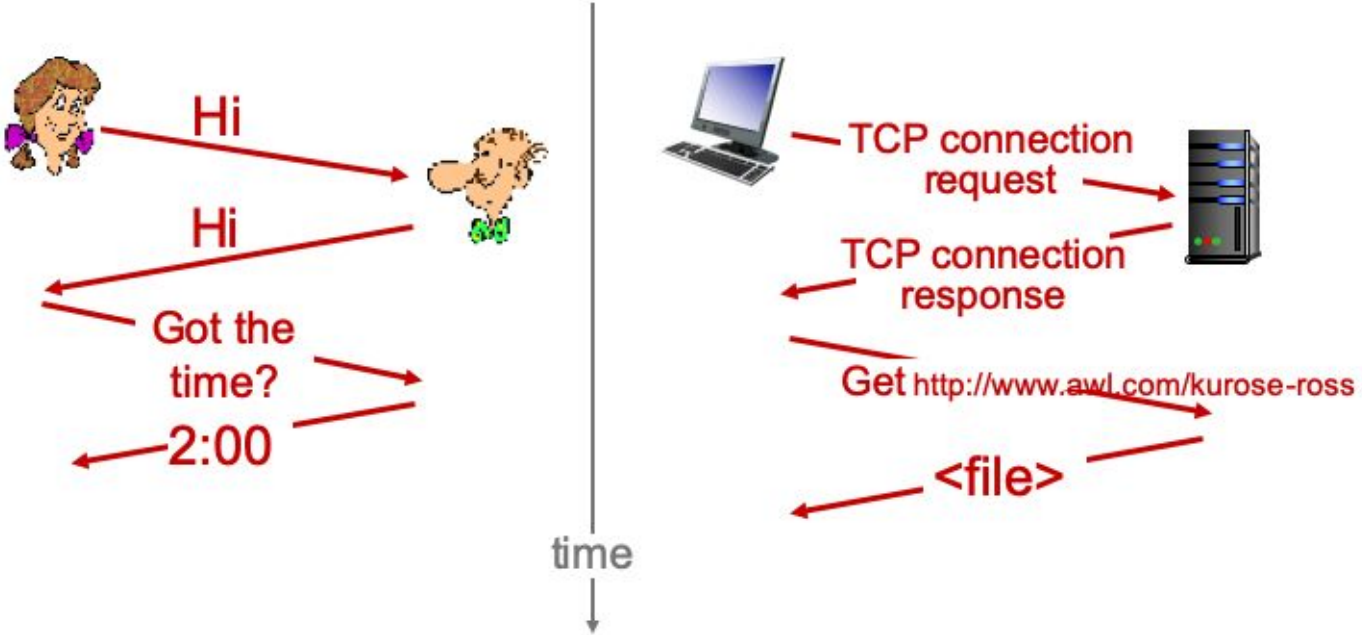
Internet structure - network of networks!



Protocol layers

What is a protocol?

For machines to understand each other.

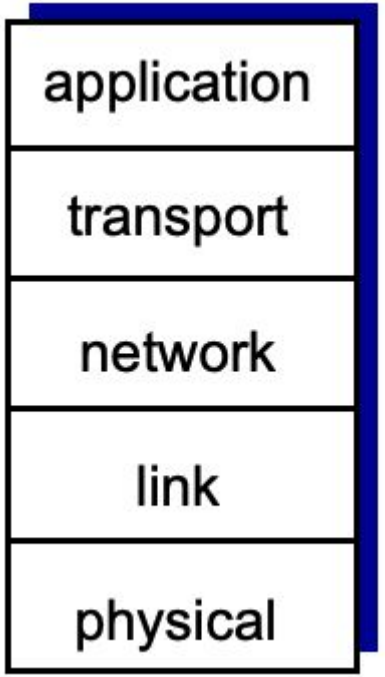


Protocol

- Each protocol specifies how to handle one aspect of communication
- Protocol can specify
  - Low level details such as voltage and frequency
  - High level details such as format visible to a user
- Many protocols exist, they are designed to work together

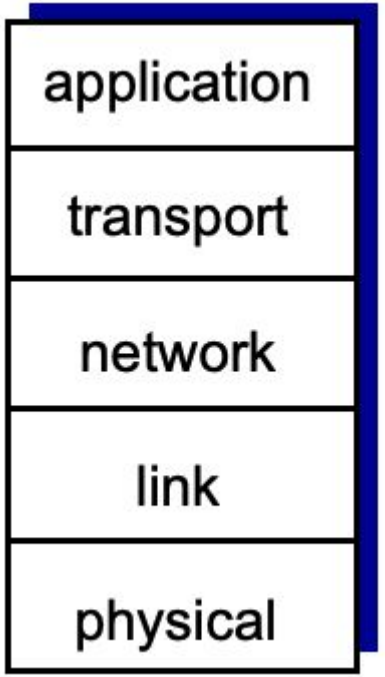
Protocol layers

5-layer reference model



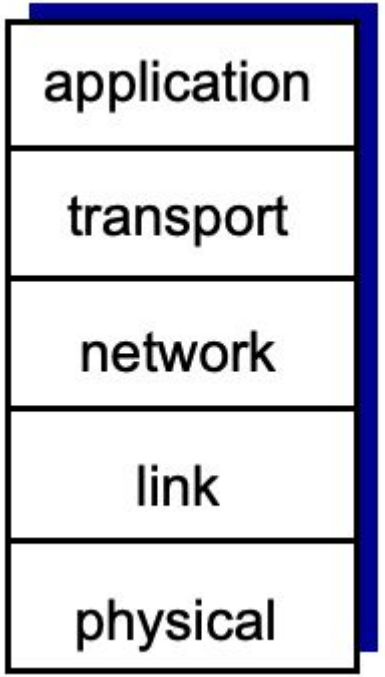
Protocol layers - physical layer

- Underlying transmission media
- Representation of information (0s and 1s) in signals
- Electrical properties such as radio frequency and voltage
- Associated hardware



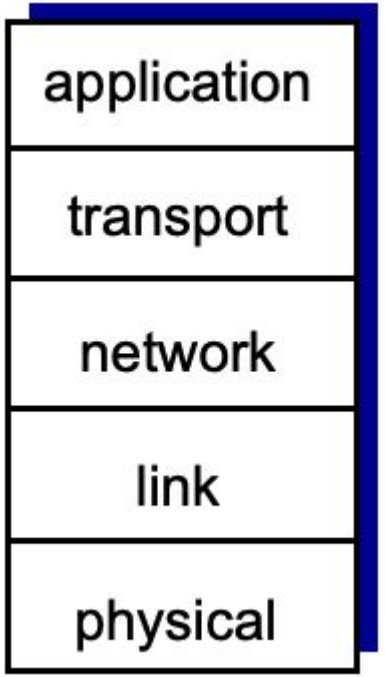
Protocol layers - link layer

- Also called MAC layer or network interface layer
- Communication between a computer and network hardware
- Hardware address (MAC address)
- Media access
- Packet formats (frame)
- Error detection



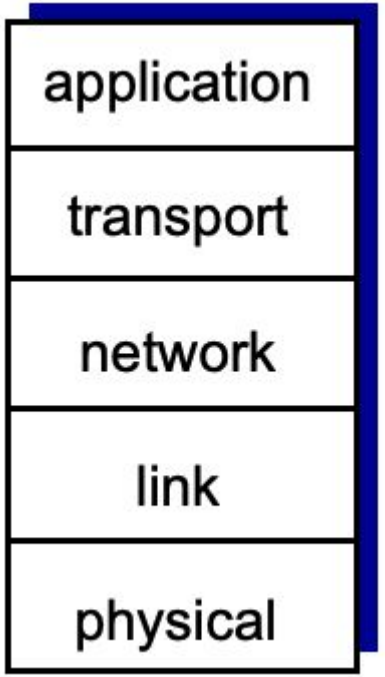
Protocol layers - network layer

- Communication between a pair of computers across the Internet
- Packet format (datagram)
- Internet address
- Error detection and reporting
- E.g. IP protocol



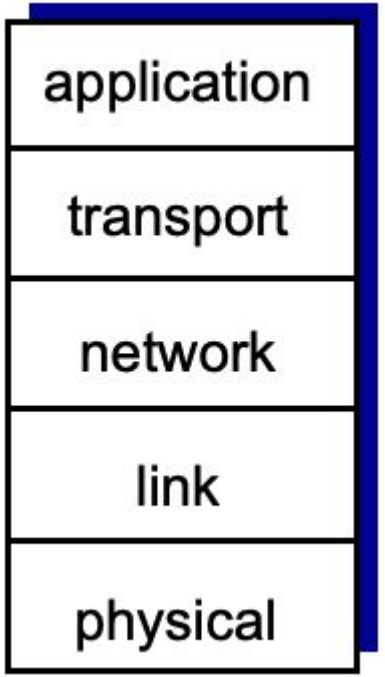
Protocol layers - transport layer

- Communication between a pair of application (processes)
- Reliable delivery and retransmission
- Control data rate and avoid congestion
- E.g. TCP, UDP

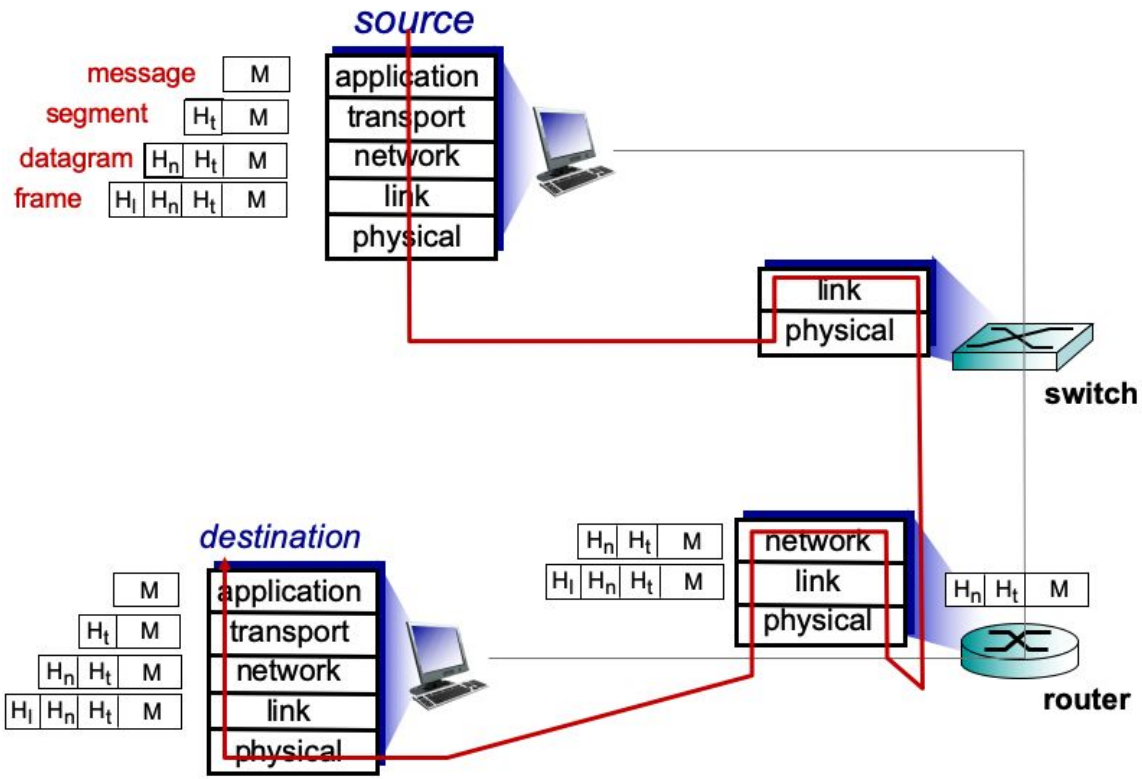


Protocol layers - application layer

- Format and meaning of messages
- E.g. HTTP, SMTP



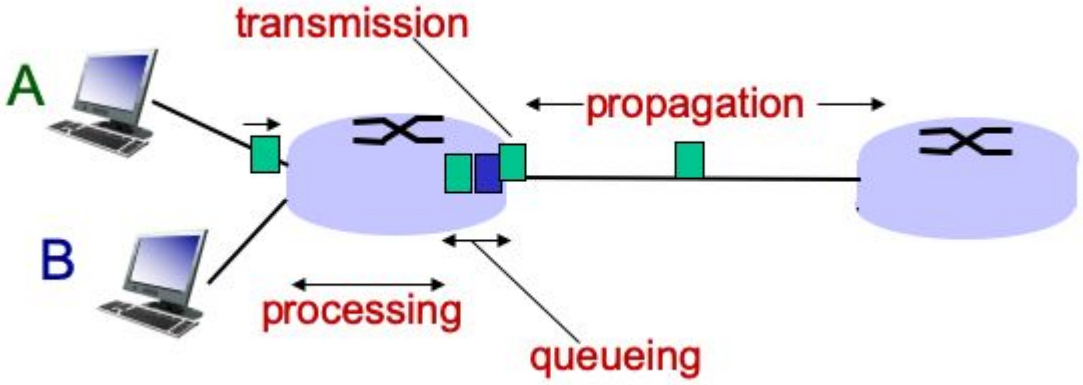
Protocol layers



Key metrics

Delay (aka latency)

- Processing delay
- Transmission delay
- Propagation delay
- Queuing delay



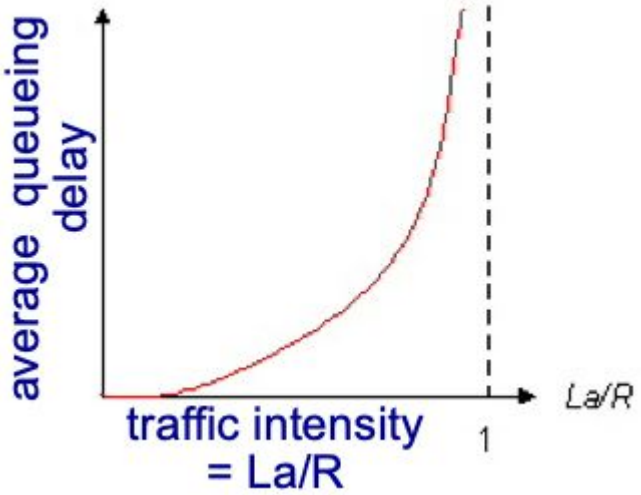
Delay

Compare transmission delay and propagation delay

- Transmission delay
  - L/R (L: packet length, R: link data rate)
- Propagation delay
  - d/s (d: length of physical link, s: propagation speed)
- Which one is more significant to overall latency?

Delay - queuing delay

- R: link data rate (bps)
- L: packet length (bits)
- a: average packet arrival rate



- La/R ~ 0: average queuing delay very small
- La/R → 1: average queuing delay large

Delay

So, which of the four source of packet delay is more significant?


DEMO?
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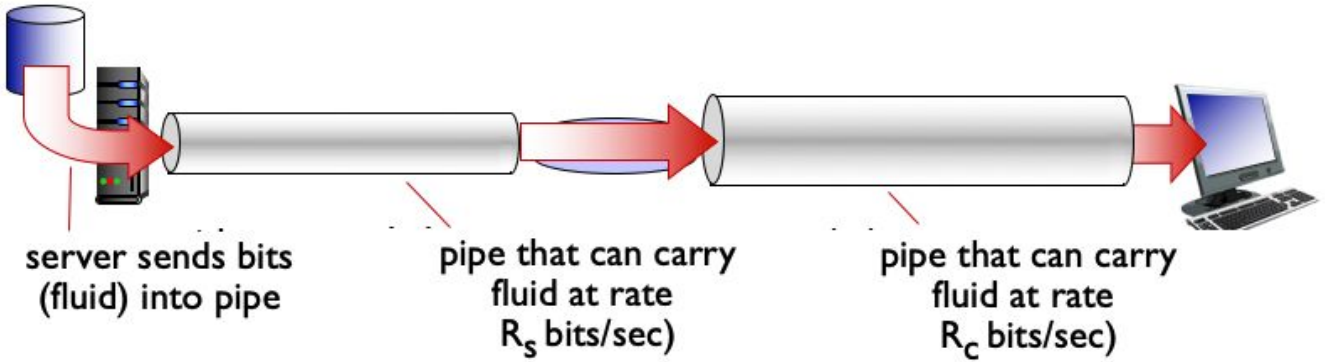
Throughput

- Rate (bits / time unit) at which bits transferred between sender and receivers
  - Instantaneous: rate at a given point in time
  - Average: rate over longer period of time

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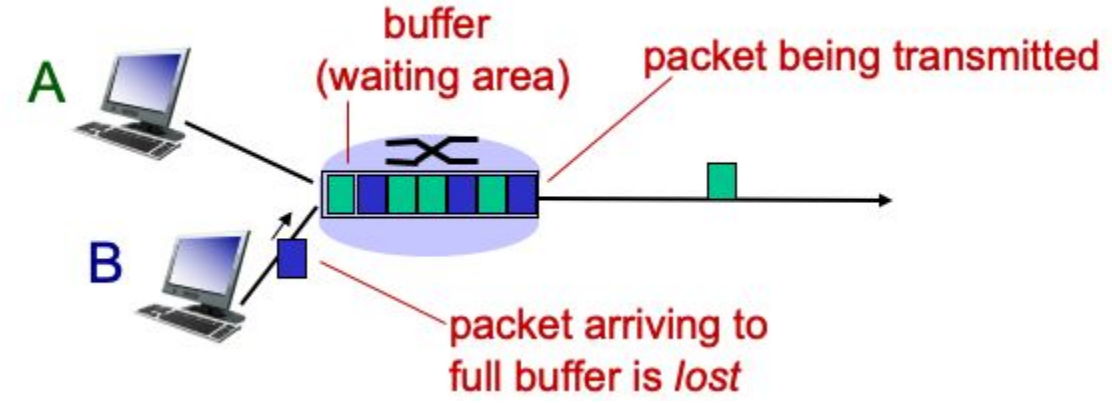
Loss

- Packet arriving to full queue (aka buffer) is dropped
- Lost packet may be retransmitted by previous node, by source end system, or not at all



Summary

- What is the Internet
  - Network edge and core
  - Structure of the Internet
- Protocol and layering
  - What are the layers, and what they do
- Key metrics
  - Delay, throughput, and loss