CS 305: Computer Networks

Fall 2024

Lecture 1： Course Overview and Introduction

Ming Tang

Department of Computer Science and Engineering
Southern University of Science and Technology (SUSTech)

Course Information

Lecture:

- Instructor: Ming Tang
- Email: tangm3@sustech.edu.cn

Lab:

- Qing Wang, wangq9@mail.sustech.edu.cn
- Wei Wang, wangw6@sustech.edu.cn

Blackboard: Computer Networks Fall 2024

QQ Group: 738651647

Marking Scheme

- Homework (2) and programming assignments (2) – 15%
- Attendance and lab practice – 10%
- Project – 15%
  - One project for everyone (CS major and non-CS major)
- Midterm Examination - 30%
- Final Examination - 30%

Assignments

- All assignments and reports should be submitted in the **Blackboard**
- **Late submission** (homework only):
  - **Within 24 hours: 60%; Otherwise: 0%**
  - Unless some special situations (e.g., medical leave)
  - The following excuses will NOT be approved for late submissions: computer crashes, disk crashes, accidental file deletions, lab computer unavailability, and the like
- **Late submission** (programming assignment & lab):
  - Inquire lab instructor about the policy

Rules about Plagiarism

No Plagiarism is allowed

- For the first time: the score of the assignment or quiz will be zero
- For the second time: the score of the course will be zero

When two assignments are nearly identical, it may be difficult to tell who actually wrote it. Thus, the policy will apply to BOTH students, unless one confesses having copied without the knowledge of the other.

Submit the **Assignment Declaration Form** on Blackboard

What are OK and NOT OK?

- It is OK to discuss an assignment with a friend and share ideas. At the time of actual writing, you should write it alone.
- It is OK to get the main idea for a solution from the web, as long as you acknowledge the source. At the time of actual writing, you should write answers on your own instead of copying from the web.
- It is OK to show your assignment to friends to explain the logic, as long as the friends write their assignment on their own later.
- It is OK to help friends debug their programs. You will probably learn a lot by doing so.

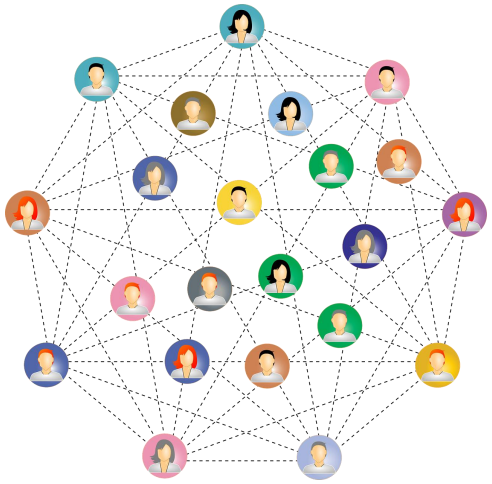
It is **NOT OK** to take the assignment of a friend, make a few cosmetic changes (variable names), and pass it as your work.

Course Overview

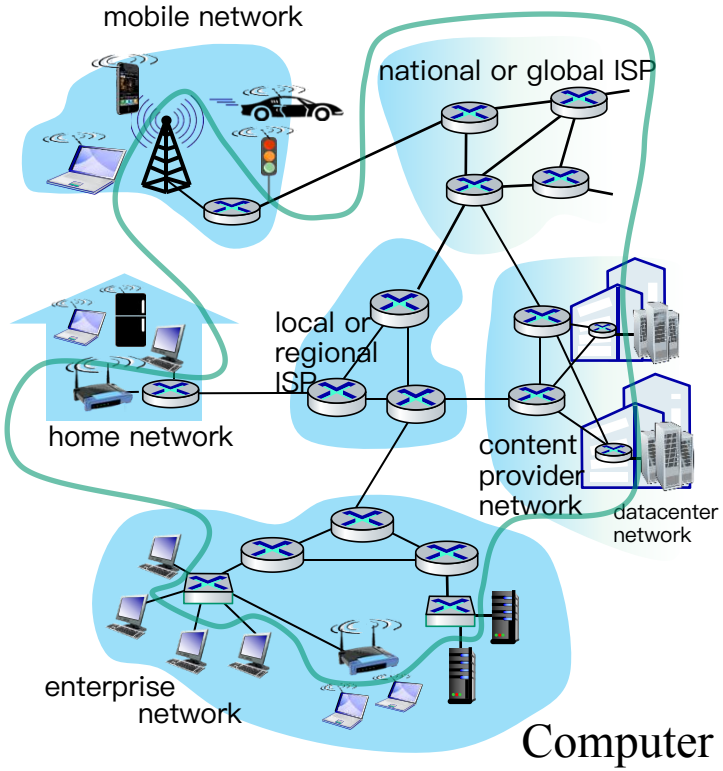
Before We Start

- What is communication?
- Communication is the act of sharing and receiving information through a variety of media to various individuals.

- What is network?



Social Network



Computer Network

What is this course about?

Data Communications:

- The transmission of digital data (discrete symbols) between two or more computers or other hosts
- Be contrasted with a range of analog data (real numbers): telephone communications

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 applications have you used?

Email

Web

Video

BitTorrent

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

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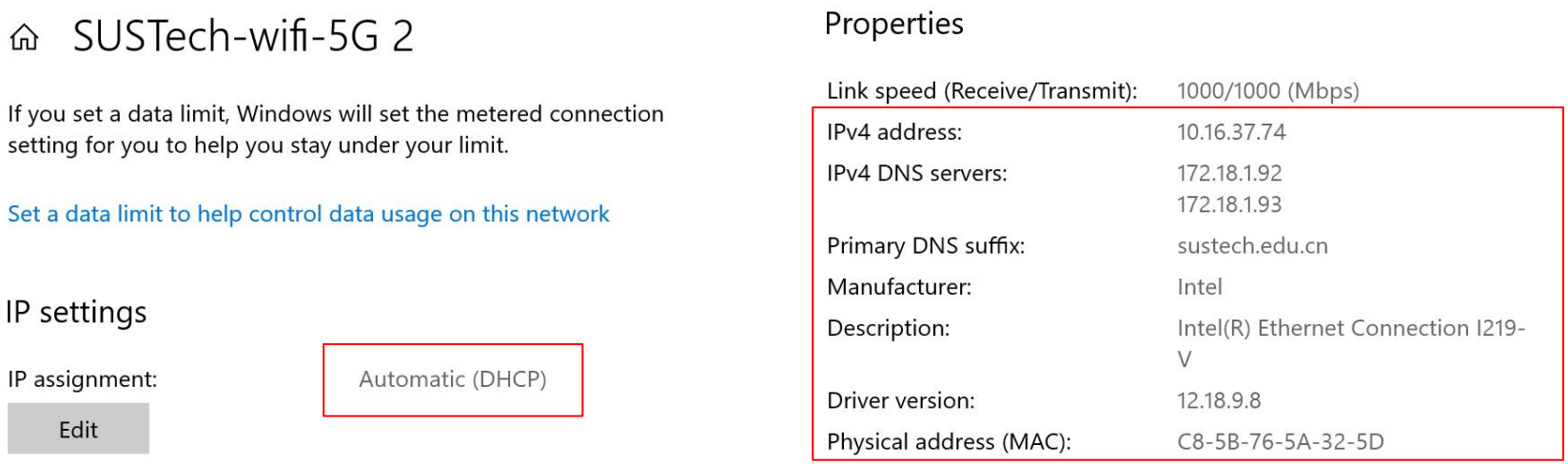

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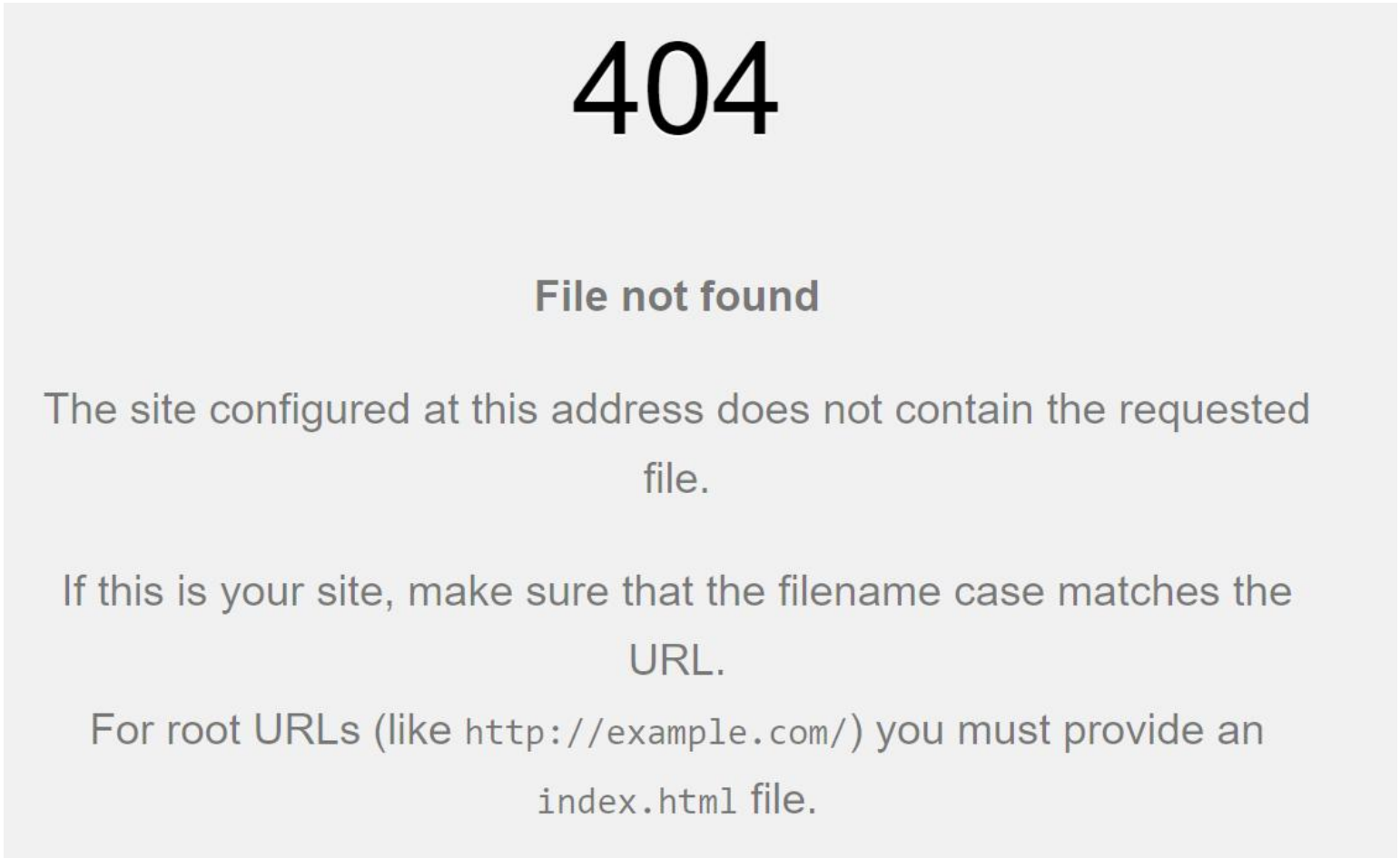


What is this course about?

Introductory (first) course in computer networking

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

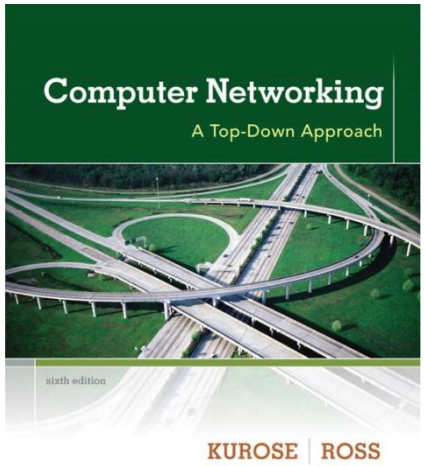
Goals:

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

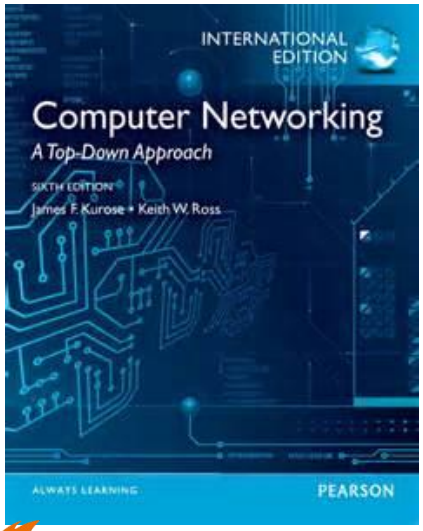
Textbook information

Course materials:

- *Computer Networking: A Top Down Approach Featuring the Internet*, J. Kurose & K. Ross, Pearson, **7th ed**., 2017 （has been uploaded to Blackboard）
- Slides (uploaded after each lecture)
- Homework



This textbook and even these slides are commonly used worldwide. You can search online to get further materials, e.g., lecture videos in Chinese: https://www.bilibili.com/video/BV1JV411t7ow?p=1



How to use the textbook?

For each lecture:

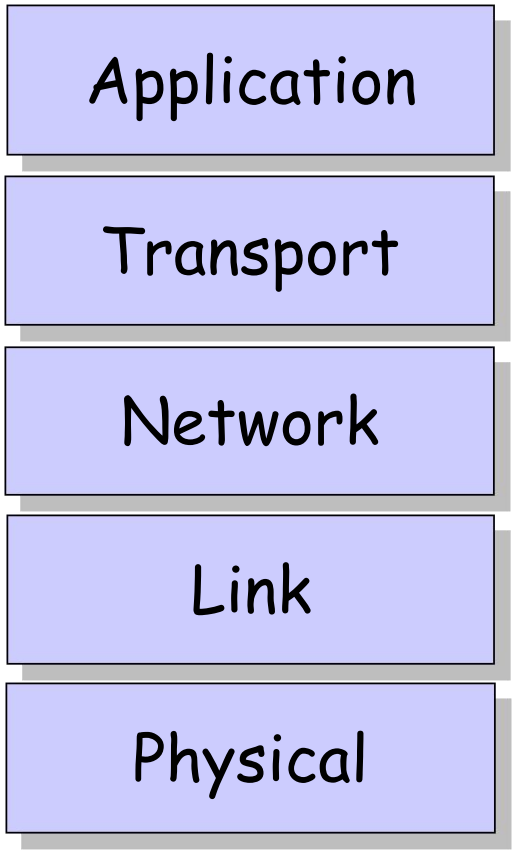
- Read corresponding content after class
- Go through the review questions
- Write homework

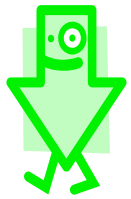
After each chapter

- 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

Tentative Schedule

Introduction （2 weeks）

Application layer （3 weeks）

Transport layer （3 weeks）

Midterm Exam

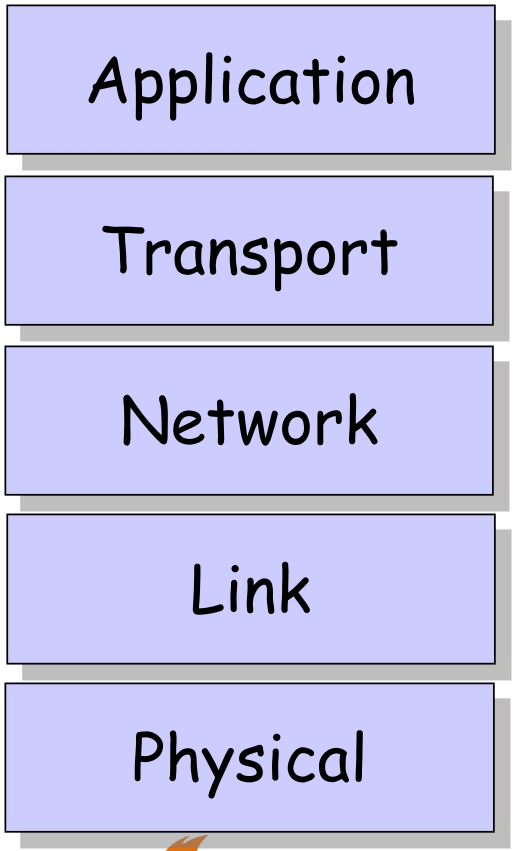
Network layer-data plane （2 weeks）

Network layer-control plane （2 weeks）

Link layer, LANs （2 weeks）

Wireless and mobile networks （1 week）

Review （1 week）



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
- 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:

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

- 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

Chapter 1: introduction

Chapter 1: introduction

Chapter goal:

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

Chapter 1: roadmap

1.1 what is the Internet?

- a “nuts and bolts” view
- a “service” view
- protocol

1.2 network edge

- end systems, access networks, links

1.3 network core

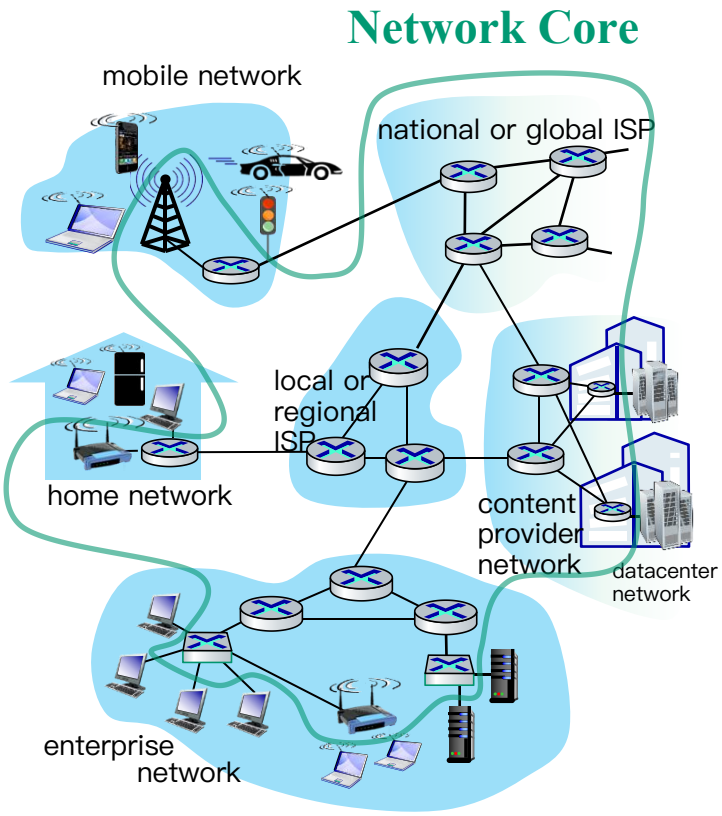
- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

1.6 networks under attack: security

The Internet: a “nuts and bolts” view



The Internet is a computer network that interconnects billions of computing devices throughout the world.

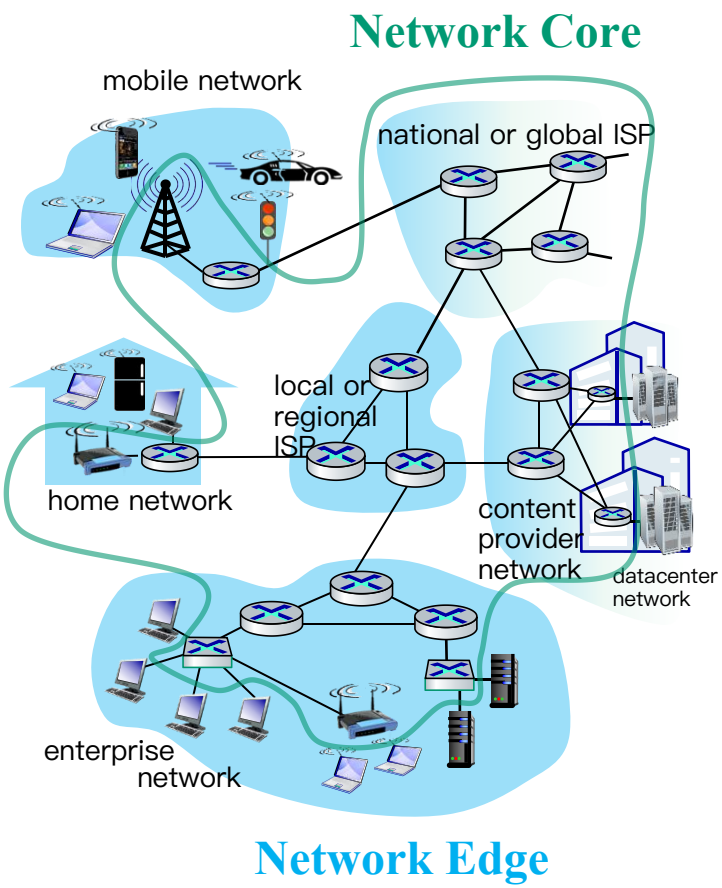
- hosts （主机） = end systems

Servers （服务器）

“things”

Network Edge: runs network applications

The Internet: a “nuts and bolts” view



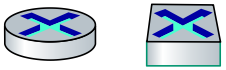
End systems are connected together by a network of communication links and packet switches.

Communication links

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

Packet switches: forward packets (chunks of data)

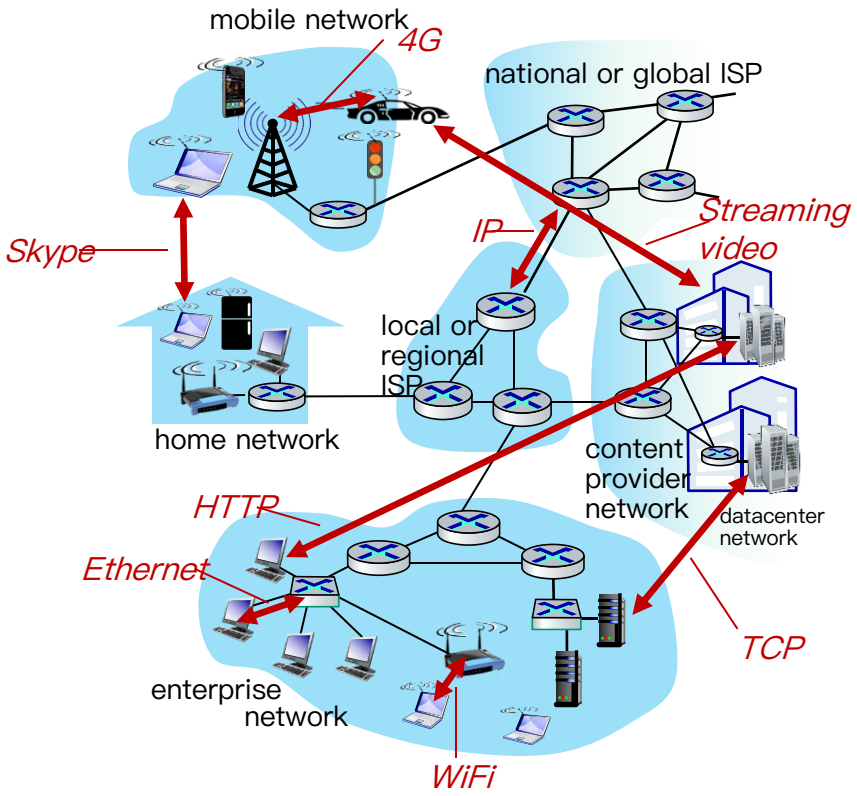
- Incoming communication links to outgoing communication links
- Routers (路由器), switches (交换机)



Networks: collection of devices, routers, links that are managed by an organization

Network Core: interconnects end systems

The Internet: a “nuts and bolts” view



End systems access the Internet through Internet Service Providers (ISPs)

- Residential ISPs, university ISPs, WiFi access, cellular data ISPs
- In itself a network of communication links and packet switches.

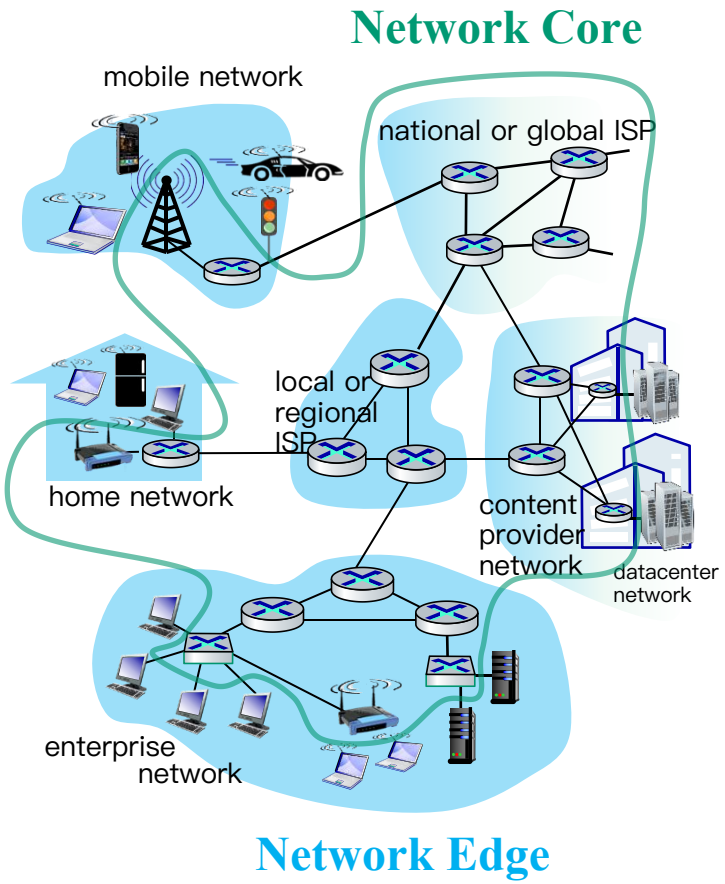
Internet: “network of networks”

- Interconnected ISPs

End systems, packet switches, and other pieces of the Internet run protocols (协议) that control the sending and receiving of information within the Internet.

- e.g., HTTP (Web), streaming video, Skype, TCP, IP, WiFi, 4G, Ethernet
- **Internet standards**
  - RFC: Request for Comments
  - IETF: Internet Engineering Task Force

Analogy: Network vs Online Purchase



End systems at network edge:

- Server - seller
- "things" (e.g., laptop) - buyers

Network core:

- Package delivery system

Internet service providers:

- Package delivery companies

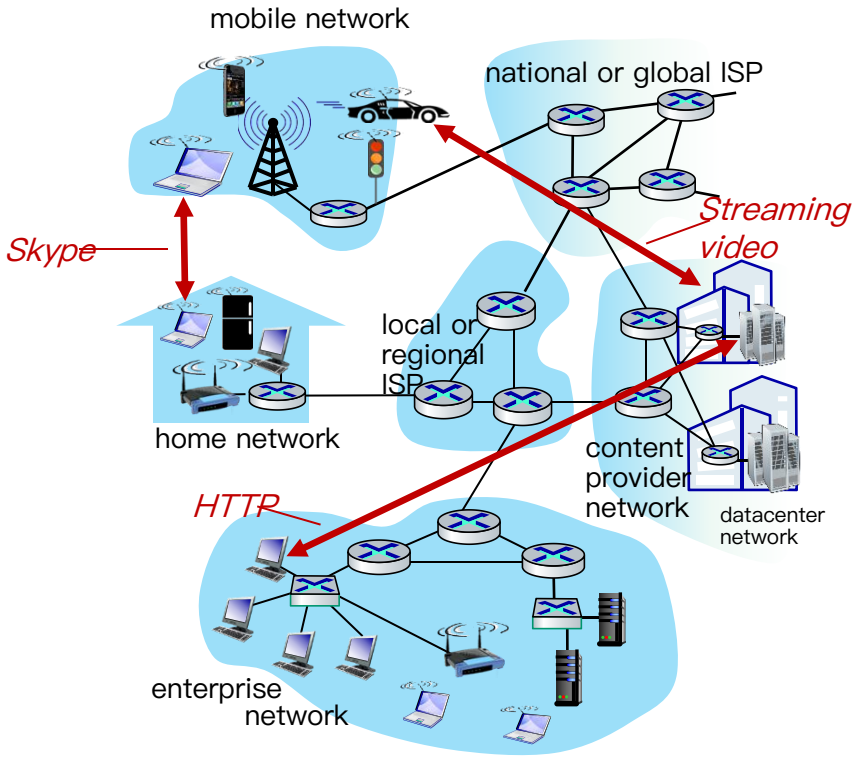
Protocols:

- Rules for delivering package

Network Edge: runs network applications

Network Core: interconnects end systems

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, …
- Internet applications run on end systems—they do not run in the packet switches in the network core

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 and packet delivery service

What's a protocol?

Human protocols:

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

… specific messages sent

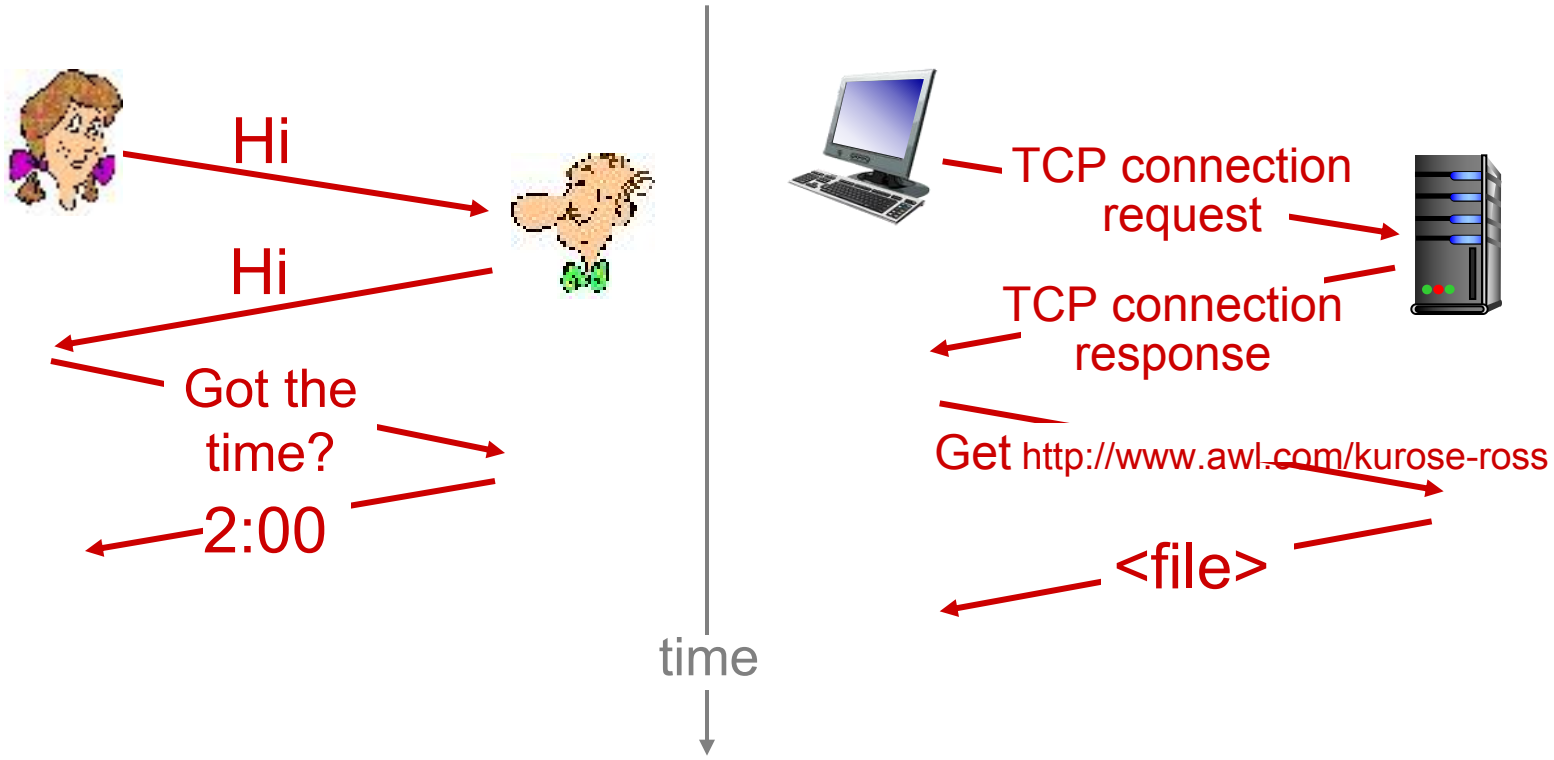
… specific actions taken when messages received, or other events

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:



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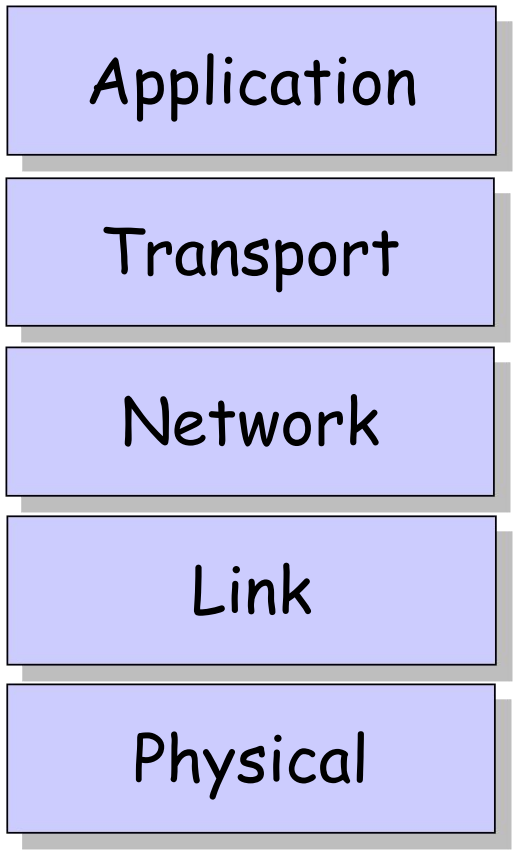
network protocols:

- 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 and/or receipt

Internet protocol stack

- Application: supporting network applications
  - IMAP, SMTP, HTTP
- Transport: process-process data transfer
  - TCP, UDP
- Network: routing of datagrams from source to destination
  - IP, routing protocols
- Link: data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- Physical: bits "on the wire"



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

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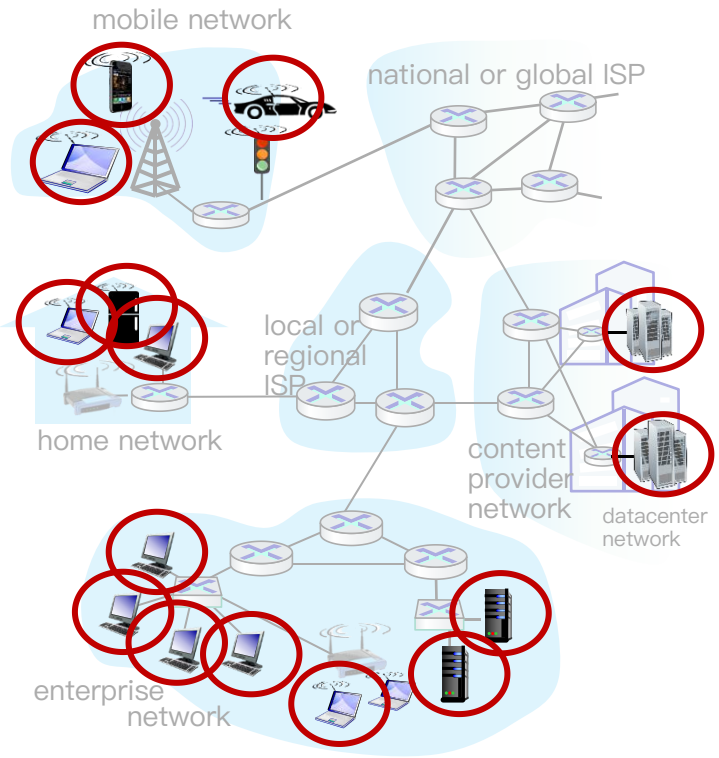
A closer look at Internet structure

Network edge:

- End systems and hosts
- Client (客户端): desktop, laptop, …
- Servers often in data centers



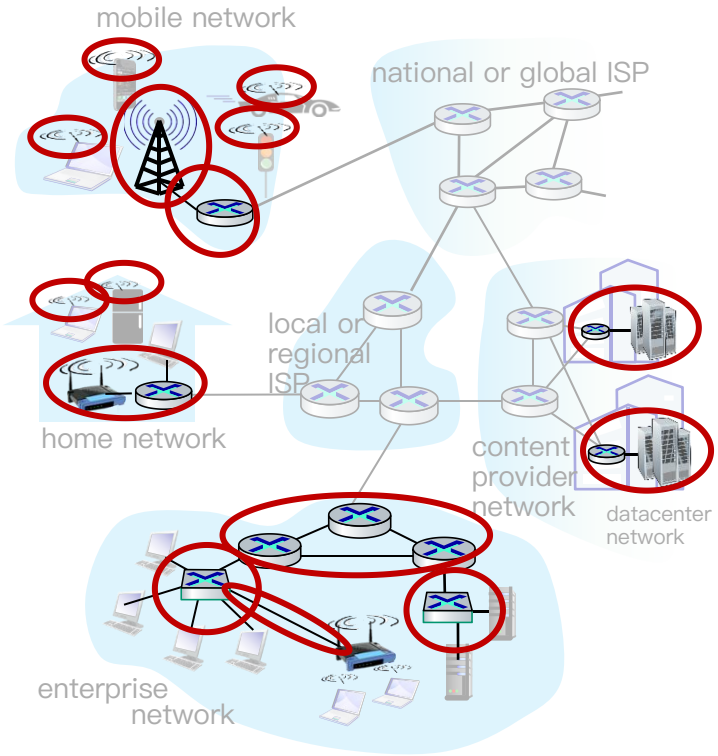
A closer look at Internet structure

Network edge:

- End systems and hosts
- Client (客户端): desktop, laptop, …
- Servers often in data centers

Access networks, physical media:

- wired, wireless communication links



A closer look at Internet structure

Network edge:

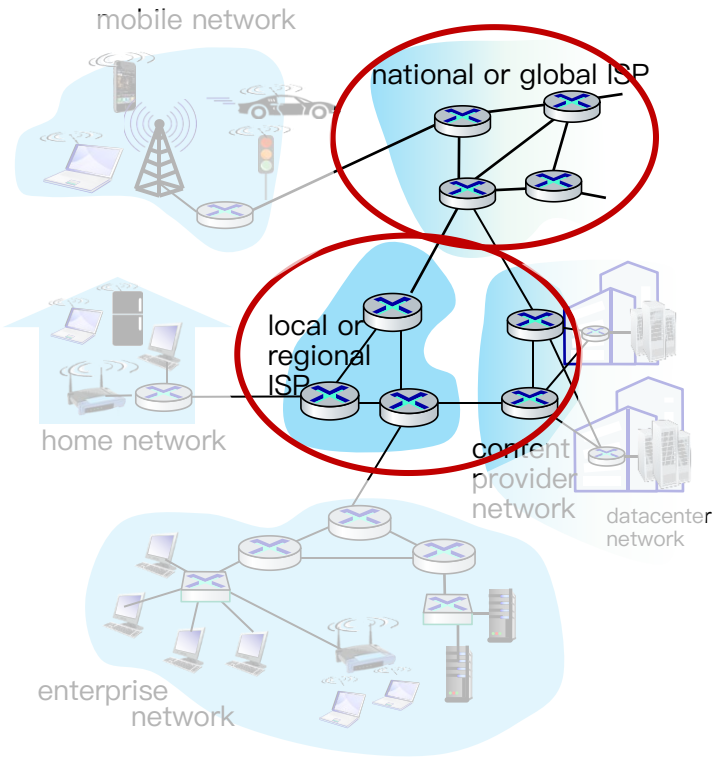
- End systems and hosts
- Client (客户端): desktop, laptop, …
- Servers often in data centers

Access networks (接入网):

- Wired, wireless communication links

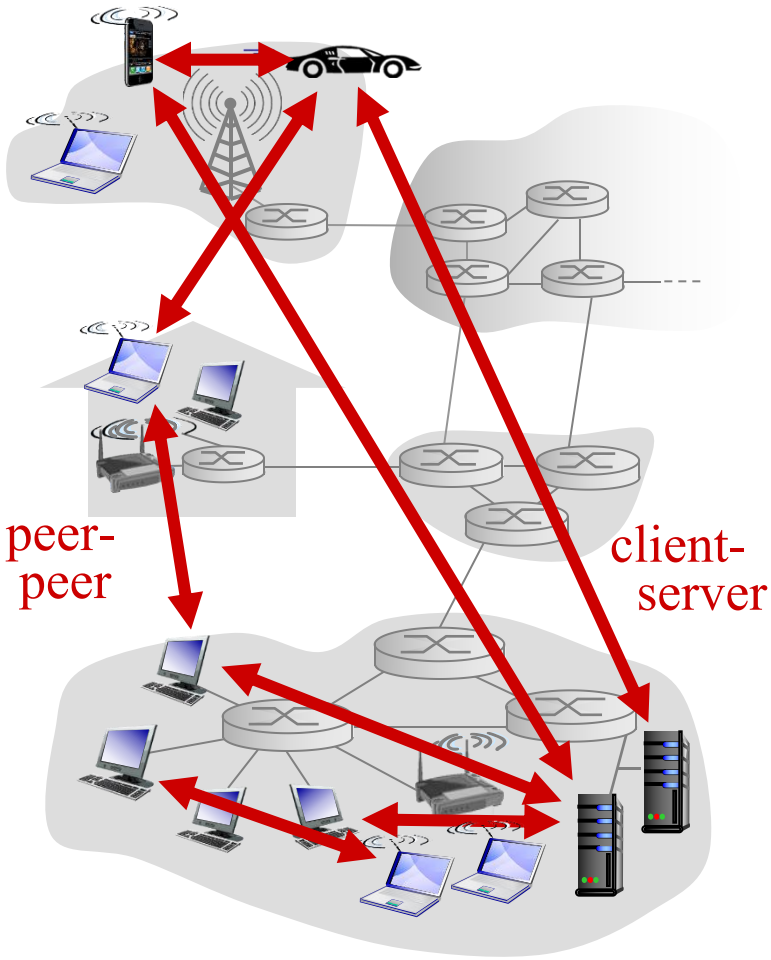
Network core:

- Interconnected routers
- Network of networks



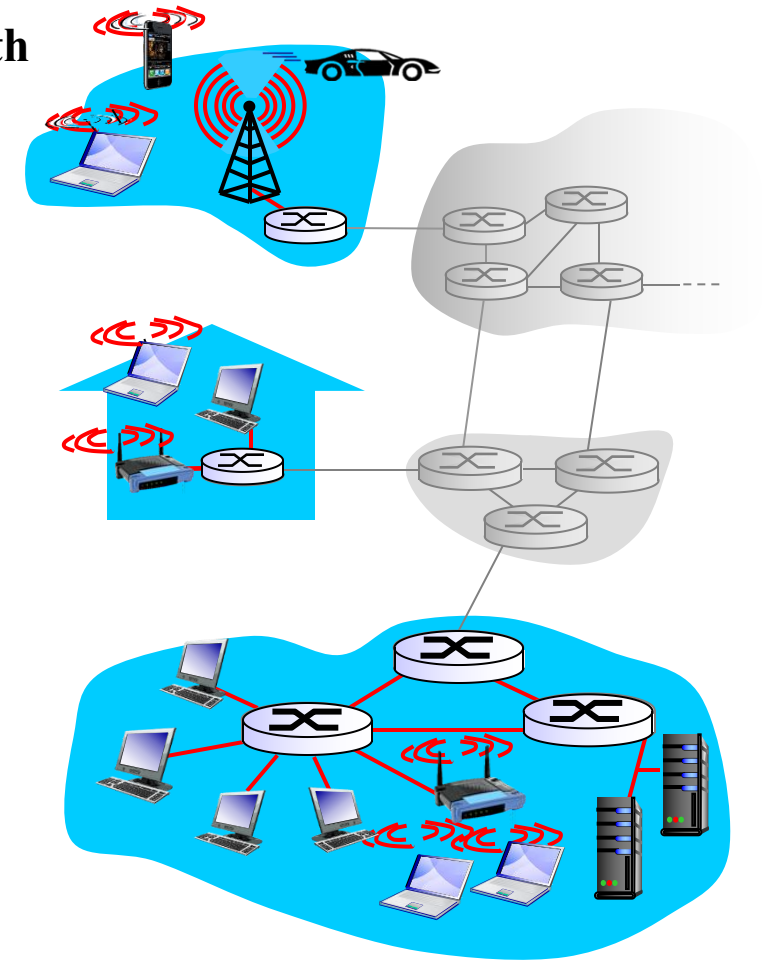
Network edge

- end systems (hosts):
  - run application programs
  - e.g. Web, email
  - at "edge of network"
- client/server model
  - client host requests, receives service from always-on server
  - e.g., Web browser/server; email client/server
- peer-peer model:
  - minimal (or no) use of dedicated servers
  - e.g. Skype, BitTorrent



Access networks

The network that physically connects an end system to the first router (edge router) on a path from the end system to any other distant end system.



Difference access networks:

- residential access nets
- institutional access networks (school, company)
- wireless access networks
- ...

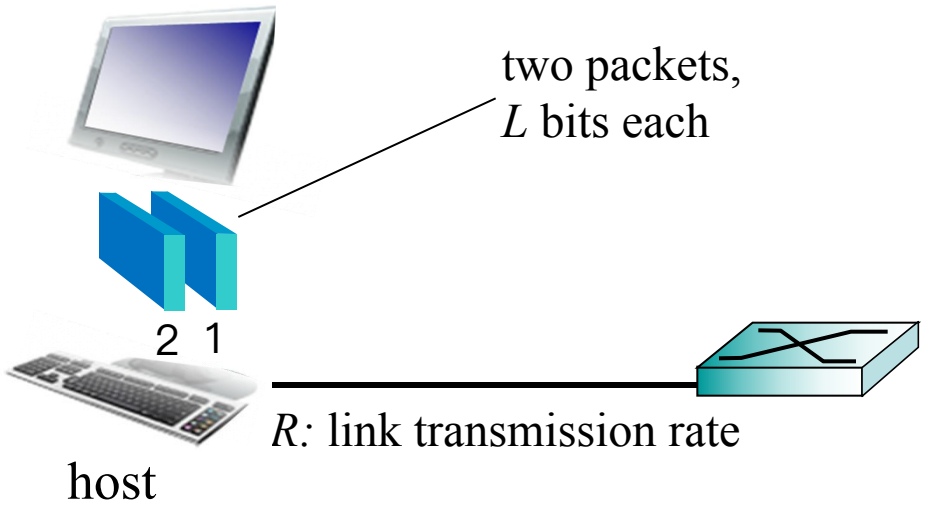
Different features:

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

Host: sends packets of data

Host sending function:

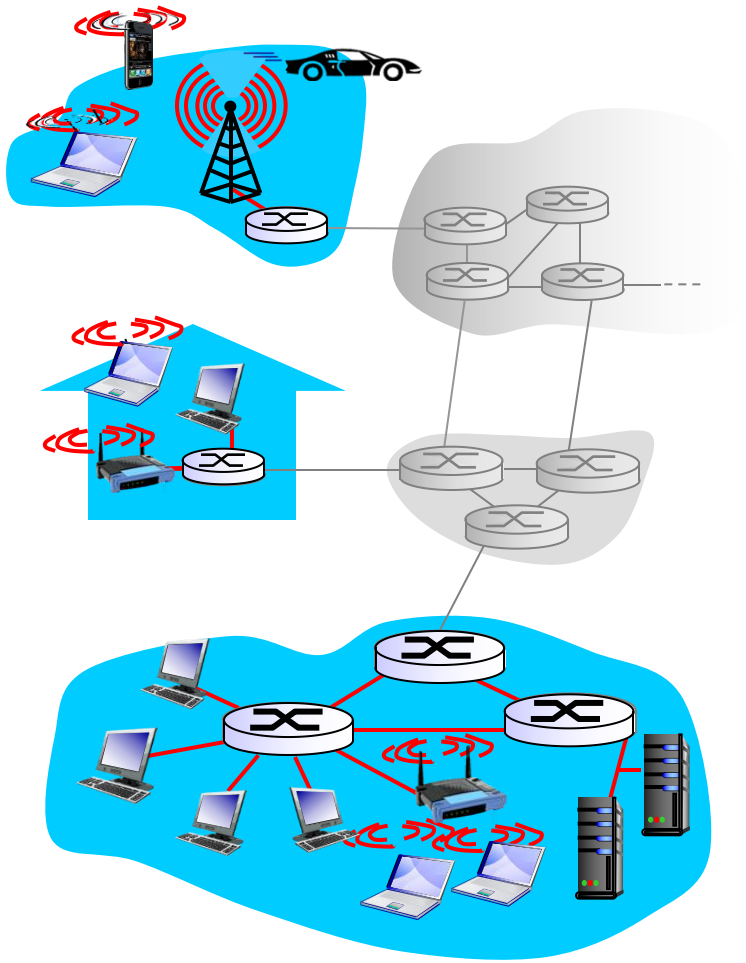
- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - aka link *capacity, bandwidth*



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

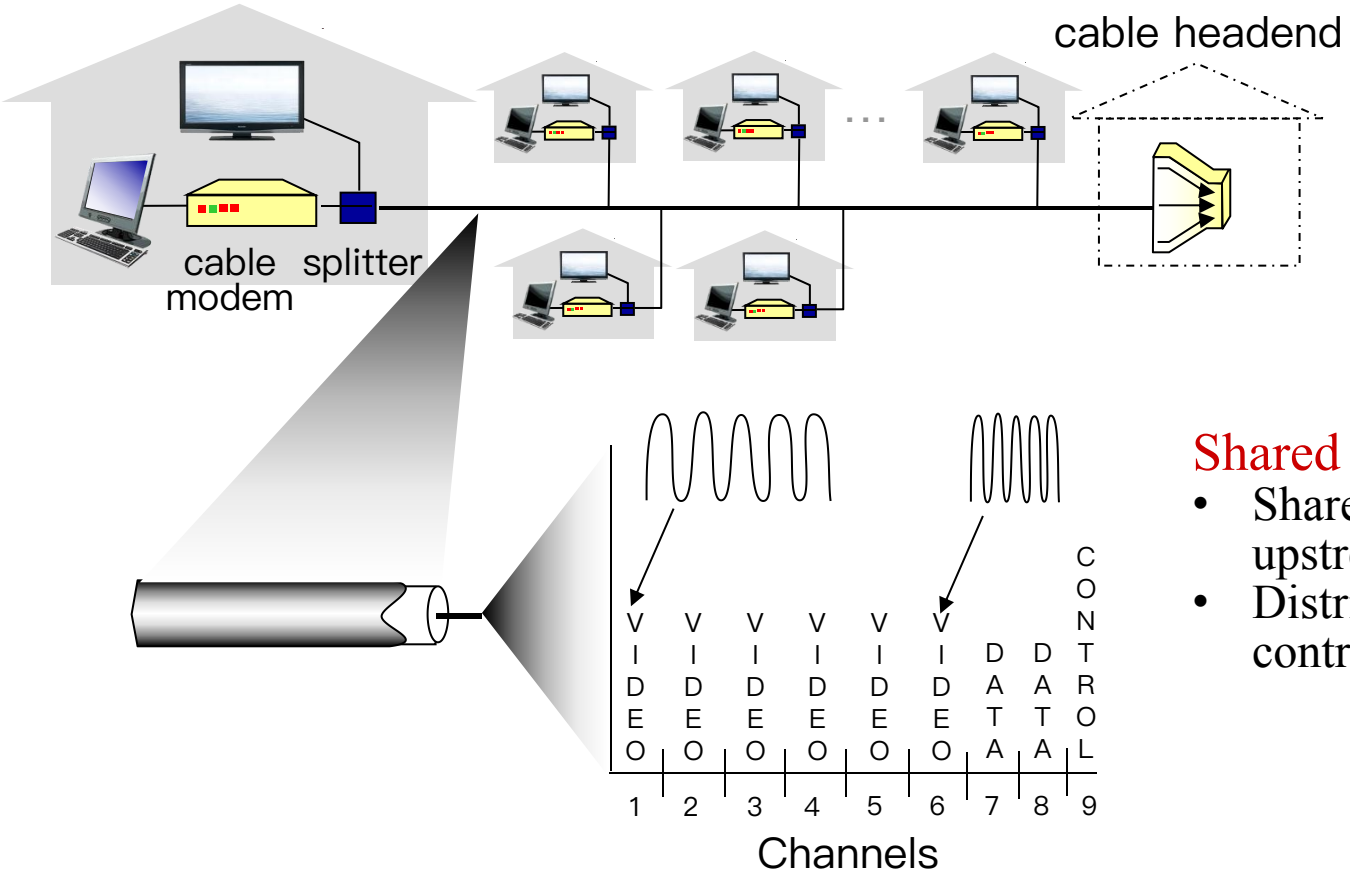
Access networks

Cable network
Digital subscriber line (DSL)
Home network
Wireless access network
Enterprise access network
…



Access net: cable network

Cable Internet access makes use of the cable television company's existing cable television infrastructure.

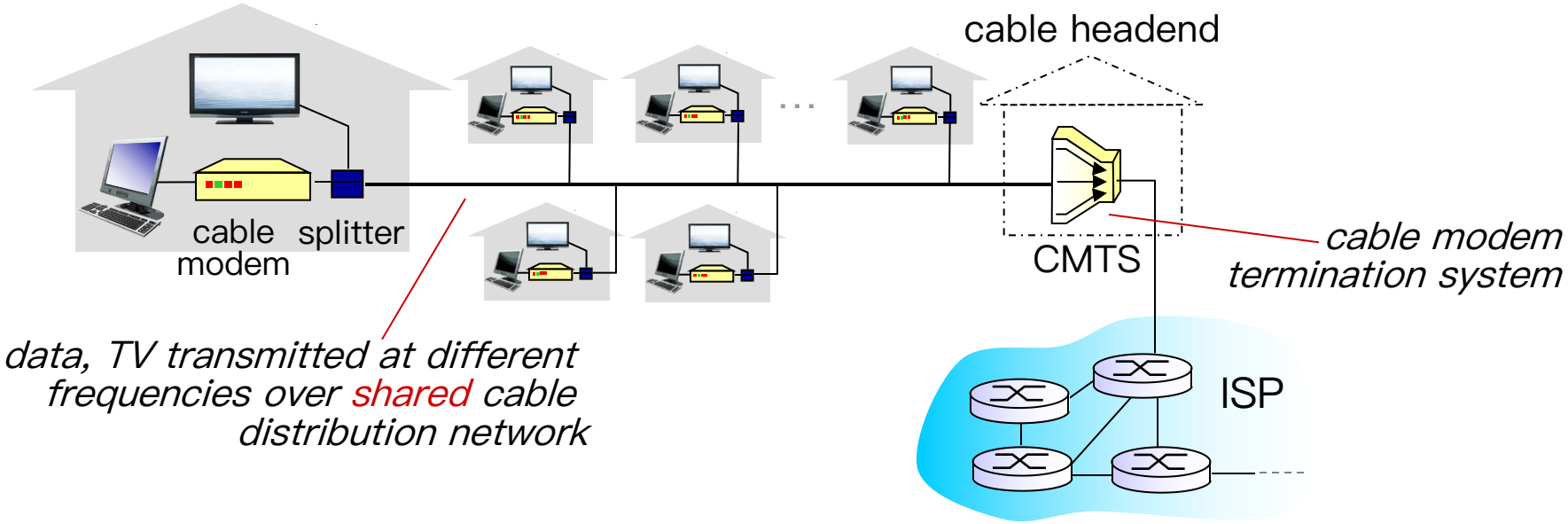


Shared broadcast medium

- Shared downstream and upstream
- Distributed multiple access control: avoid collision

Frequency division multiplexing: different channels transmitted in different frequency bands

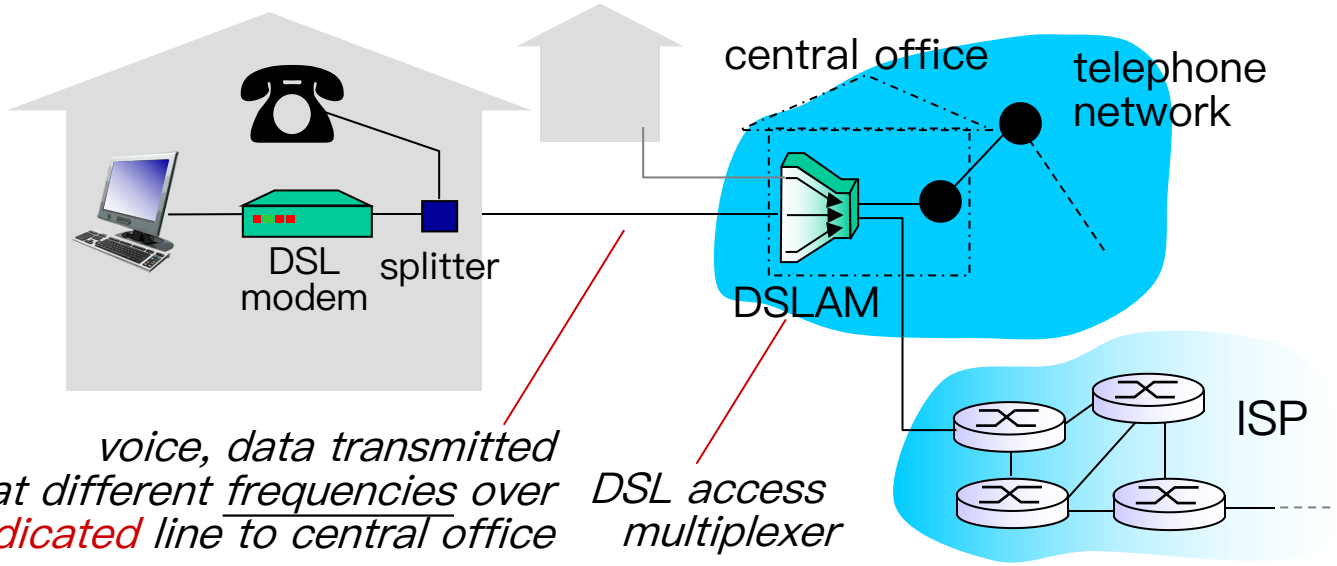
Access net: cable network



- Hybrid fiber coax (HFC): fiber + coaxial cable
  - 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

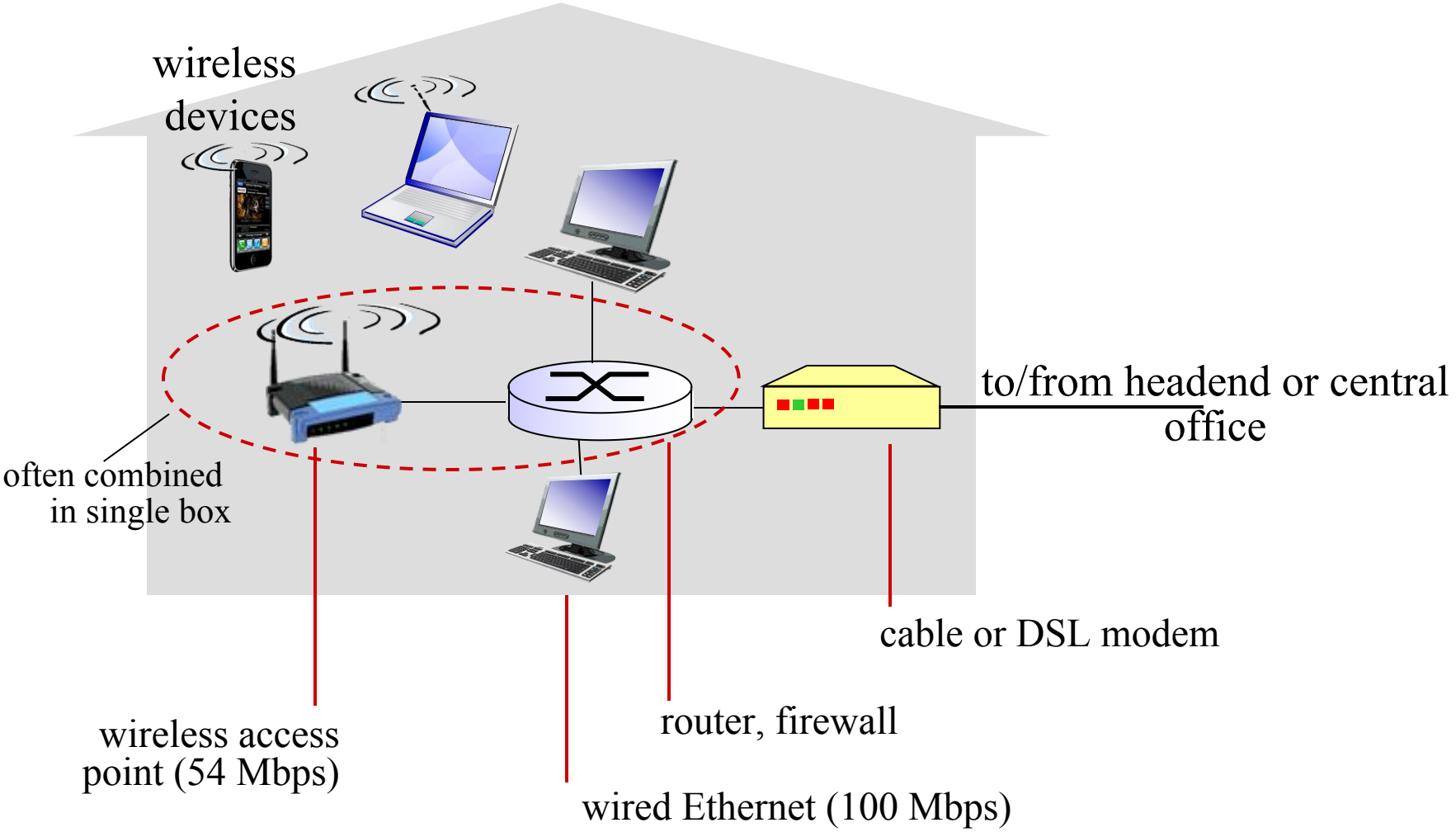
Access net: digital subscriber line (DSL)

Digital subscriber line (DSL) makes use of the its wired local phone access of local telephone company (telco).



- 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

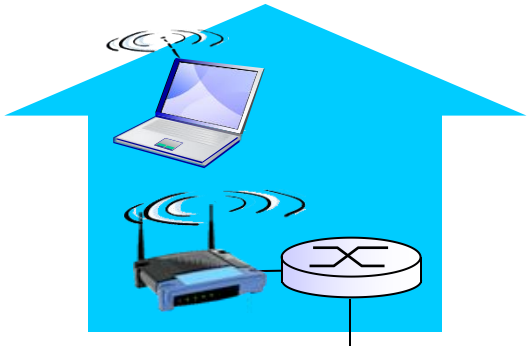
- Shared **wireless** access network connects end systems to router
  - via base station aka "access point"

Wireless LANs:

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

Wide-area wireless access

- provide by telco (cellular) operator
- 10 Mbps, 100Mbps, 10Gbps
- 3G, 4G, 5G

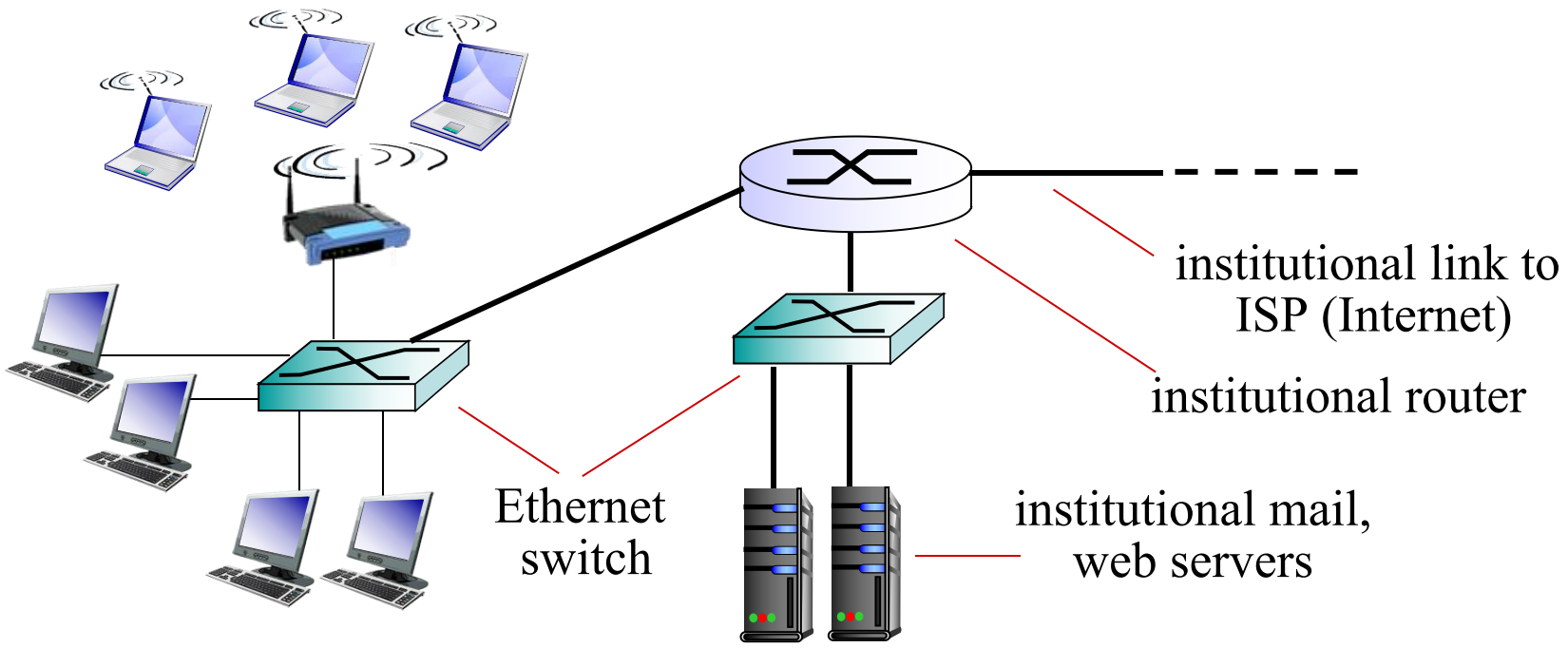


to Internet

to Internet

Enterprise access networks

On university campuses, companies, and home settings, a local area network (LAN) is used to connect an end system to the edge router.



- Companies, universities, etc.
- Mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
  - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps

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

- Usually used for LAN
- Category 5: 100 Mbps, 1 Gpbs Ethernet
- Category 6: 10Gbps

Physical media: coax, fiber

Coaxial cable:

- two concentric copper conductors
- Common in cable television systems; shared medium
- broadband:
  - multiple channels on cable
  - cable Internet access

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

Radio

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

- 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

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

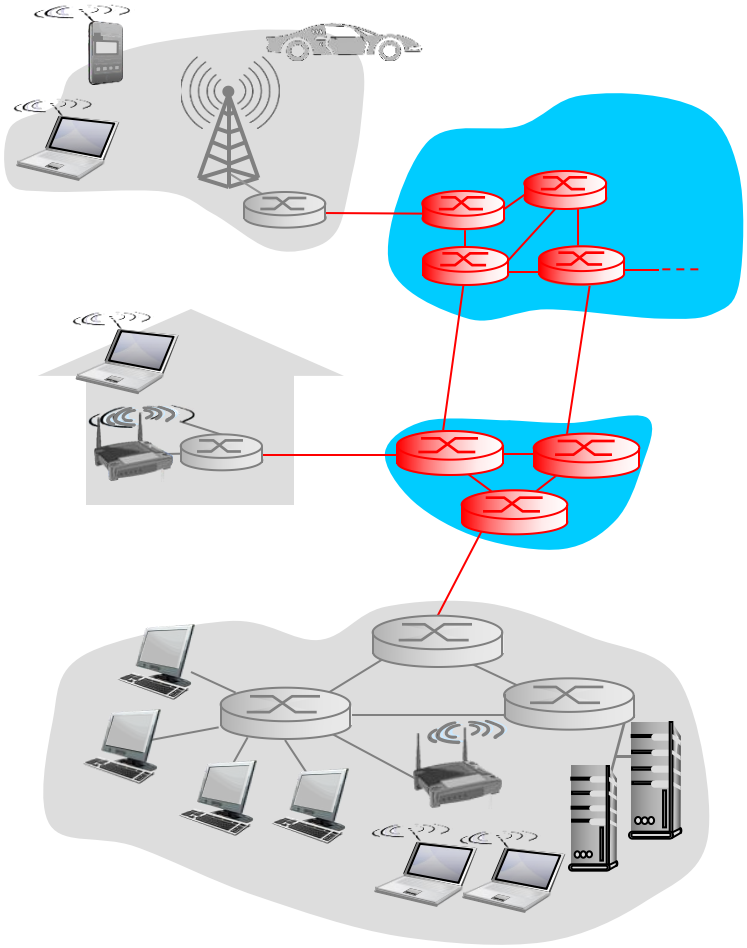
1.5 protocol layers, service models

1.6 networks under attack: security

1.7 history

The network core

The mesh of **packet switches and links** that interconnects the Internet's end systems.



Packet switching:

- Internet
- not reserved (on demand); may wait

Circuit switching:

- telephone
- reserved

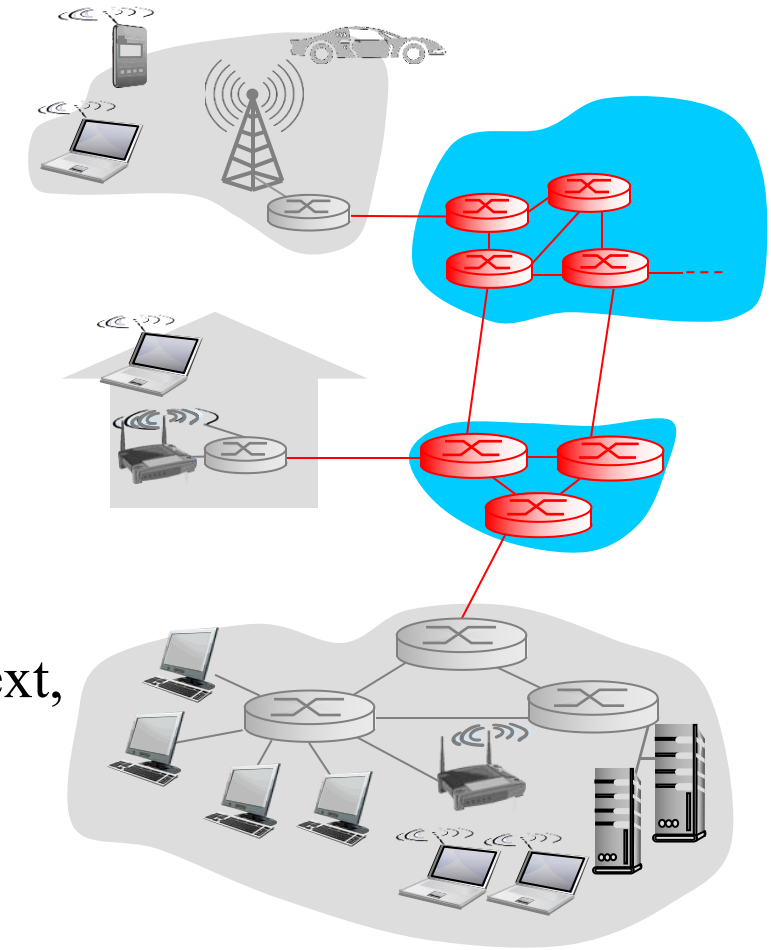
The network core

Packet switching:

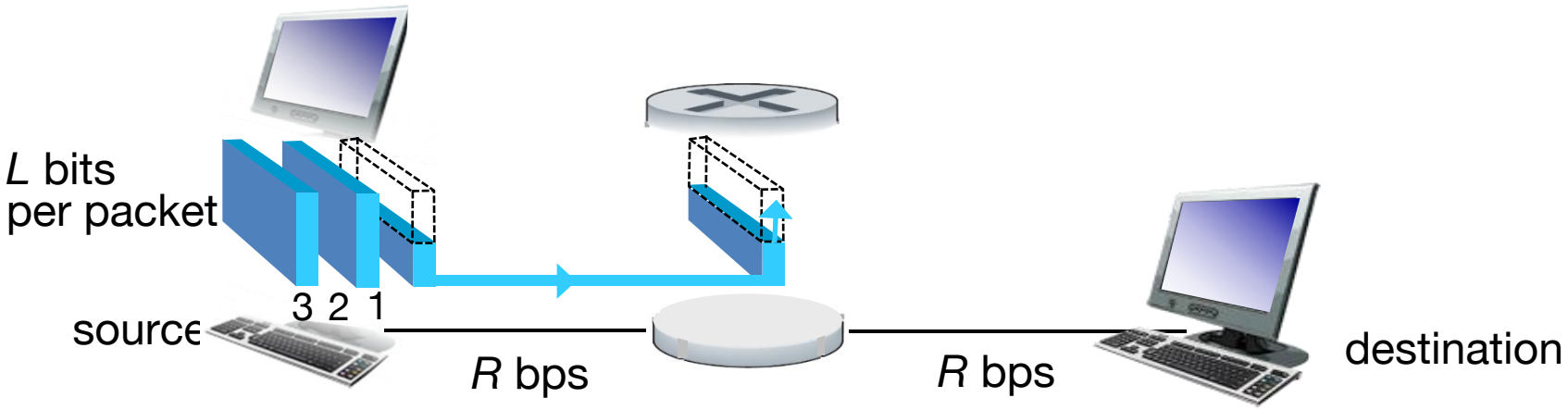
Hosts break long messages into packets; each packet is forwarded independently

- store-and-forward
- each packet is transmitted at full link capacity
- not reserved → queueing delay and packet loss

Forward packets from one router to the next, across links on path from source to destination → routing and forwarding



Packet-switching: store-and-forward



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

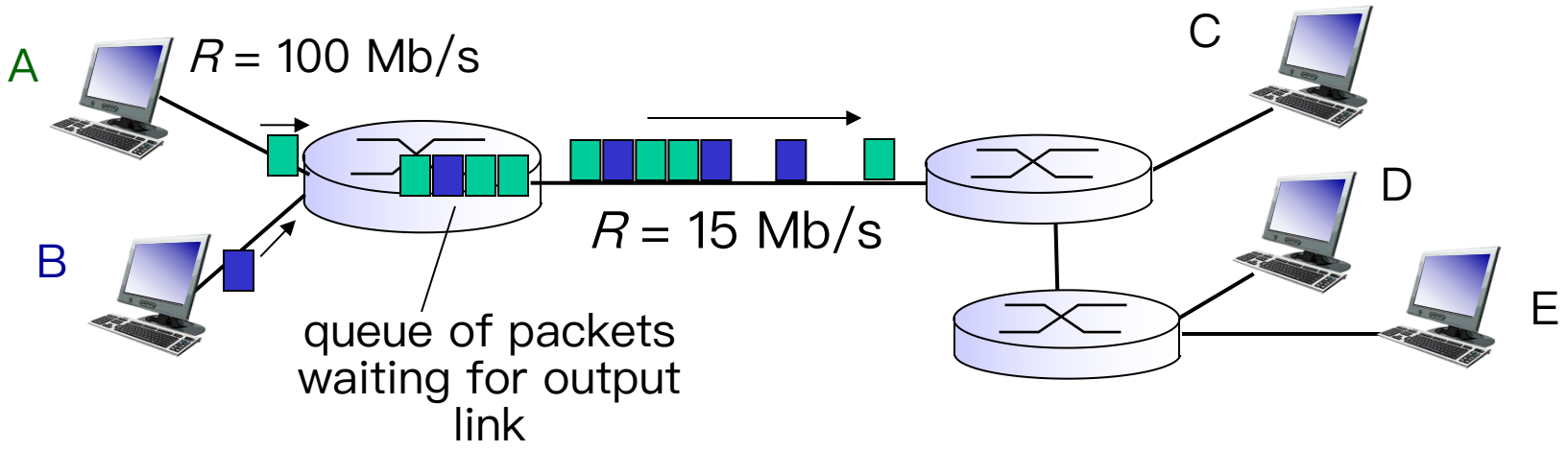
Example:

- L = 7.5 Mbits; R = 1.5 Mbps
- One-hop transmission delay = L/R = 5 sec
- End-end delay = $2L/R$ (assuming zero propagation delay)

more on delay shortly …

How about one packet of length L sending over a path of N links, each of rate R?

Packet switching: delay and packet loss



Output buffer stores packets that the router is about to send into that link.

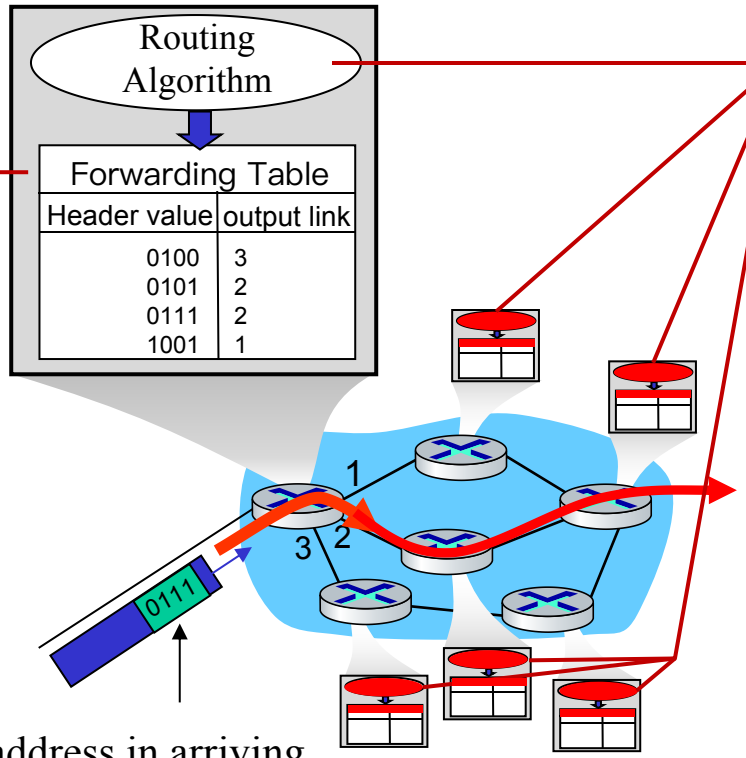
If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:

- packets will queue, wait to be transmitted on link → queuing delay
- packets can be dropped (lost) if memory (buffer) fills up → packet loss

Packet switching: forwarding and routing

Forwarding:

local action: move arriving packets from router's input link to appropriate router output link



destination address in arriving packet's header

Routing:

- global action: determine source-destination paths taken by packets
- routing algorithms

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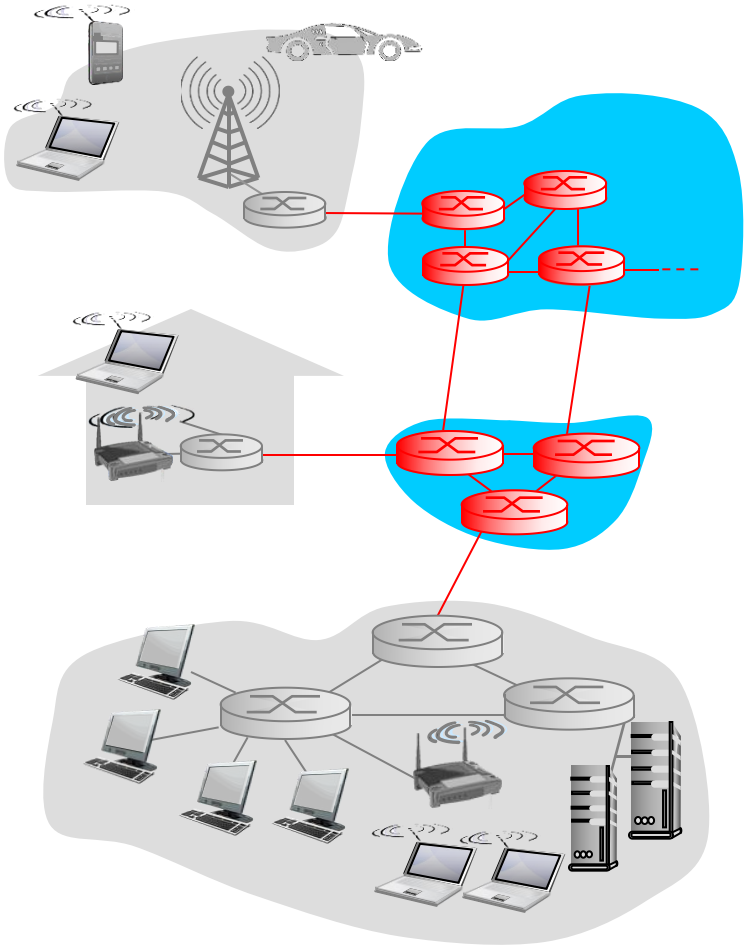


Packet switching:

- Internet
- not reserved

Circuit switching:

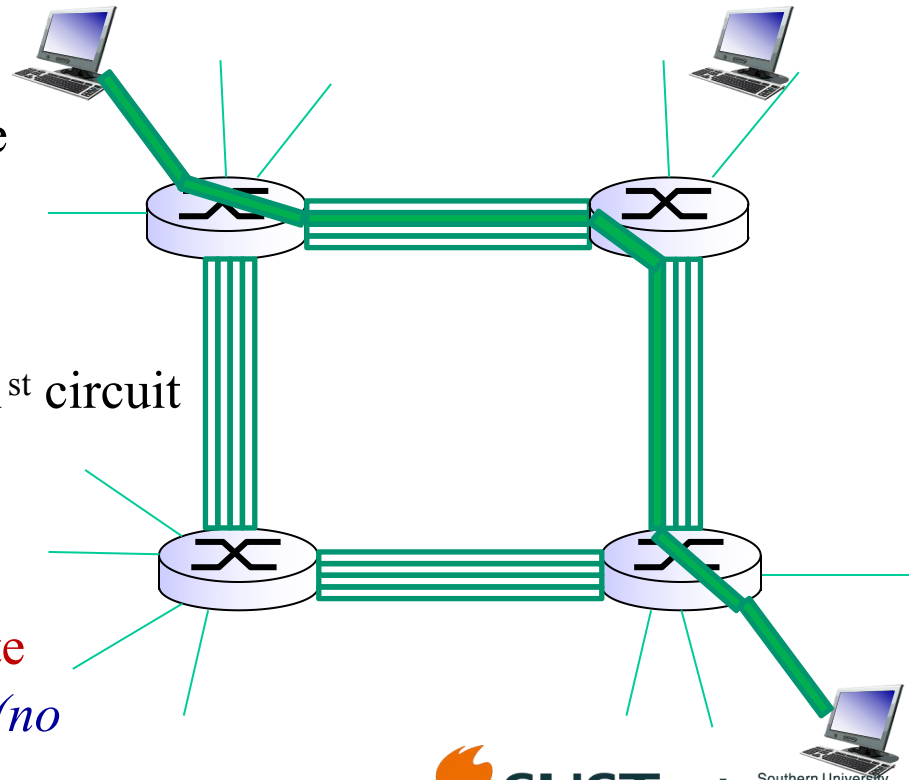
- telephone
- reserved

Alternative core: circuit switching

Packet switching: on demand; may wait

Circuit switching: end-end resources reserved for "call" between source and destination; guaranteed rate

- (buffer, link, transmission rate)
- commonly used in traditional telephone networks



In diagram, each link has four circuits.

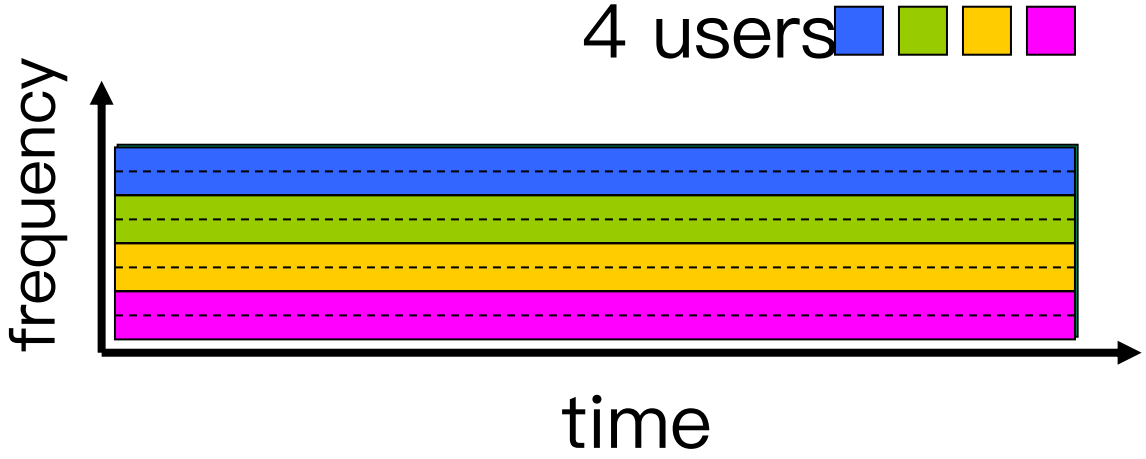
- call gets 2nd circuit in top link and 1st circuit in right link.

- dedicated resources: no sharing
  - a fraction of each link's capacity
  - circuit-like; guaranteed constant rate
- circuit segment idle if not used by call *(no sharing)*

Circuit switching: FDM versus TDM

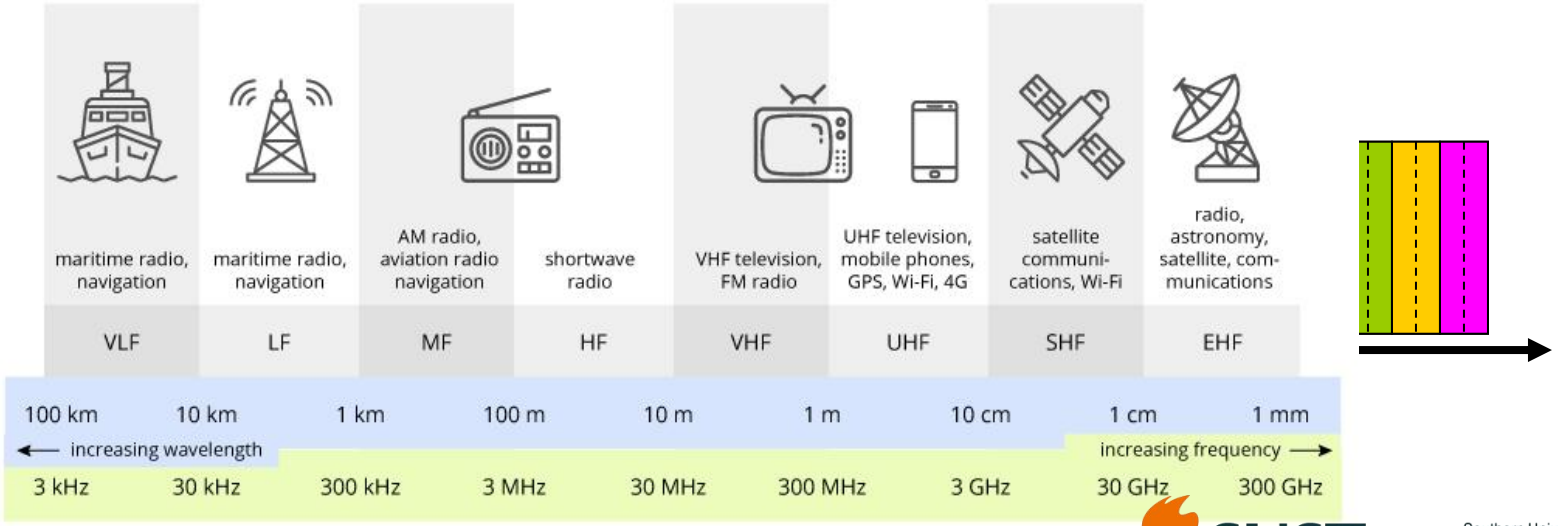
Frequency Division Multiplexing (FDM)

- Optical, electromagnetic frequencies divided into (narrow) frequency bands → bandwidth
- At max rate of that narrow band



Time Div Multiplex

- Time d
- At max (wider) band, b its time



Next Lecture

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