Introduction

CS5700

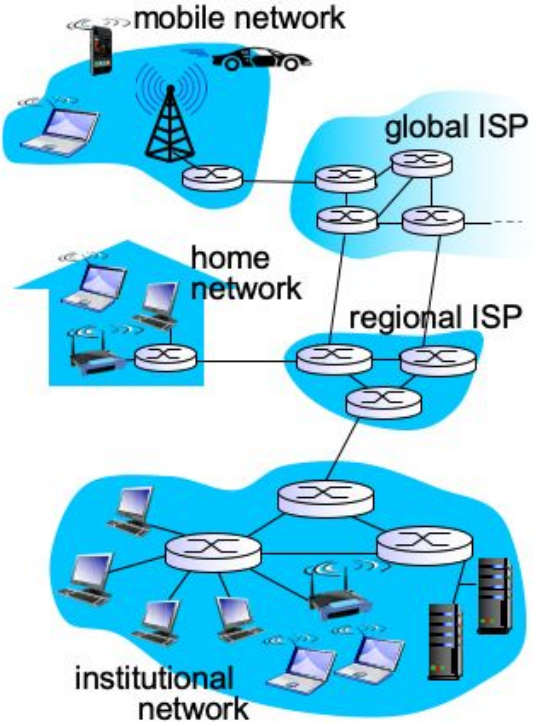
Agenda

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

What is the Internet?

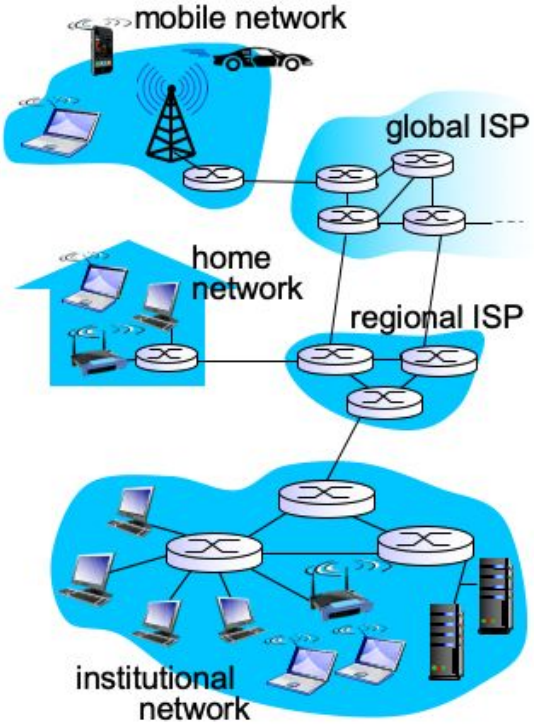
Components

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



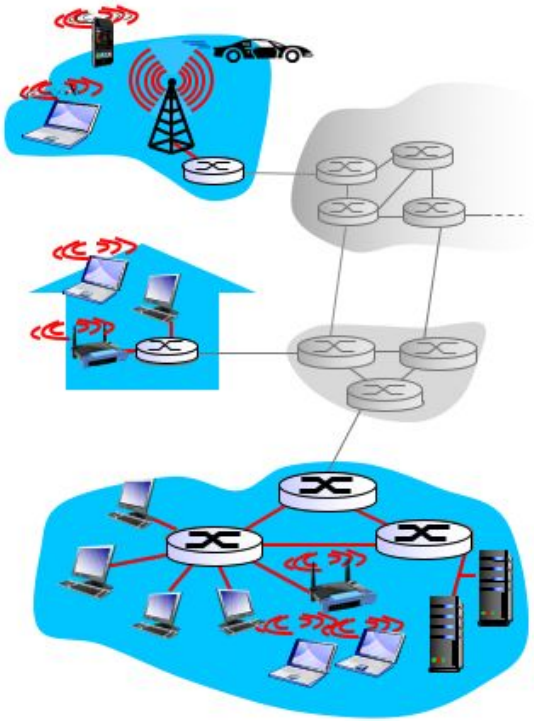
Structure

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



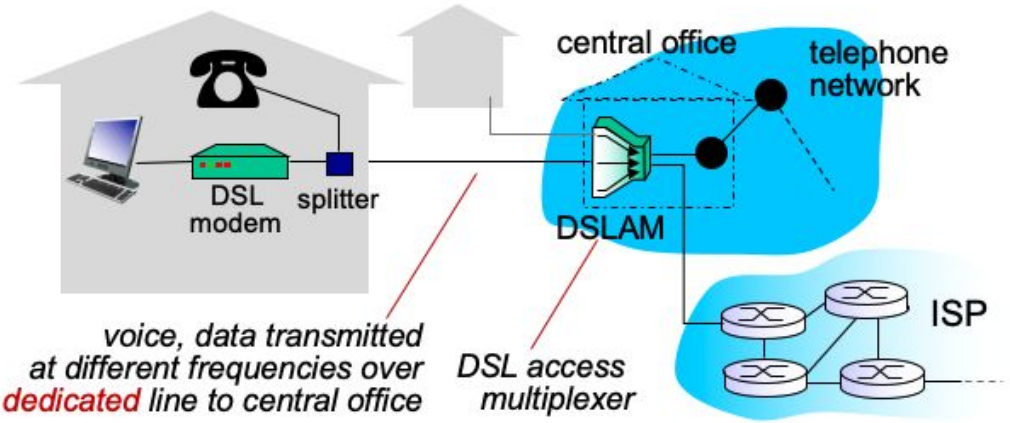
Network edge - access network

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



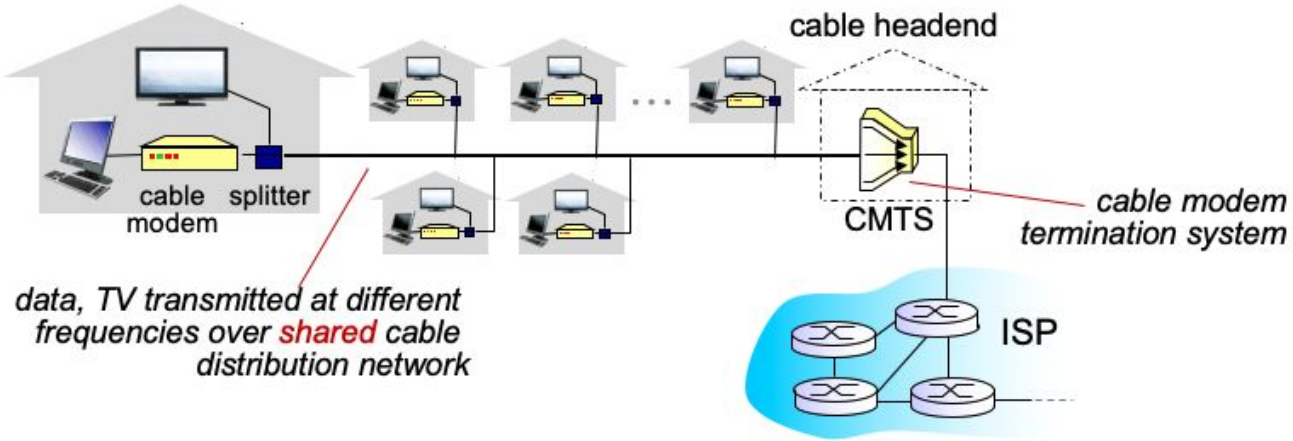
Network edge - access network

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

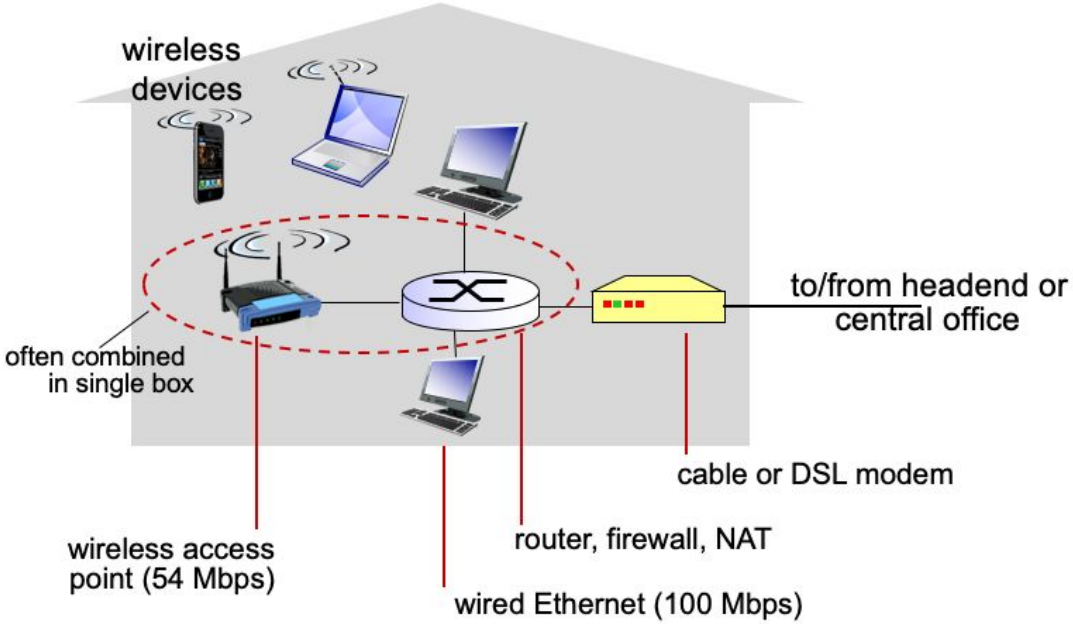


Network edge - access network

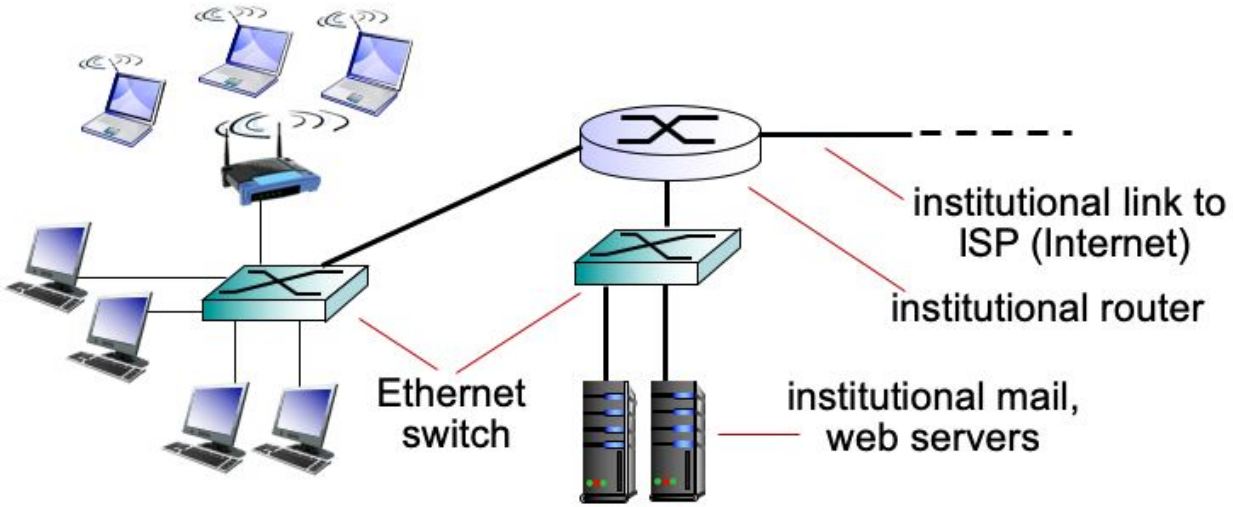
- Cable network [~30Mbps]
- Frequency division multiplexing 频分多路复用



Network edge - access network

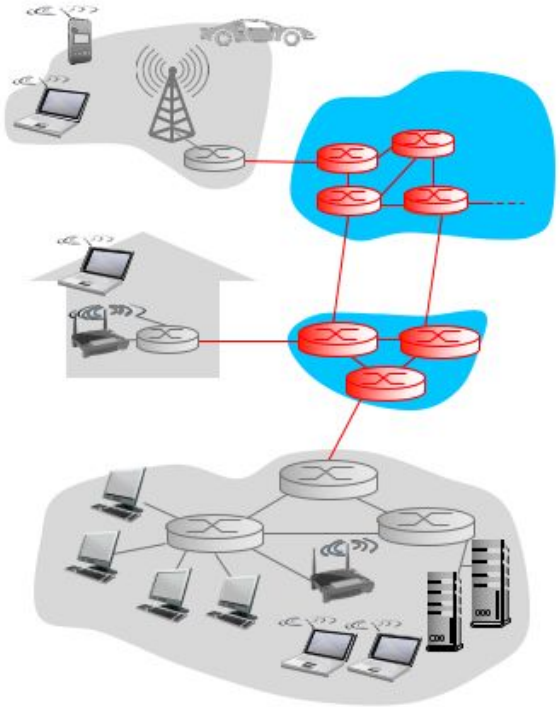


Network edge - access network



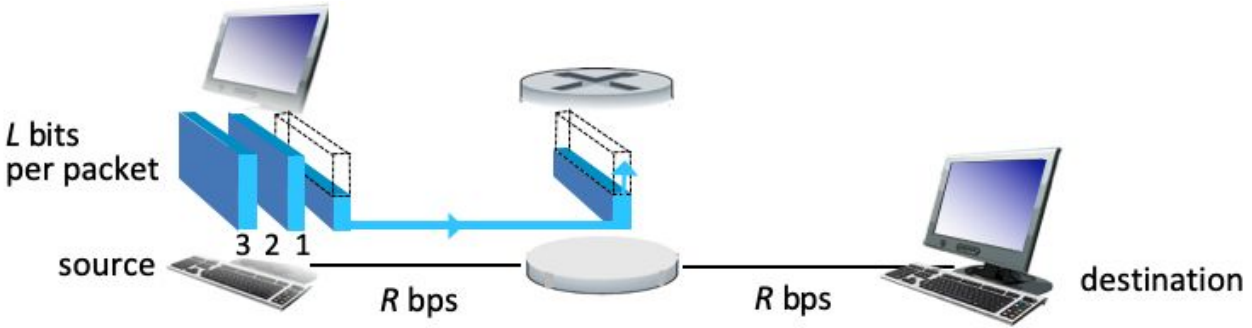
Network core

- 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

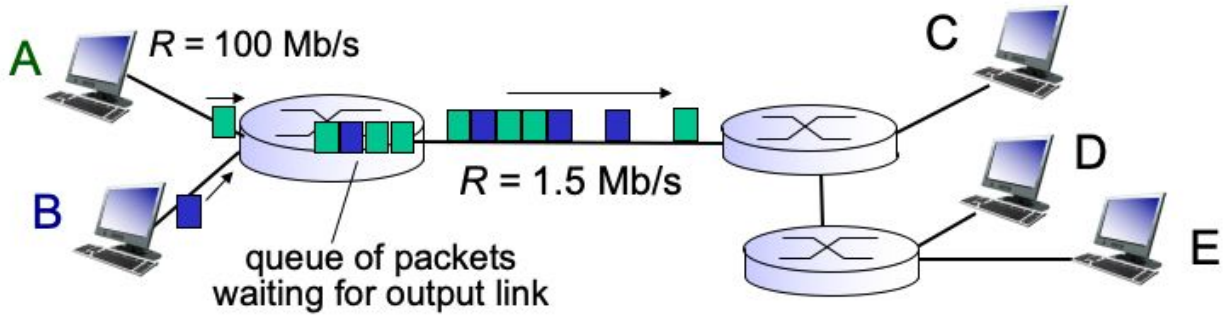
- Each router store-and-forward
- What's the end-to-end delay? 单向延迟



数据包从源到目标通过网络所花时间

Network core - packet switching

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



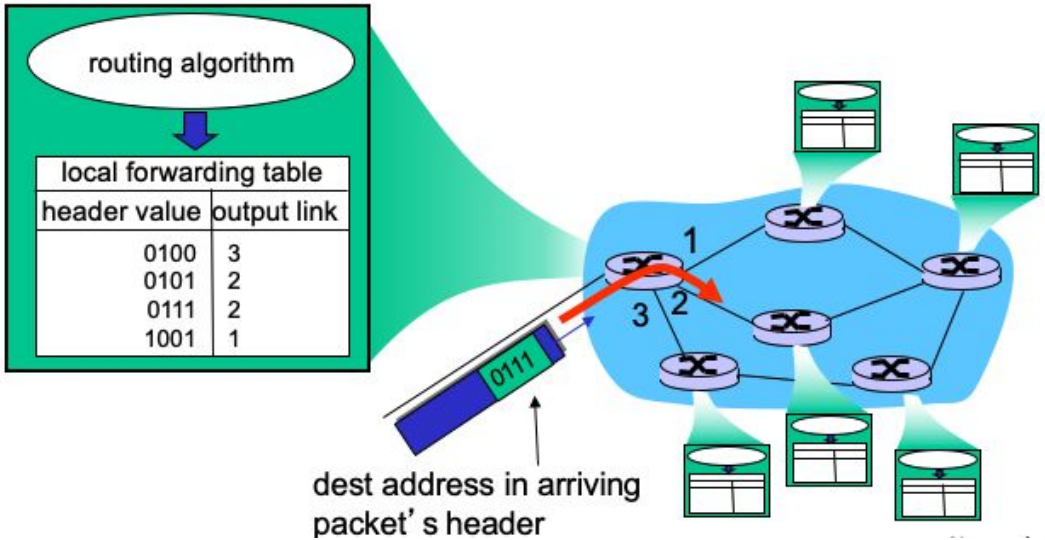
Network core - packet switching

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~~ link to appropriate output ~~port~~ link

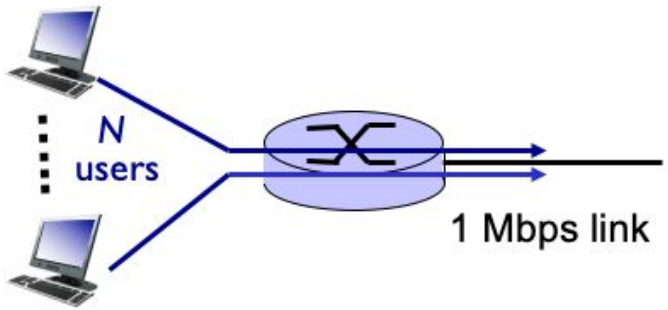
routing

Network core - packet switching



Network core - packet switching

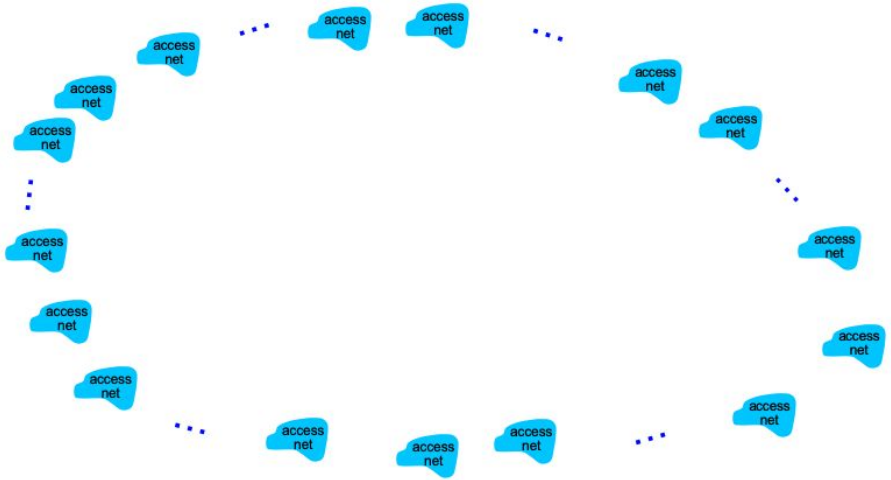
Resource utilization



- 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

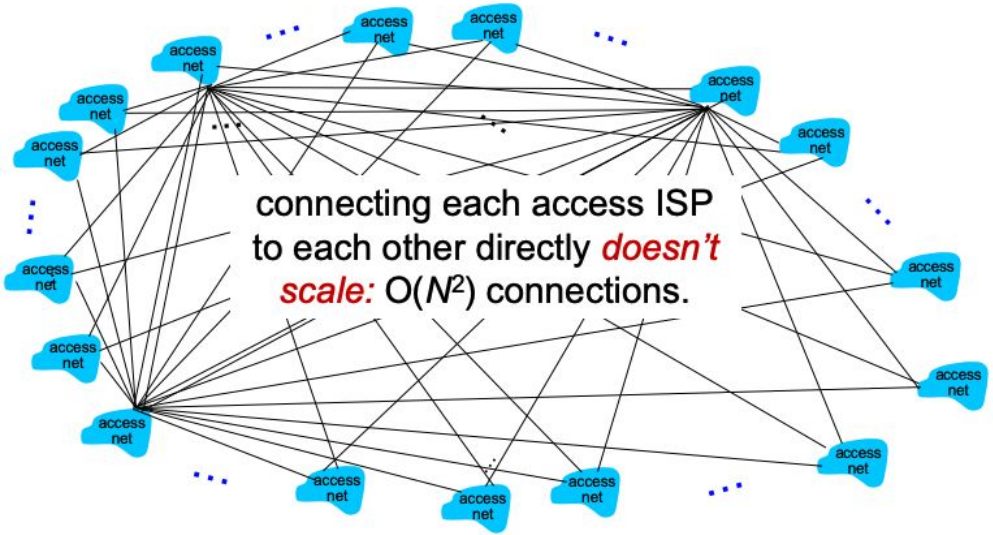
Internet structure

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



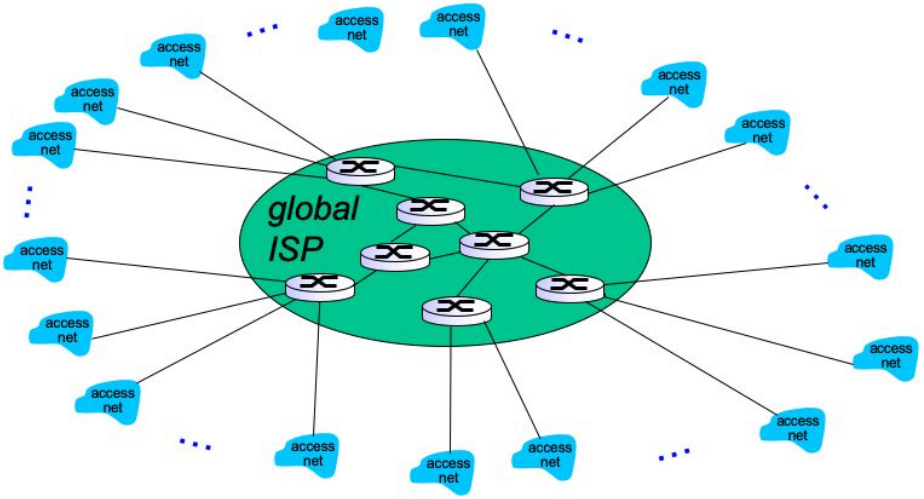
Internet structure

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

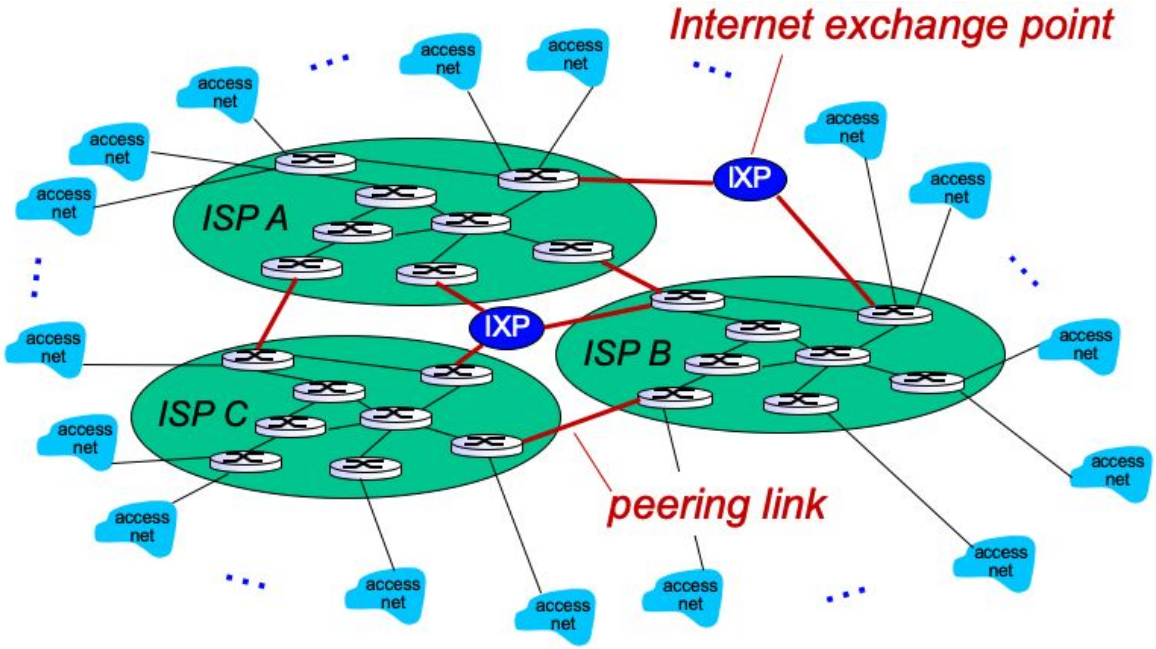


Internet structure

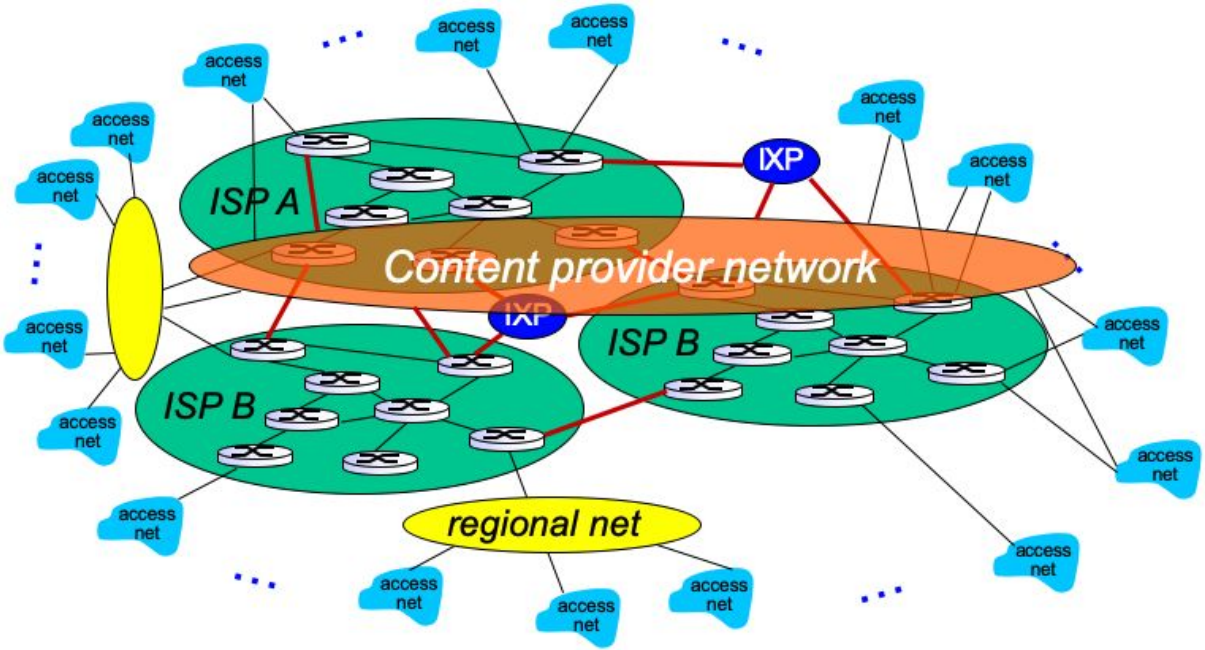
Option: connect each access ISP to a global transit ISP?



Internet structure

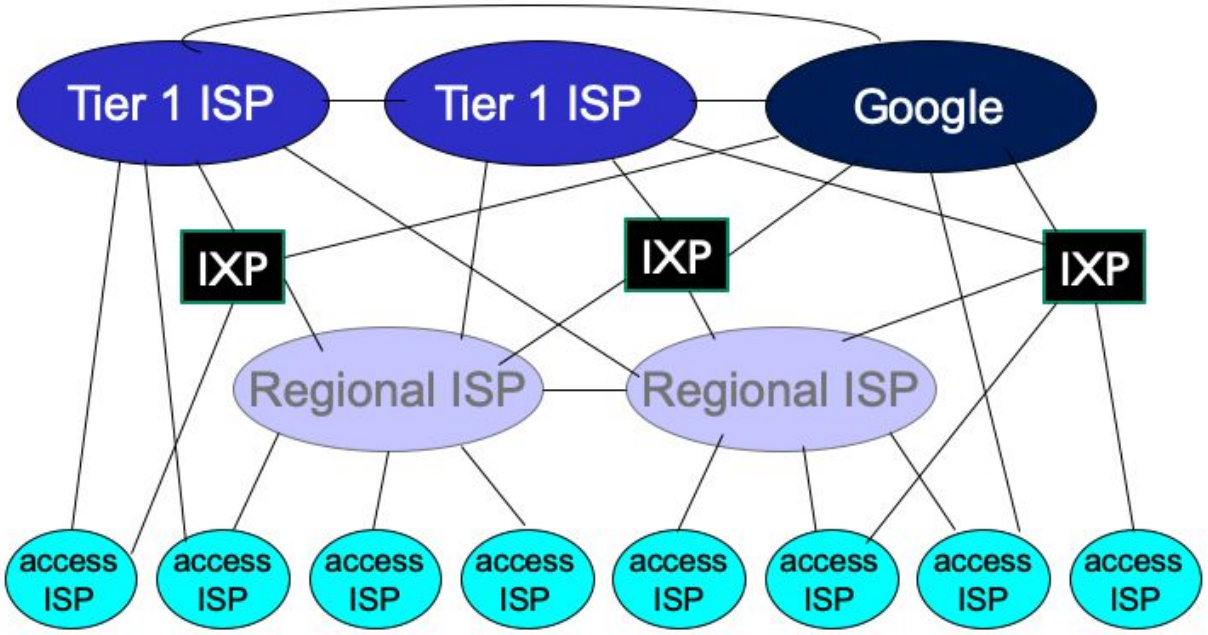


Internet structure



understand edge & core

Internet structure - network of networks!

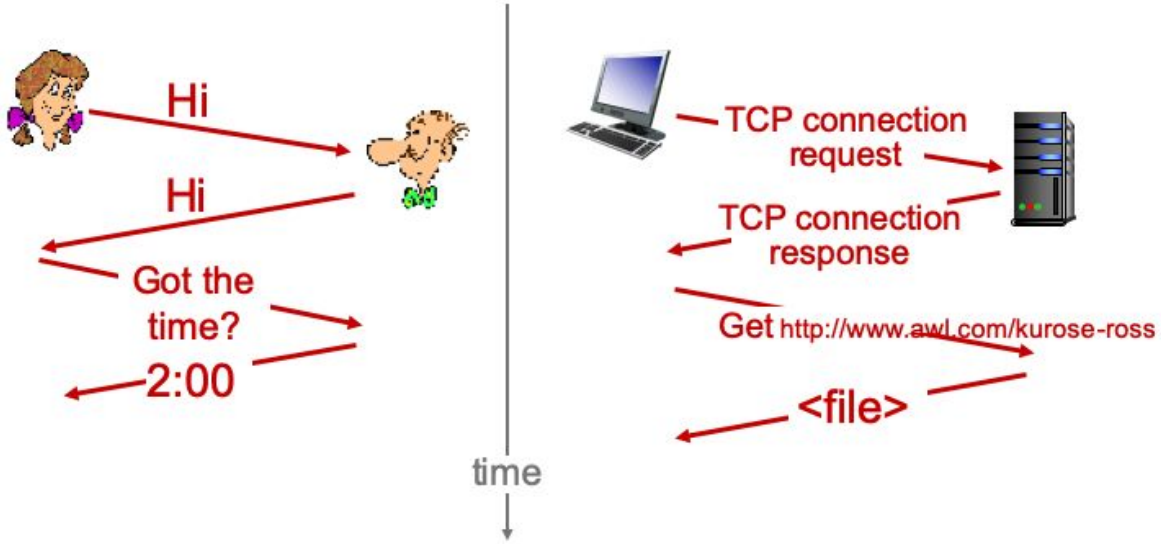


An Internet eXchange Point (IXP) is a physical location through which Internet infrastructure companies such as Internet Service Providers (ISPs), CDNs, web enterprises, communication service providers, cloud and SaaS providers connect to exchange Internet traffic.

Protocol layers

What is a protocol?

For machines to understand each other.

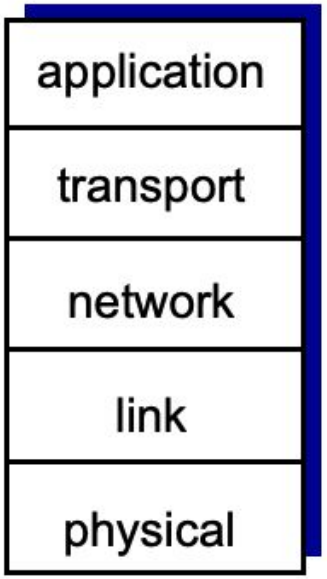


Protocol

- 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

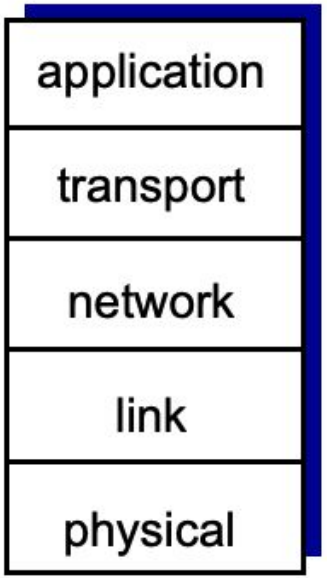
Protocol layers

5-layer reference model



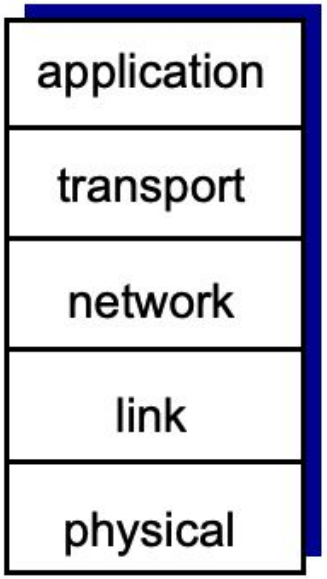
Protocol layers - physical layer

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



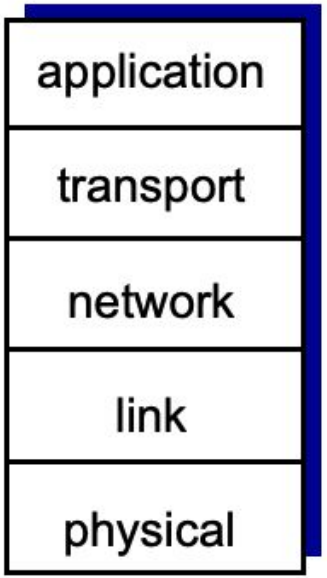
Protocol layers - link layer

- 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



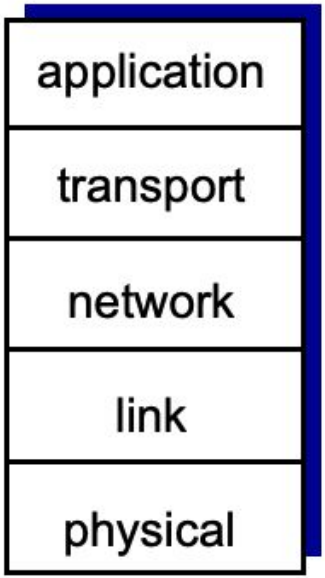
Protocol layers - network layer

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



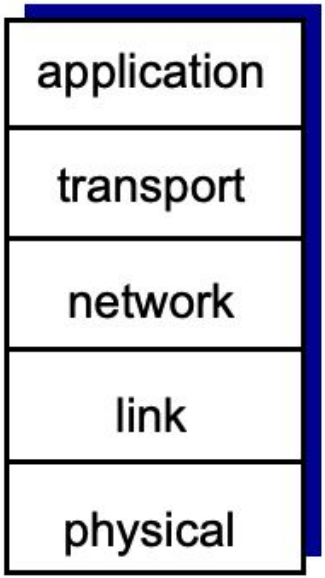
Protocol layers - transport layer

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

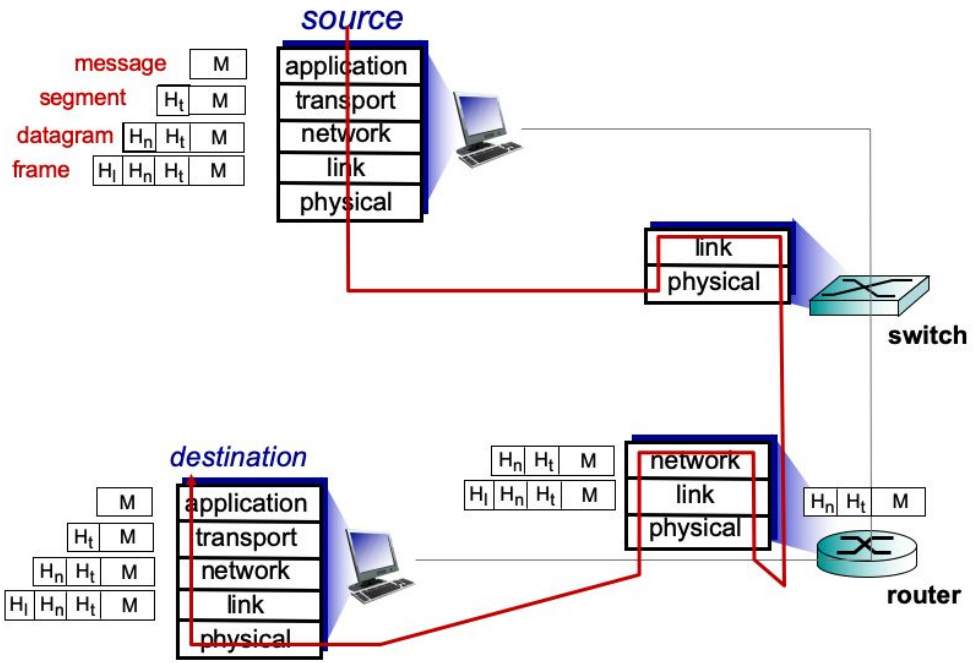


Protocol layers - application layer

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



Protocol layers



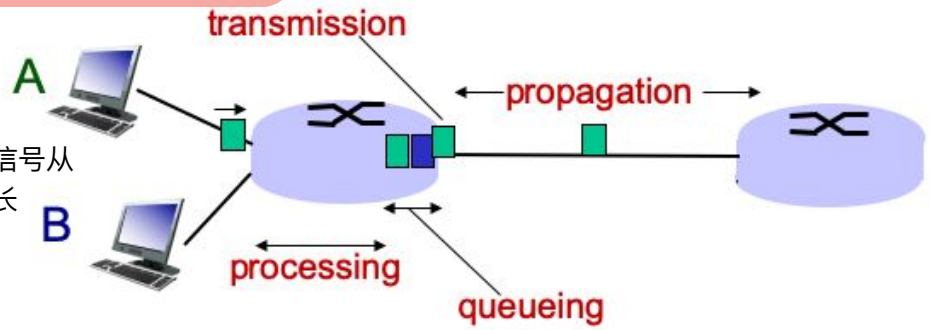
Key metrics

Delay (aka latency)

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

在基于数据包交换的网络中，处理延迟是路由器处理数据包报头所花费的时间。处理数据包期间，路由器可能会检查数据包中在传输期间发生的位级错误，并确定数据包的下一个目标位置。高速路由器中的处理延迟通常约为微秒或更短。在此节点处理之后，路由器会将数据包定向到可能发生进一步延迟的队列。

传输时延又名存放及转送延迟，是将数据包中所有比特推向链路所需要的时间



传播延迟，在通信、计算机网络领域中，意指信号从发讯方传播到收讯方时，该传播过程的时间总长

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

A: Dig is a tool designed to query DNS servers. Ping is a tool to send ICMP ECHO_REQUEST to another machine, typically used to ensure the remote machine can communicate with the network. Although ping does resolve an IP address, it uses different mechanisms to do so. Dig will use DNS only.

Delay

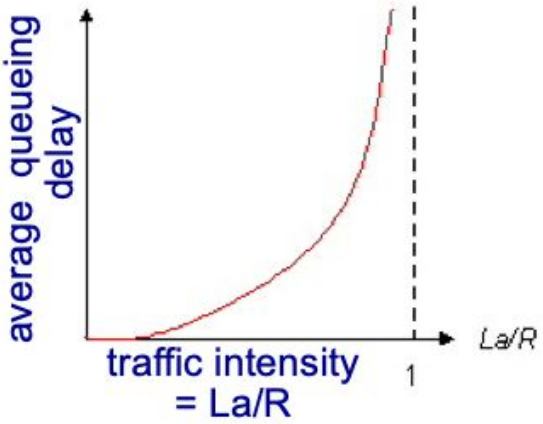
Compare transmission delay and propagation delay

- 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?

How much

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 how long

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


DEMO?
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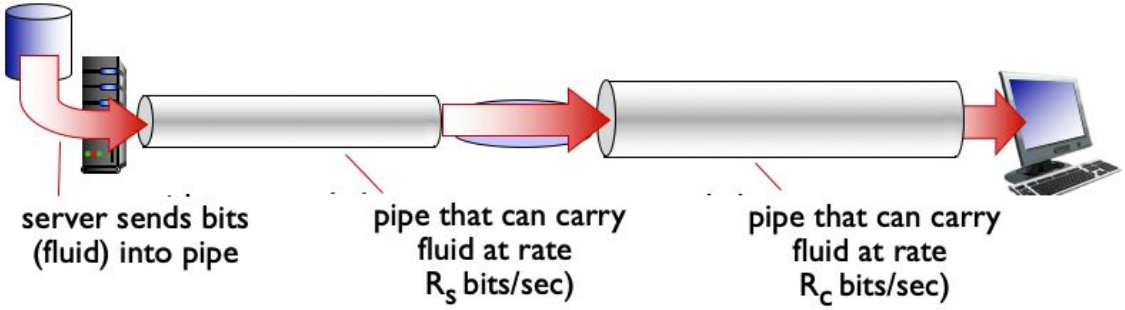
Throughput how much

- 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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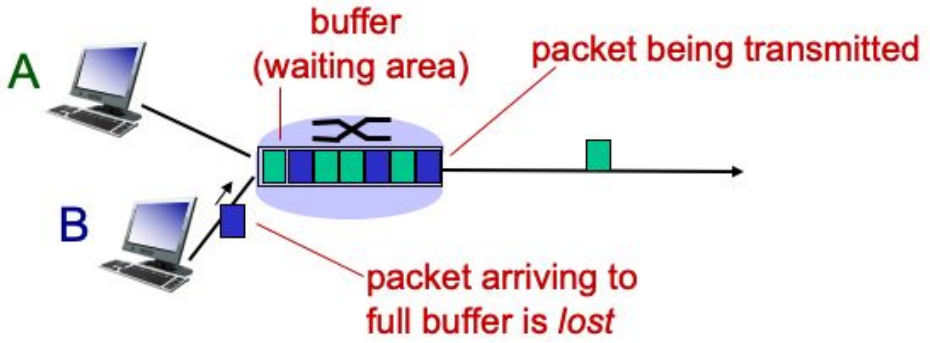
Loss

- 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