CS 305
Computer Networks

Spring 2022

Instructor: Zhuozhao Li
Lab: Qing Wang
Department of Computer Science and Engineering

Course Information

Lecture:

- Instructor: Zhuozhao Li, lizz@sustech.edu.cn
  Office: RM 516, South Tower, CoE Building（工学院南楼516）
- Lectures: Wednesday 4:20 PM – 6:10 PM
- Location: Room 306, First Teaching Building

Lab:

- Qing Wang, wangq9@mail.sustech.edu.cn
  Office: Room 110, South Tower, CoE Building
  Location: Room 204, Second Teaching building

Introduction

- Dr. Zhuozhao Li
- Assistant Professor, Department of Computer Science and Engineering
- Homepage: https://zhuozhaoli.github.io/
- Office hour: Friday 3-4pm or by email appointment

Course Information

- Sakai
  - https://sakai.sustech.edu.cn/portal/site/db0d4bc0-03ad-4b69-83bd-0dd2ec67c8d1
  - CS305-2022Spring
- QQ group: 763411362
- Schedule (Tentative)
  - https://zhuozhaoli.github.io/courses/CS305A/2022Spring/#schedule

Grading Policy

Grading is based on

- Homework and programming assignments – 15%
- Attendance and lab practice – 10%
- Project – 15%
  - Submit on time: all the assignments and reports should be submitted in the Sakai system, late submission will not be accepted in the system
- Midterm Examination - 30%
- Final Examination - 30%

Assignments

- No late assignment will be accepted (not even 1 second)
  - Unless some special situations (e.g., medical leave) which will be reviewed by all the instructors
  - The following excuses will **NOT** be approved for late submissions: **computer crashes, disk crashes, accidental file deletions, lab computer unavailability**, and the like

Rules about Plagiarism

No Plagiarism is allowed

- If plagiarism on homework or project is found for the first time, the plagiaristic part is graded as 0 and warning is given to the students
- If plagiarism is found for the second time, the course is graded as 0
- For project report, any sentence that is copied from other paper or article should cite the original source as the reference, otherwise, the report is considered as plagiarism

Submit the commitment letter on Sakai system before homework #1

What will we learn in this course?

- What is network? What is communication?
- What networks do we use in daily life? Any other network ever heard?
  - Mobile network, WWW, social network, neural network, etc.
- What applications require network access?
  - WeChat, games, websites, etc.

What is this course about?

What is Data Communications?

- the transmission of digital data between two or more computers or other hosts
- vs. telegram and telephone communications

What is Computer networking?

- a telecommunications network that allows computers to exchange data
- a best known computer network is the Internet
- we use internet to introduce computer network

What network problems have you ever met in your real life?

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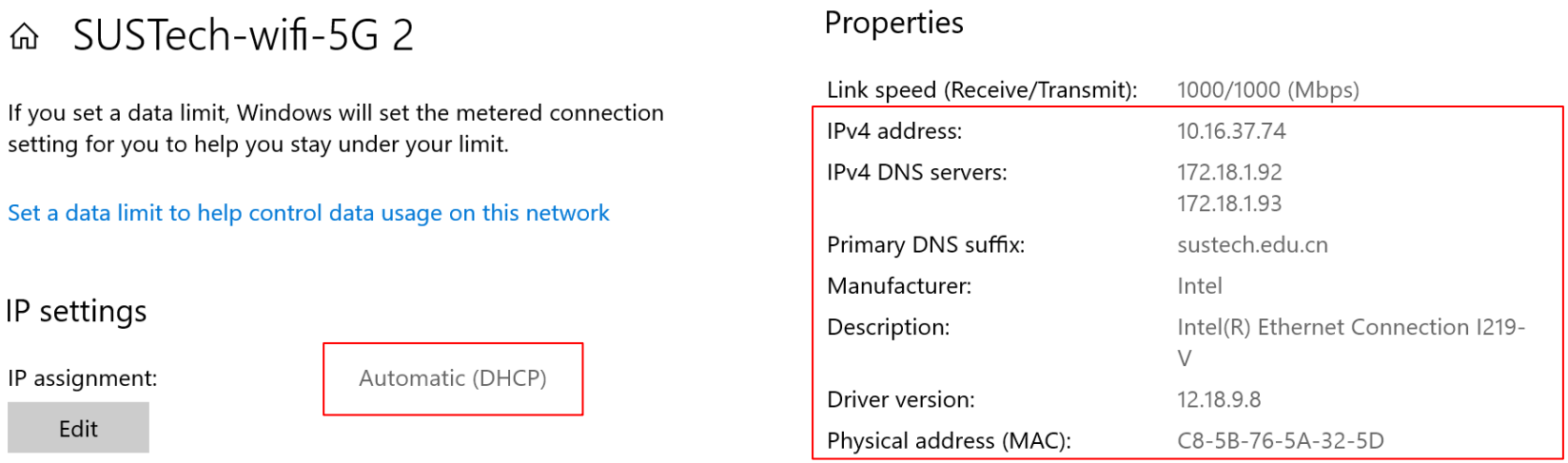

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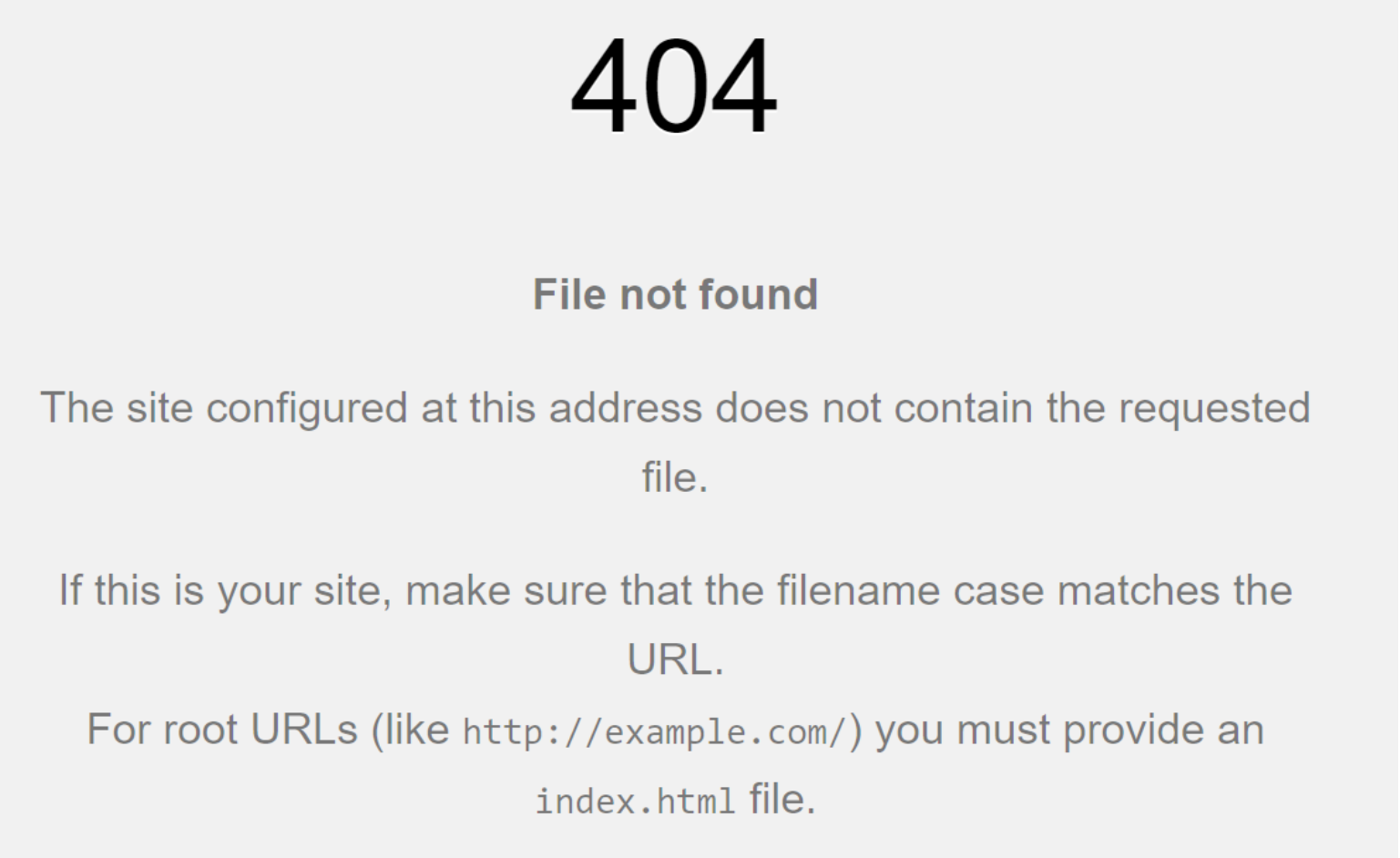


What network problems have you ever met in your real life?

What is this course about?

introductory (first) course in computer networking

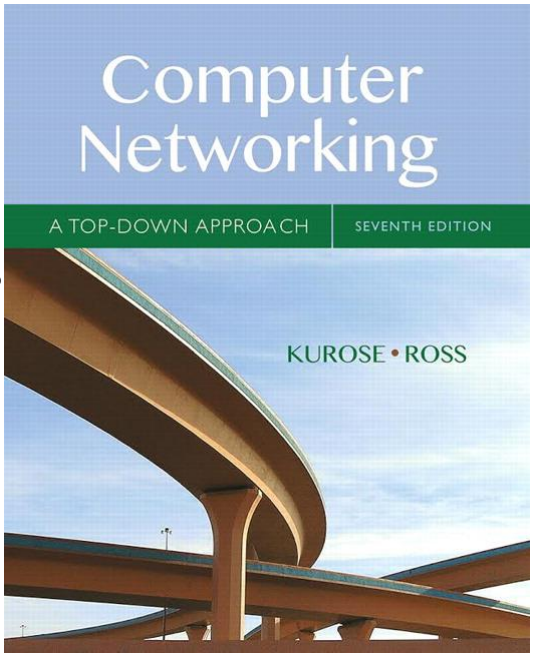
- learn principles of computer networking
- learn practice of computer networking
- Internet architecture/protocols as case study

Goals:

- learn a lot (not just factoids, but principles and practice)
- have fun (well, it should be interesting, at least)

Textbook information

- course materials:
  - text: *Computer Networking: A Top Down Approach Featuring the Internet*, J. Kurose & K. Ross, Pearson, 7th ed., 2017
  - slides
- online resources:
  - http://sakai.sustc.edu.cn
  - Textbook in pdf
  - Slides
  - Homework
  - Projects



How to use the textbook?

For each lecture:

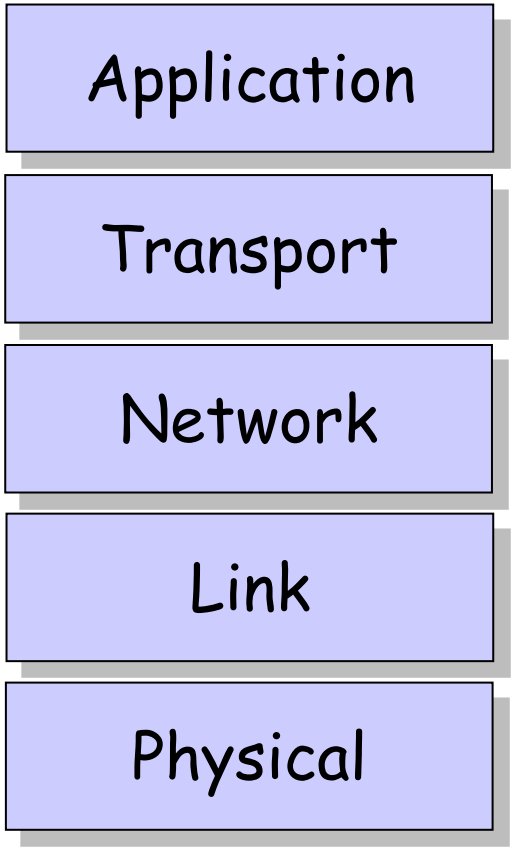
- Read corresponding content after class
- Go through the review questions
- Write homework

After each chapter

- read summary and interview if interested

Textbook information

Computer Networking: A Top-Down Approach, James Kurose and Keith Ross, Pearson (7th Ed.)



- **Bottom Up**: Start with physical (e.g., wires) layer and move up to applications (e.g., mail, web browsers) layer explaining how functions are implemented
- **Top Down** : Start with Application layer and move down to Physical layer, explaining what expectations from applications, and how such services are implemented

Course overview:

Introduction *(2 classes, text: Chapter 1)*

- what is the Internet, what is a protocol?
- network edge, network core, network access
- physical media
- delay, loss, throughput in packet-switched networks
- protocol layers, service models
- Internet backbones, ISPs, IXPs
- brief history of networking, Internet

Course overview:

Application layer *(3 classes, text: Ch. 2)*

- principles of application-layer protocols
- World Wide Web: HTTP
- video streaming and content distribution networks
- electronic mail in the Internet
- the Internet's directory service: DNS
- P2P: Skype
- socket programming

Course overview:

Transport layer *(3 classes, text Ch. 3)*

- transport-layer services and principles
- multiplexing and demultiplexing applications
- connectionless transport: UDP
- principles of reliable of data transfer
- TCP case study
- PROGRAMMING ASSIGNMENT 2
- principles of congestion control
- TCP congestion control

MIDTERM EXAM (approx)

Course overview:

Network layer *(4 classes, text: Ch. 4)*

- introduction and network service model
- what's inside a router?
- routing principles (algorithms)
- hierarchical routing
- IP: the Internet Protocol
- Internet routing: RIP, OSPF, BGP

In Textbook 7th edition:

Network layer – Data Plane

Network layer – Control Plane

- Software defined network (SDN)

Course overview:

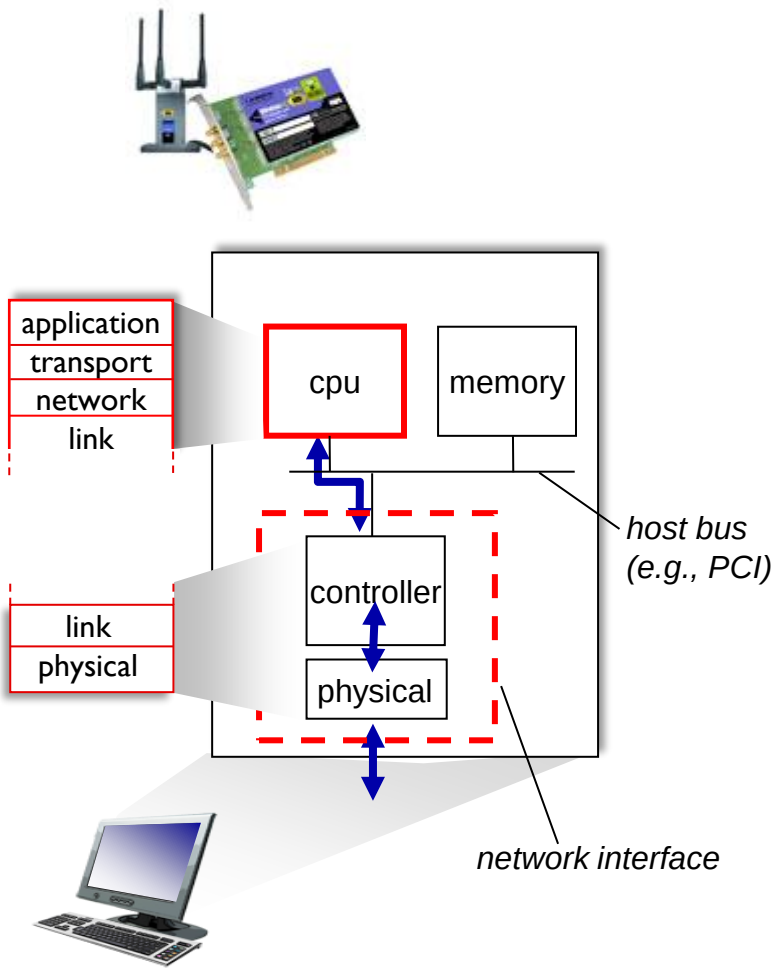
Link layer, LANs *(2 classes, text: Ch. 5)*

- introduction, services
- error detection, correction
- multiple access protocols, LANs
- LAN addresses, ARP
- Ethernet
- network as a link layer: MPLS
- a day in the life of a web request (synthesis)

We will add more physical layer content in this chapter

Course overview:

combination of hardware, software, firmware



Course overview:

Wireless and mobile networks (1 class, Ch 6)

- wireless link characteristics
- the wireless link:
  - 802.11
  - cellular Internet access
  - mobility principles
- mobility in practice:
  - mobile IP
  - mobility in cellular networks

Lab

Basic content:

- Basic network commands
- Packet capture using Wireshark
- Protocol analysis
- Socket programming

Make your hands dirty!

- Setup switch and router
- Setup wireless networks
- Analyze network performance

Tips for attending lecture

- Having around 100 students in one room is horrible
- To get the best use of lecture
  - interactive
  - ask whenever you have question, interrupt whenever you want
  - Ask immediately after the class if you are shy
  - Give me suggestions and feedback frequently
- Get the main idea in class, read the details after class

Tips for this course

- Computer network is a human-invented object
  - No strict right or wrong, science vs. technology
  - limited by many factors → trade-off
- We can meet almost all the content in our daily life
  - Think about: where do we use it when we learn a new application or protocol? What's your own experience?
- Take yourself as the designer of the internet.
  - Think how to design the protocol before learn it.
  - Try every idea out.
- Computer network always mimics social network
  - Computer vs. people
  - Protocol vs. people communication

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  - Try ev
- Computer
  - Computer vs. people
  - Protocol vs. people communication

Be active!
You can change the world!

Chapter 1: introduction

Chapter goal:

- get "feel" and terminology
- more depth, detail *later* in course
- approach:
  - use Internet as example

Overview / roadmap:

- what's the Internet?
- what's a protocol?
- network edge; hosts, access net, physical media
- network core: packet/circuit switching, Internet structure
- performance: loss, delay, throughput
- security
- protocol layers, service models
- history

Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

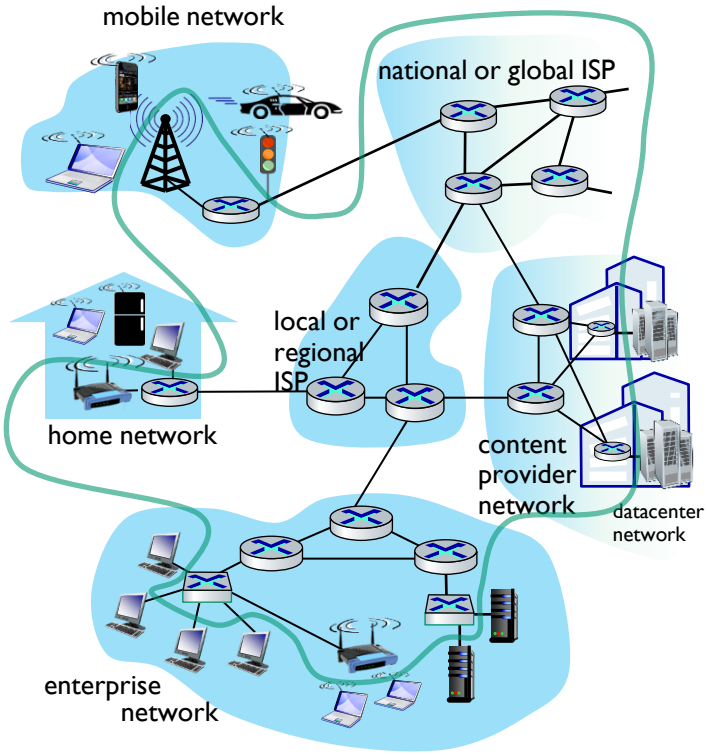
1.6 networks under attack: security

1.7 history

The Internet: a "nuts and bolts" view

Billions of connected computing *devices*:

- *hosts* = *end systems*
- running *network apps* at Internet's "edge"



“Fun” Internet-connected devices

Amazon Echo

Internet refrigerator

IP picture frame

Pacemaker & Monitor

Tweet-a-watt: monitor energy use

Security Camera

Slingbox: remote control cable TV

Web-enabled toaster + weather forecaster

AR devices

Internet phones

sensorized, bed mattress

Fitbit

Others?

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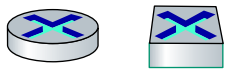


Packet switches: forward packets (chunks of data)

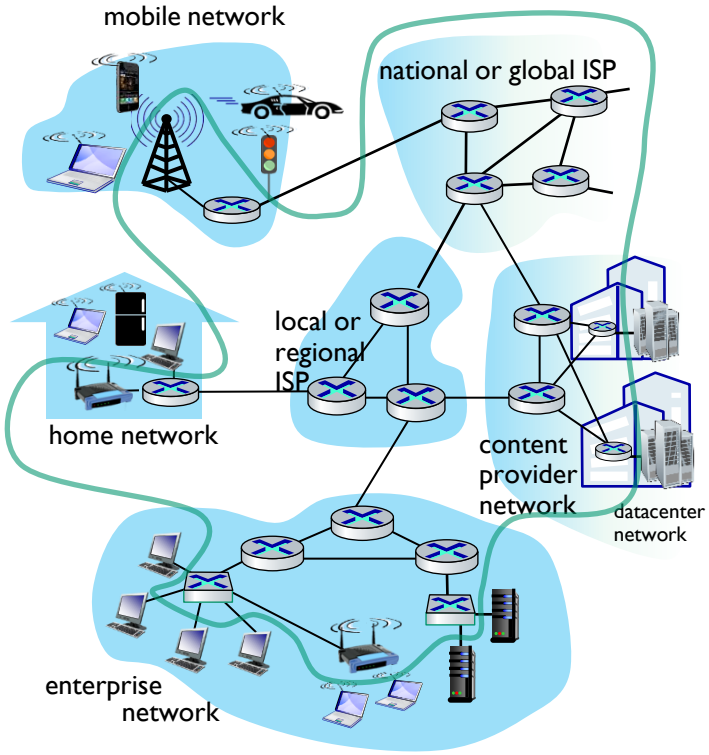
- *routers*, *switches*

Communication links

- fiber, copper, radio, satellite
- transmission rate: *bandwidth*

Networks

- collection of devices, routers, links: managed by an organization

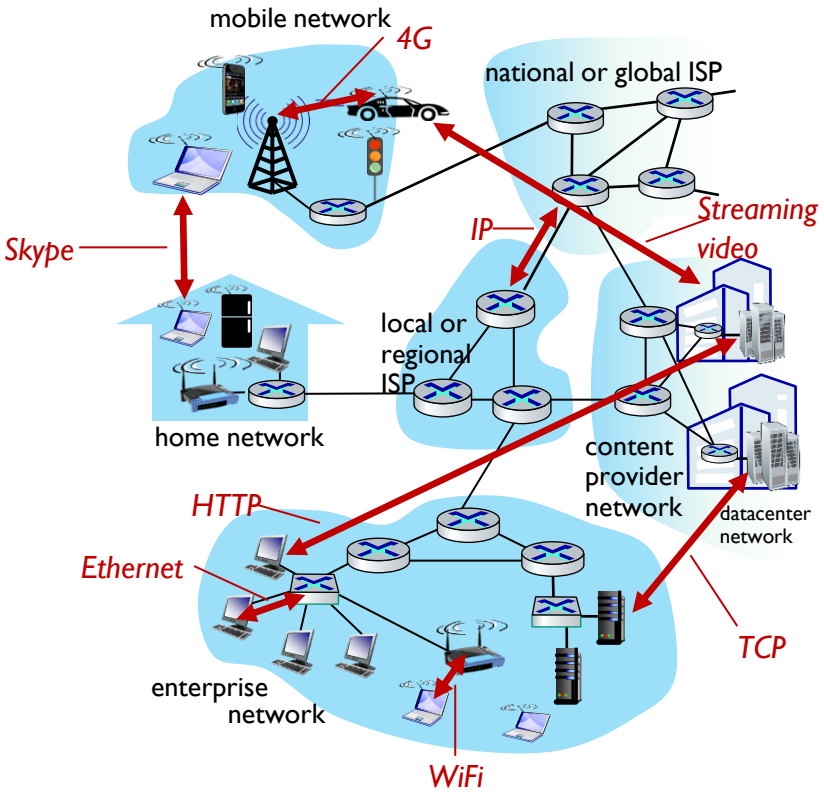


The Internet: a "nuts and bolts" view

- *Internet*: "network of networks"
  - Interconnected ISPs

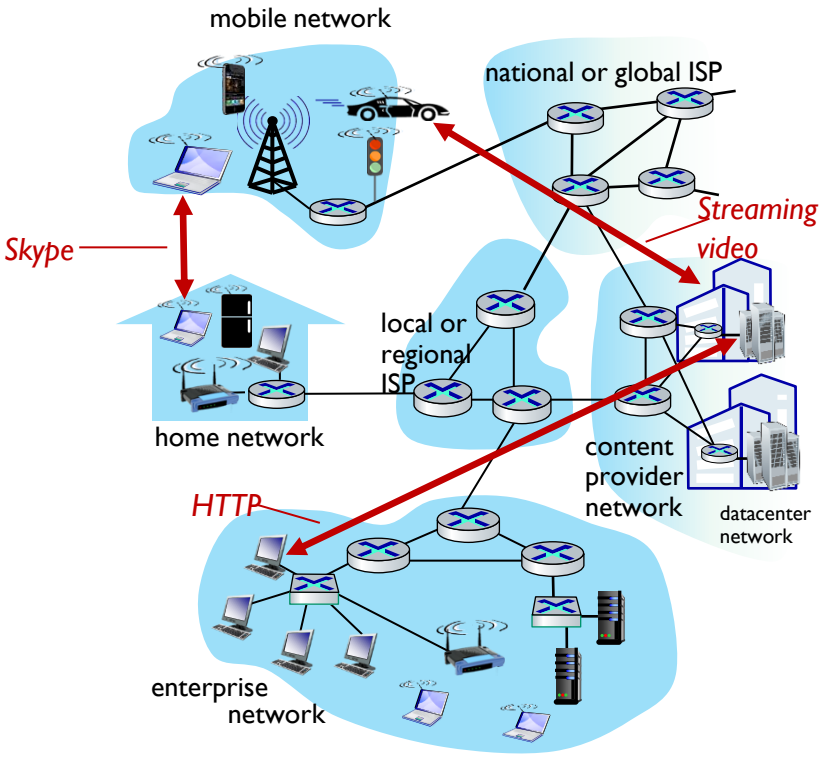
- *protocols* are *everywhere*
  - control sending, receiving of messages
  - e.g., HTTP (Web), streaming video, Skype, TCP, IP, WiFi, 4G, Ethernet

- *Internet standards*
  - RFC: Request for Comments
  - IETF: Internet Engineering Task Force



The Internet: a "service" view

- *Infrastructure* that provides services to applications:
  - Web, streaming video, multimedia teleconferencing, email, games, e-commerce, social media, inter-connected appliances, …
  - provides *programming interface* to distributed applications:
    - "hooks" allowing sending/receiving apps to "connect" to, use Internet transport service
    - provides service options, analogous to postal service



What's a protocol?

human protocols:

- "what's the time?"
- "I have a question"
- introductions

… specific messages sent

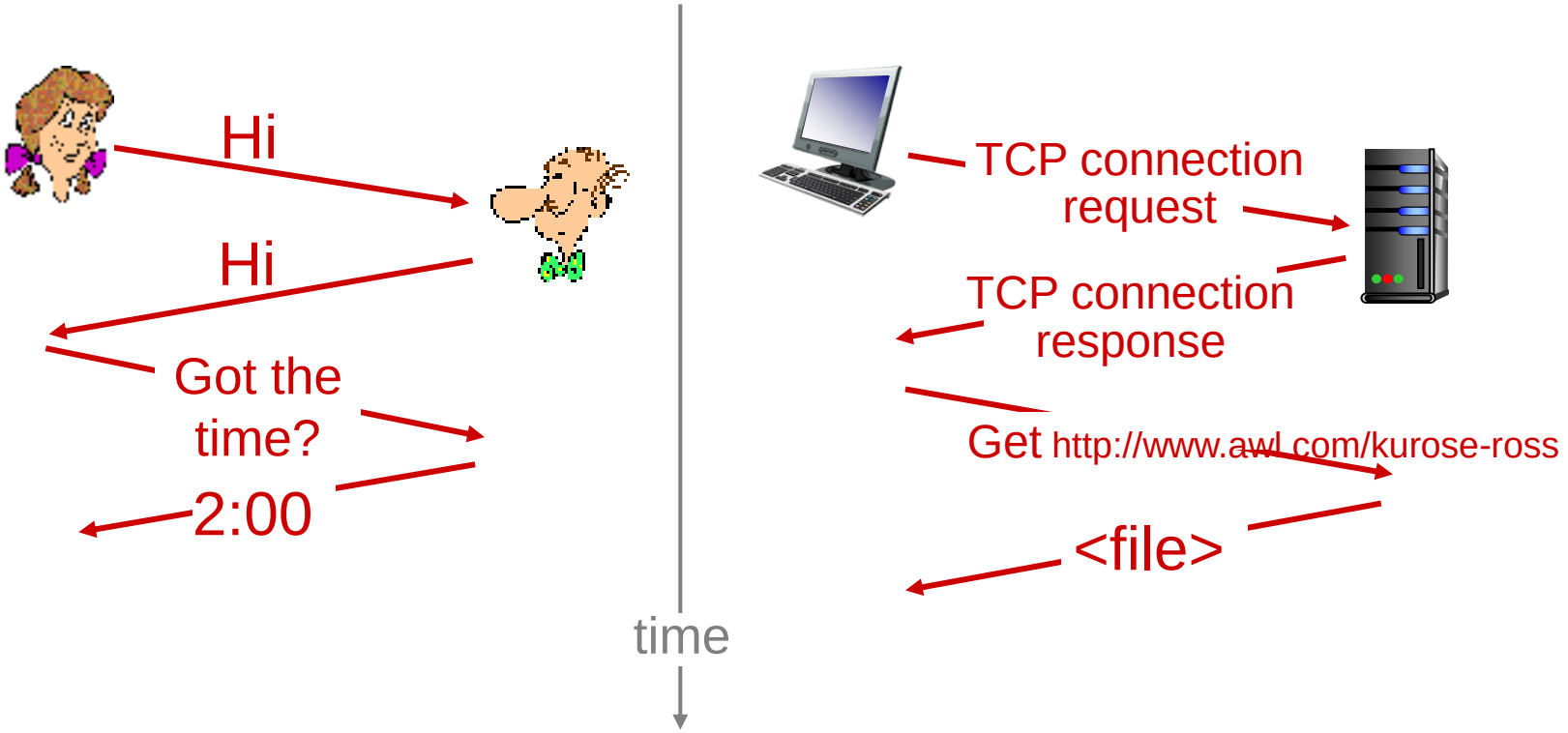
… specific actions taken when messages received, or other events

network protocols:

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

What's a protocol?

a human protocol and a computer network protocol:



Q: other human protocols?

What's a protocol?

human protocols:

- "what's the time?"
- "I have a question"
- introductions

… specific messages sent

… specific actions taken when messages received, or other events

network protocols:

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

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

Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

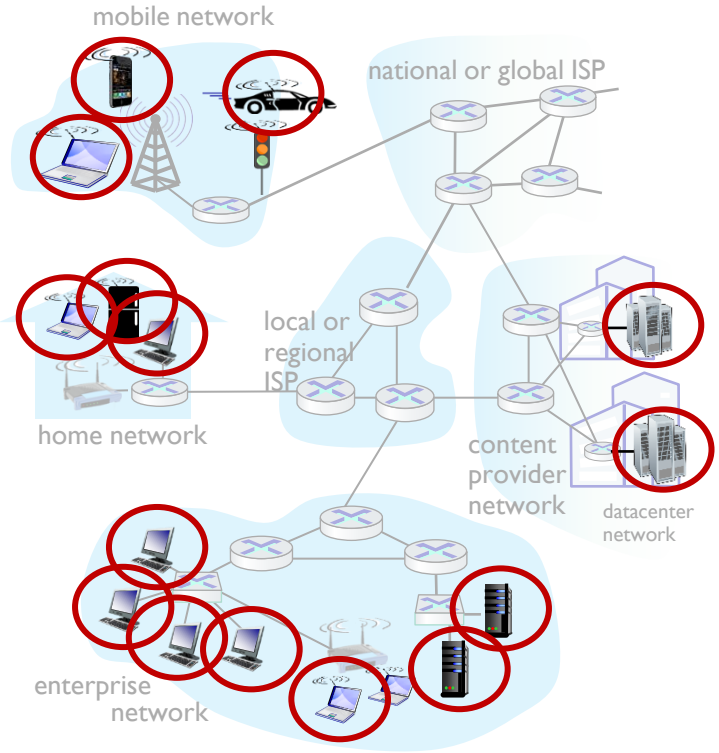
1.6 networks under attack: security

1.7 history

A closer look at Internet structure

Network edge:

- hosts: clients and servers
- servers often in data centers



A closer look at Internet structure

Network edge:

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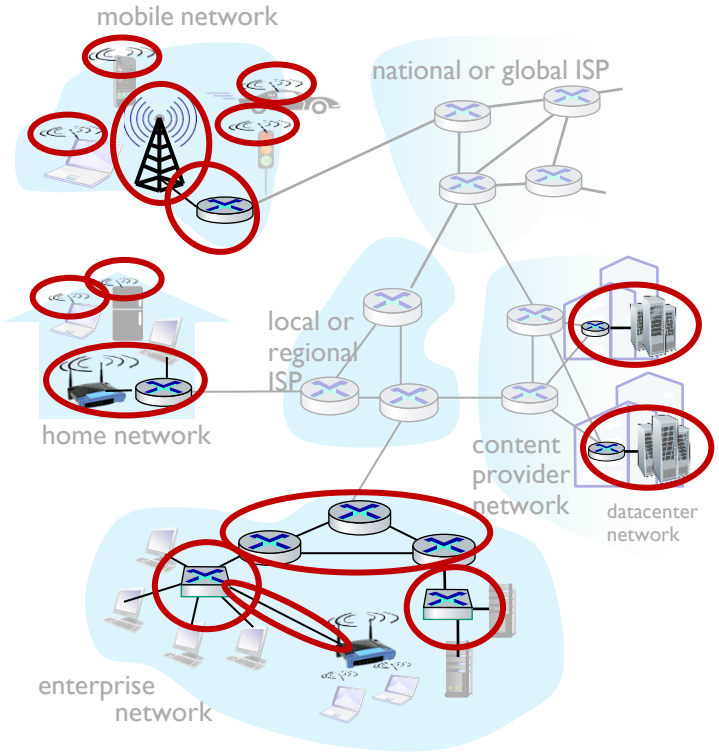
Access networks, physical media:

- wired, wireless communication links



A closer look at Internet structure

Network edge:

- hosts: clients and servers
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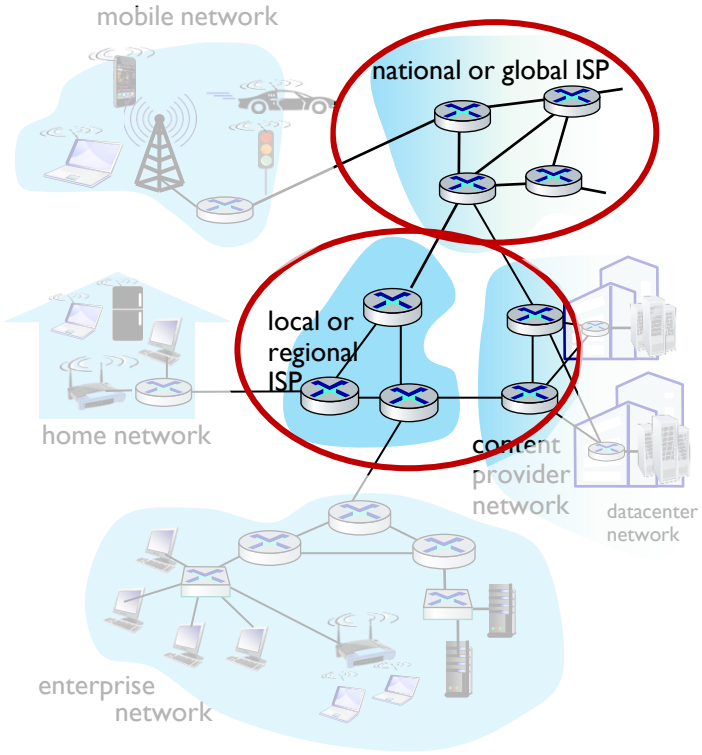
Access networks, physical media:

- wired, wireless communication links

Network core:

- interconnected routers
- network of networks



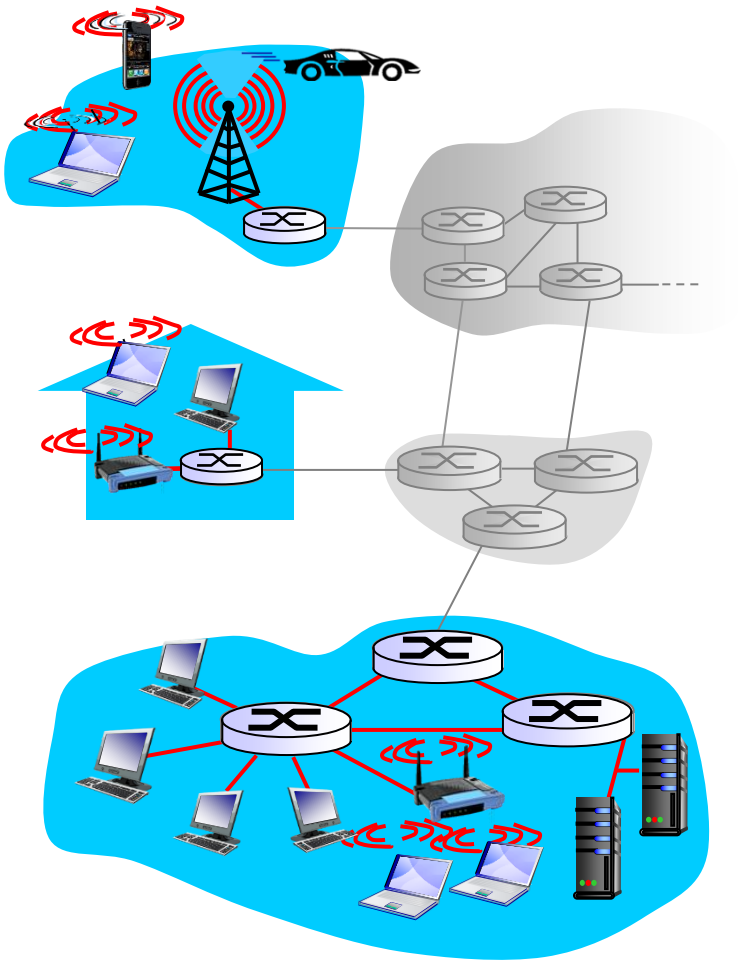
Access networks and physical media

Q: How to connect end systems to edge router?

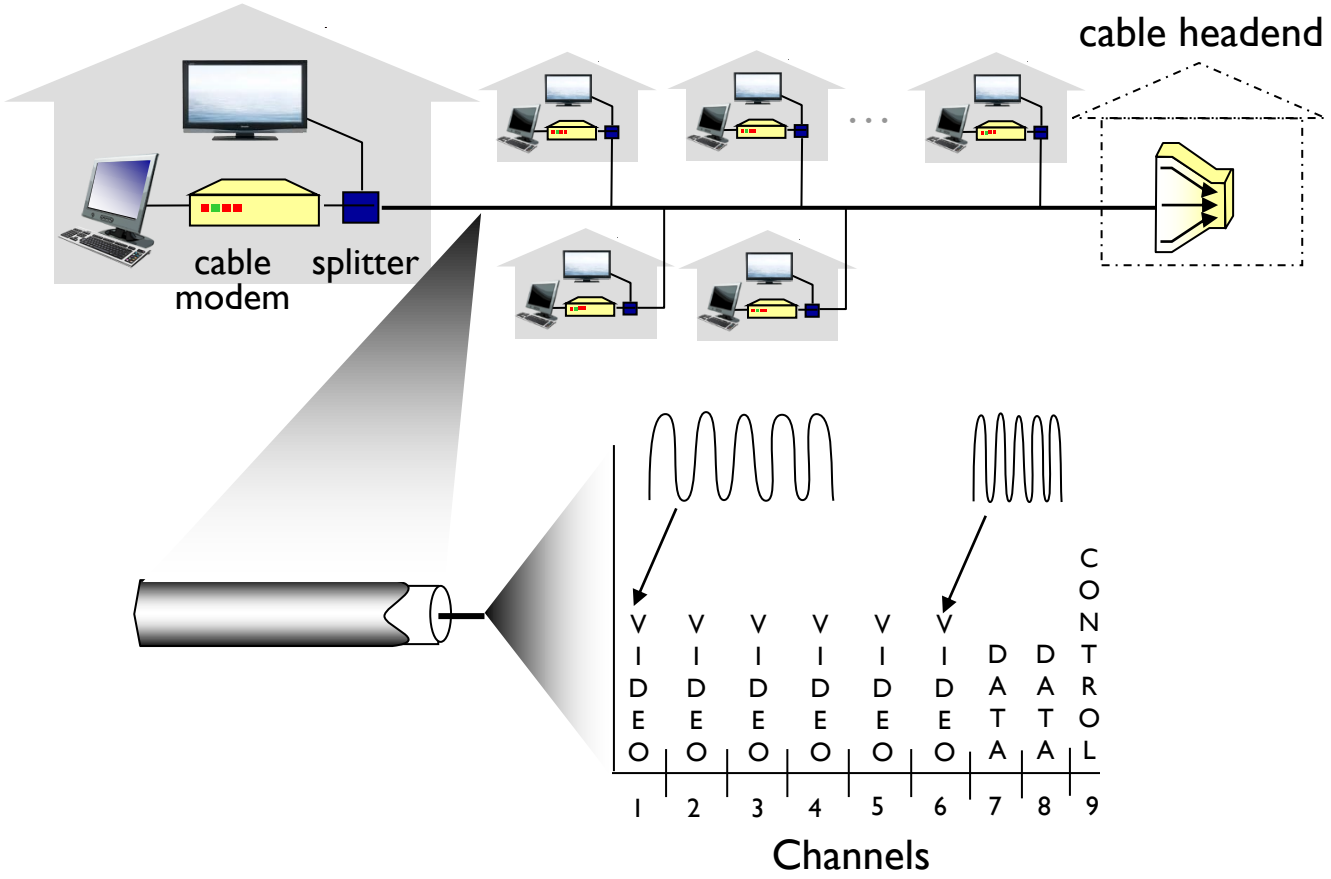
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

- bandwidth (transmission rate, bits per second) of access network?
- shared or dedicated?

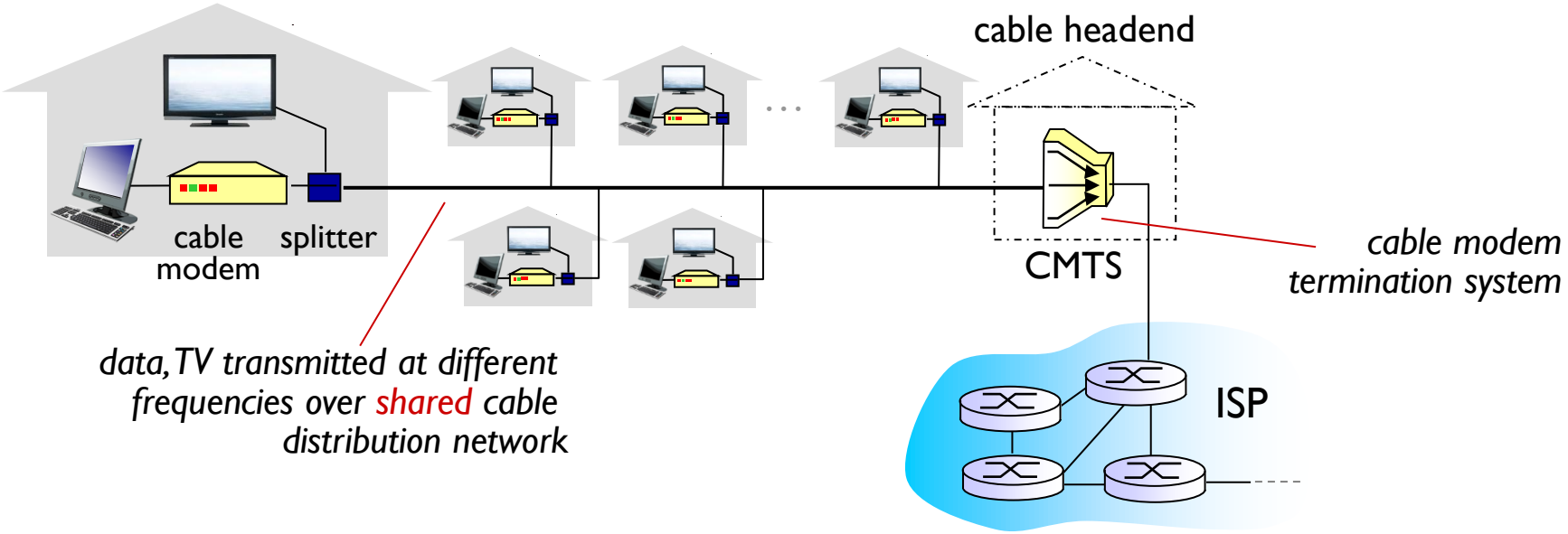


Access net: cable network



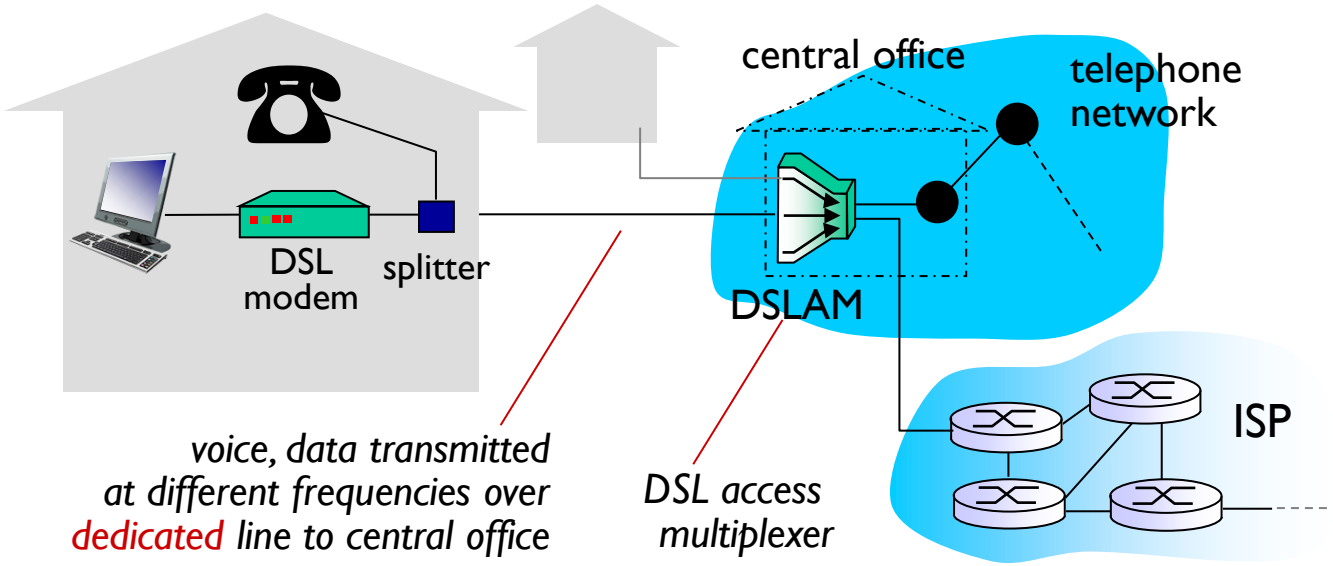
frequency division multiplexing: different channels transmitted in different frequency bands

Access net: cable network



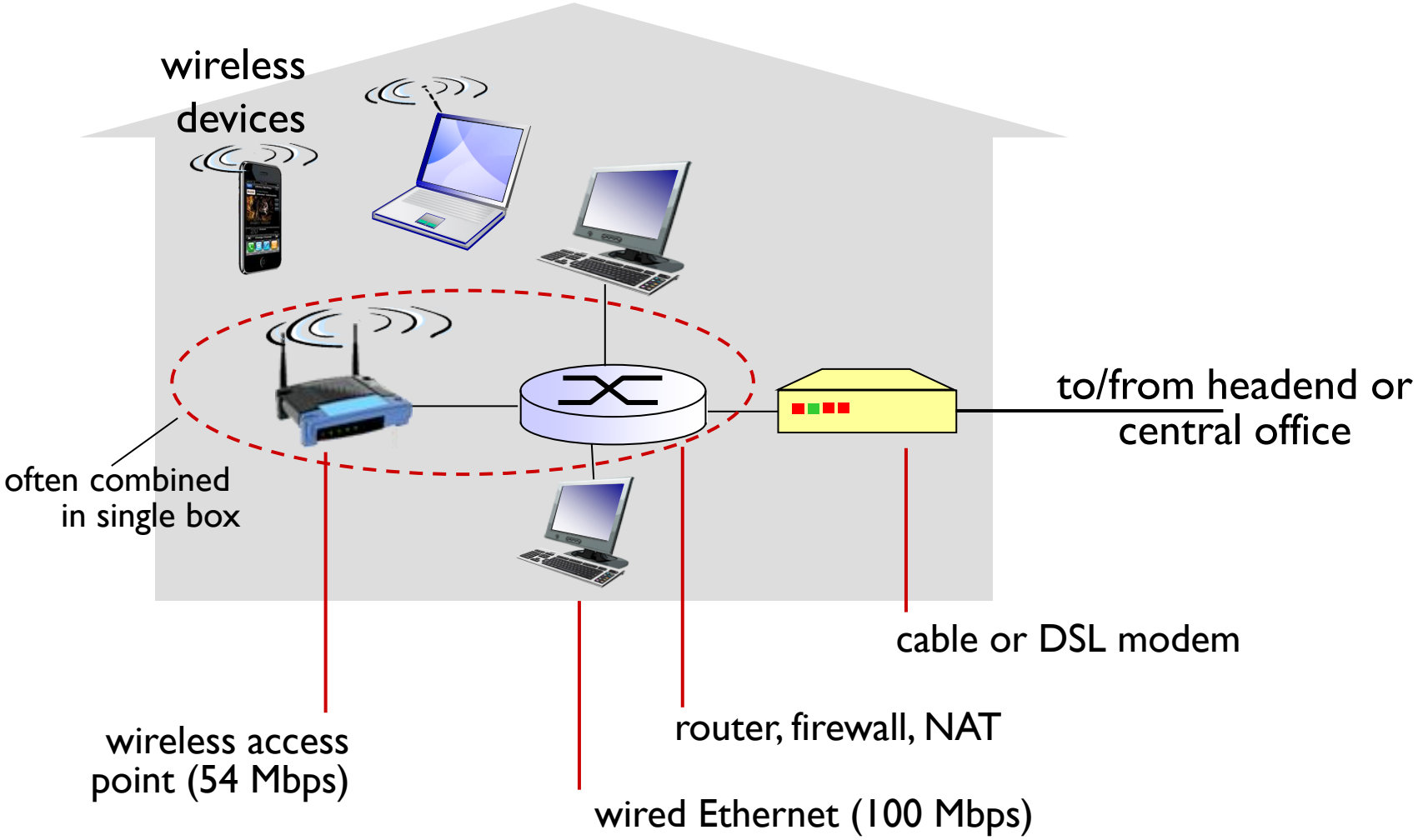
- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend

Access net: digital subscriber line (DSL)



- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

Access net: home network



Wireless access networks

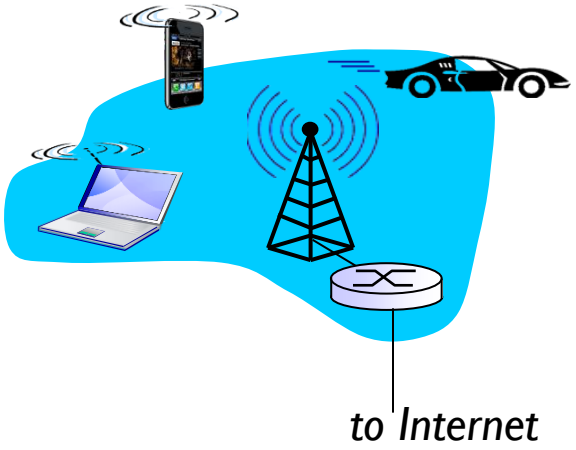
- shared *wireless* access network connects end system to router
  - via base station aka "access point"

wireless LANs:

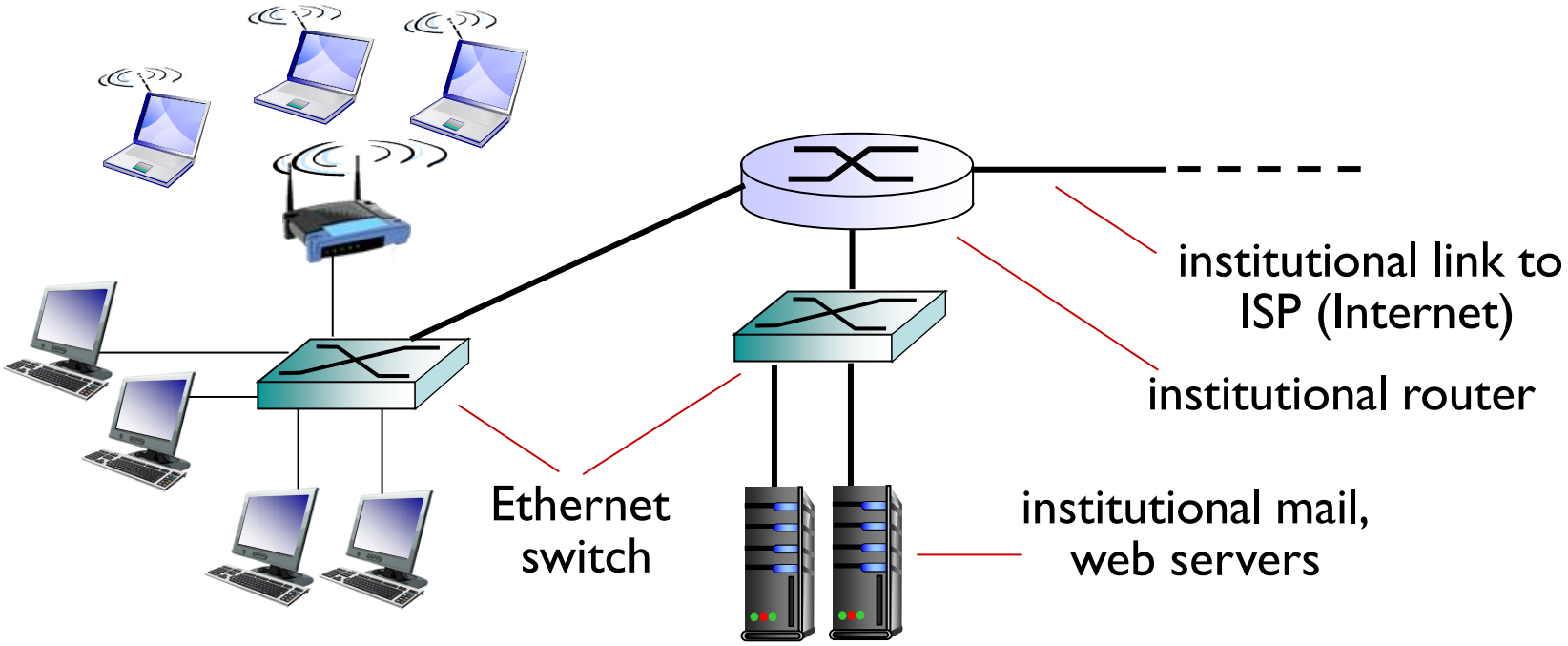
- within building (100 ft)
- 802.11b/g/n/ac (WiFi): 11, 54, 800, 1733 Mbps transmission rate

wide-area wireless access

- provided by telco (cellular) operator, 10's km
- 10 Mbps, 100Mbps, 10Gbps
- 3G, 4G, 5G



Enterprise access networks (Ethernet)

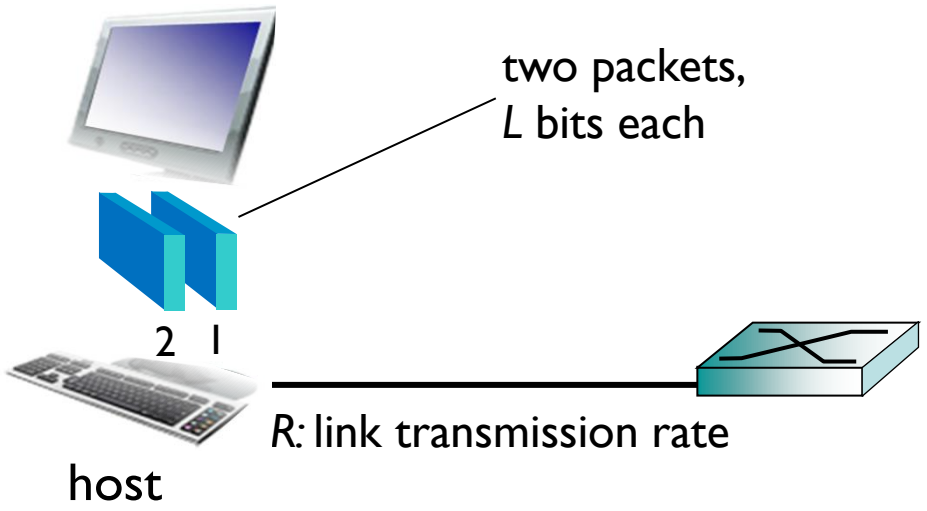


- typically used in companies, universities, etc
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

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*



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

Physical media

- bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- guided media:
  - signals propagate in solid media: copper, fiber, coax
- unguided media:
  - signals propagate freely, e.g., radio

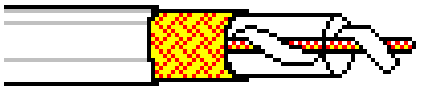
twisted pair (TP)

- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gpbs Ethernet
  - Category 6: 10Gbps

Physical media: coax, fiber

coaxial cable:

- two concentric copper conductors
- bidirectional
- broadband:
  - multiple channels on cable
  - HFC



fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10's-100's Gpbs transmission rate)
- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise

Physical media: radio

- signal carried in electromagnetic spectrum
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

radio link types:

- terrestrial microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., WiFi)
  - 11Mbps, 54 Mbps
- wide-area (e.g., cellular)
  - 3G cellular: ~ few Mbps
- satellite
  - Kbps to 45Mbps channel (or multiple smaller channels)
  - 270 msec end-end delay
  - geosynchronous versus low altitude