



UNIVERSITY OF  
**WATERLOO**

# CS 456/656

# Computer Networks

## Lecture 1: Introduction – Part 1

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Fall 2023

# About me

- I do research on computer networks.
  - Specifically, software-defined and programmable networks, and network verification.
- I got my PhD from Princeton University in 2019
- Then, I did a post-doc at Cornell University until 2022
- I joined University of Waterloo as an assistant professor in July 2022
- A major part of my job is to continue doing research on computer networks
  - Feel free to reach out if you want to talk about research!

# About this course

- What is a computer network?
- How do modern computer networks work?
- The Internet is one of the most important collections of computer networks.
- So, we will use it as our guiding example throughout the course.

# Why learn about computer networks?

- Because they are everywhere!
  - Every time you connect to an online service, you are sending and receiving data through multiple computer networks.
  - Most large-scale online services are distributed applications that use computer networks to communicate and collectively processes millions of requests per second.
- Our world is already relying on computer networks for its day-to-day operation
- Our dependence on computer networks is only going to grow over time.

# Today's agenda

- A high-level overview of computer networks and the Internet
- Course logistics
- But before we start...

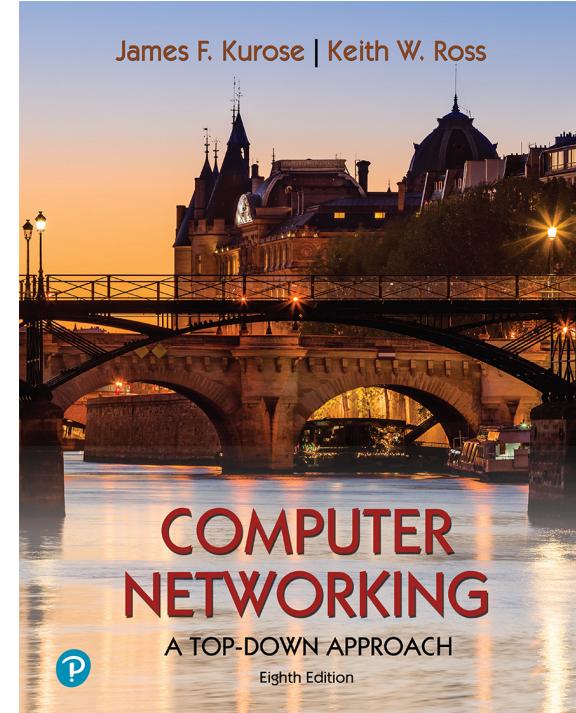
# Territorial Acknowledgement

*The University of Waterloo acknowledges that much of our work takes place on the traditional territory of the Neutral, Anishinaabeg and Haudenosaunee peoples. Our main campus is situated on the Haldimand Tract, the land granted to the Six Nations that includes six miles on each side of the Grand River. Our active work toward reconciliation takes place across our campuses through research, learning, teaching, and community building, and is centralized within the Office of Indigenous Relations.*

# A note on the slides

Adapted from the slides that accompany this book.

All material copyright 1996-2023  
J.F Kurose and K.W. Ross, All Rights Reserved



*Computer Networking: A  
Top-Down Approach*  
8<sup>th</sup> edition  
Jim Kurose, Keith Ross  
Pearson, 2020

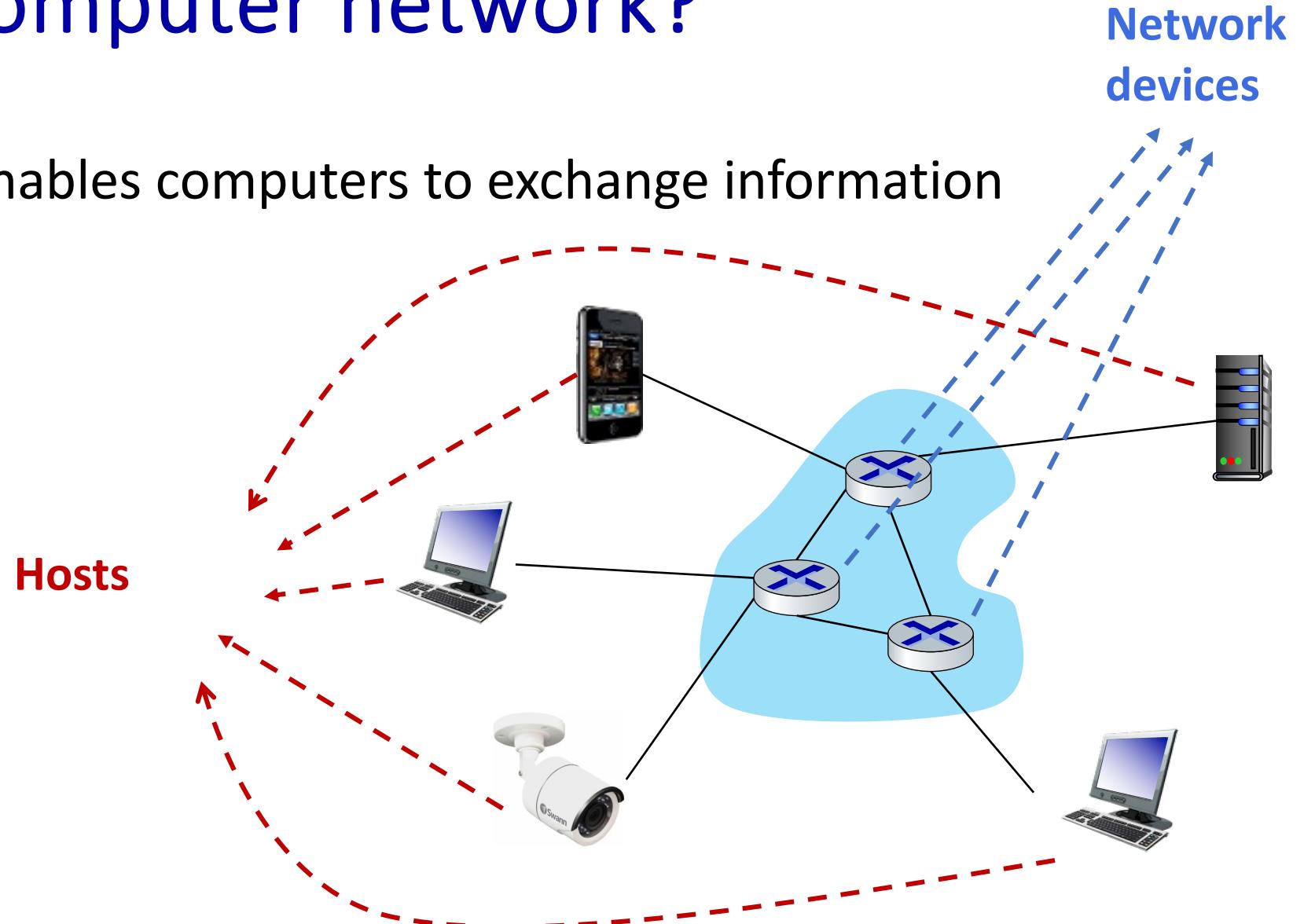
# Introduction

What is a computer network?

What is the Internet?

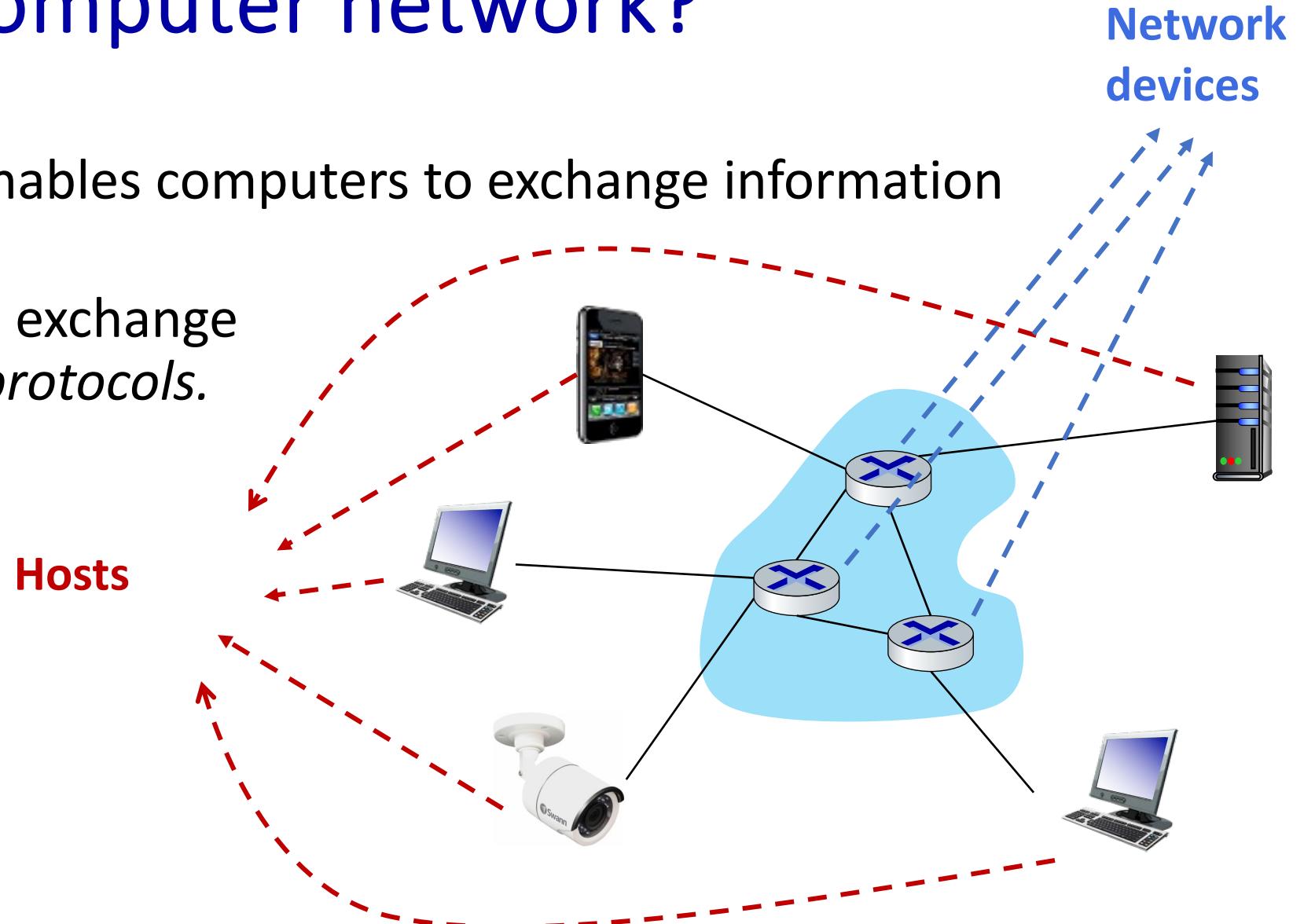
# What is a computer network?

- A system that enables computers to exchange information



# What is a computer network?

- A system that enables computers to exchange information
- The information exchange is governed by *protocols*.

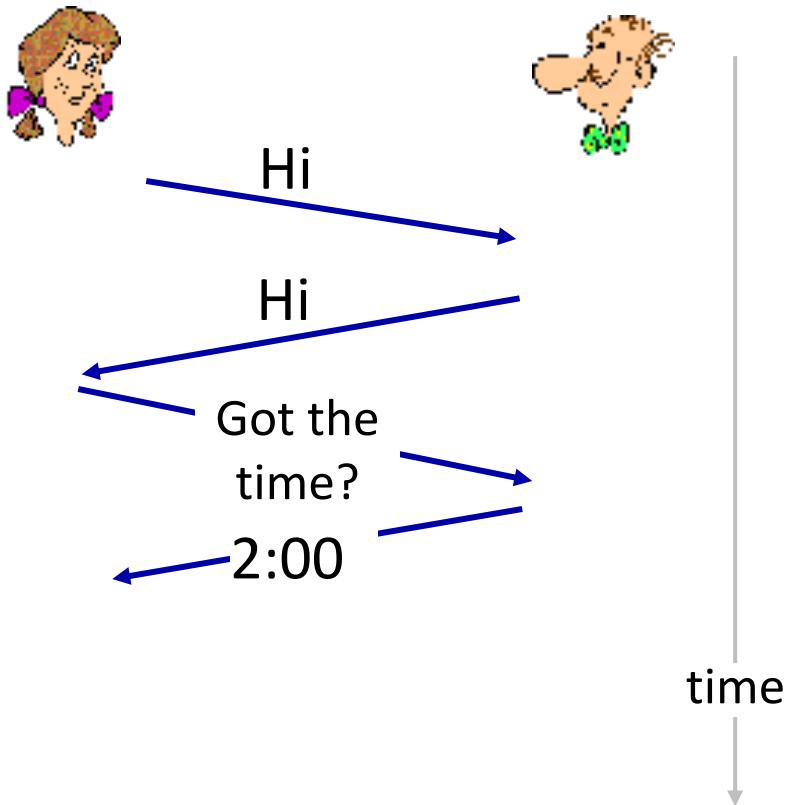


# What is a protocol?

*A protocol defines:*

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

# Humans have protocols too



Rules for:

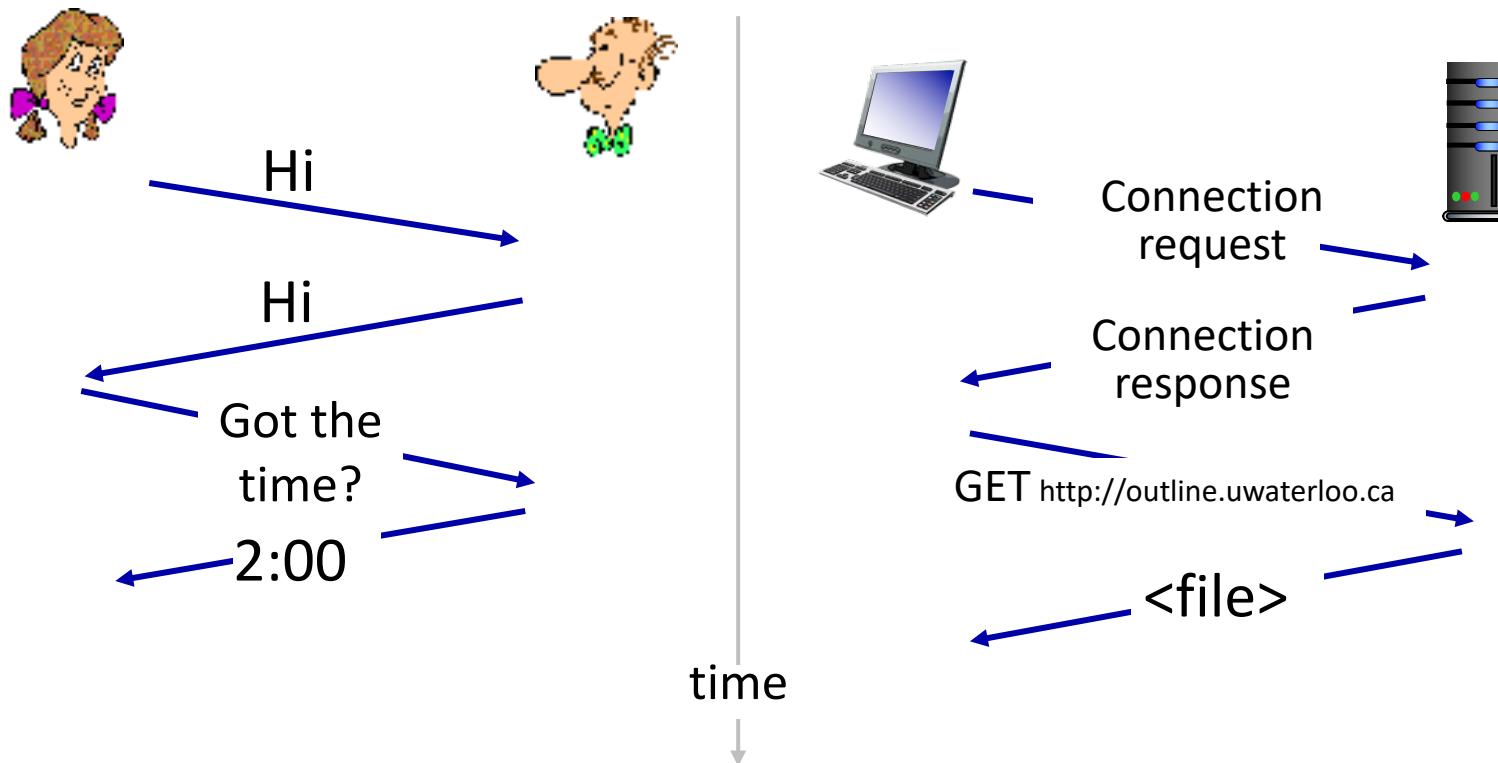
- ... specific messages sent
- ... specific actions taken  
when message received,  
or other events

# Network protocols

- Network protocols are between computers (devices) rather than humans

# Network Protocols

- Network protocols are between computers (devices) rather than humans



# Sounds simple, right?

- Turns out, when you want to connect everyone in the globe, things get complicated very fast.

# The Internet: a “nuts and bolts” view



Billions of connected computing *devices*



Thousands of network devices,  
i.e., *switches/routers*, that forward data

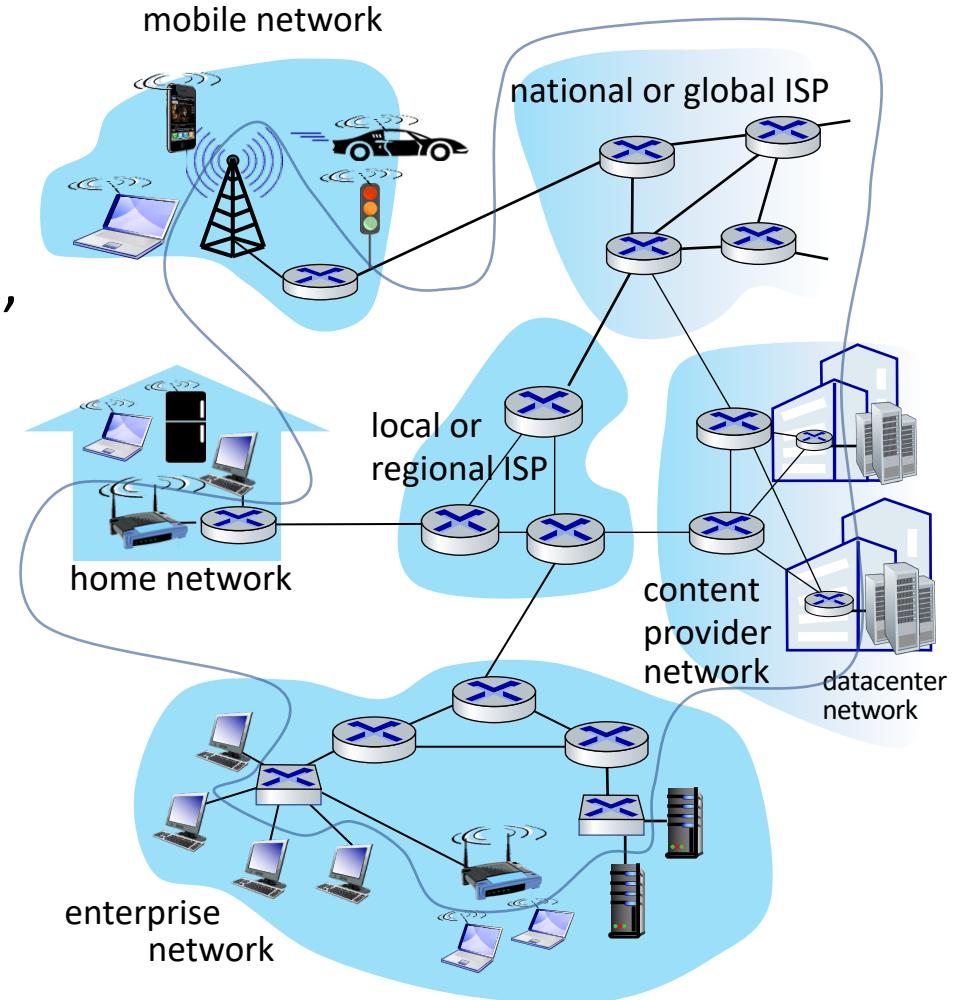


Connected with many different types of *communication links*

- fiber, copper, radio, satellite

Grouped into many *networks*

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



# Before diving in

- Don't worry if this feels overwhelming
- We will cover all these “nuts and bolts” in more depth *later* in the course.

# The Internet: a “nuts and bolts” view



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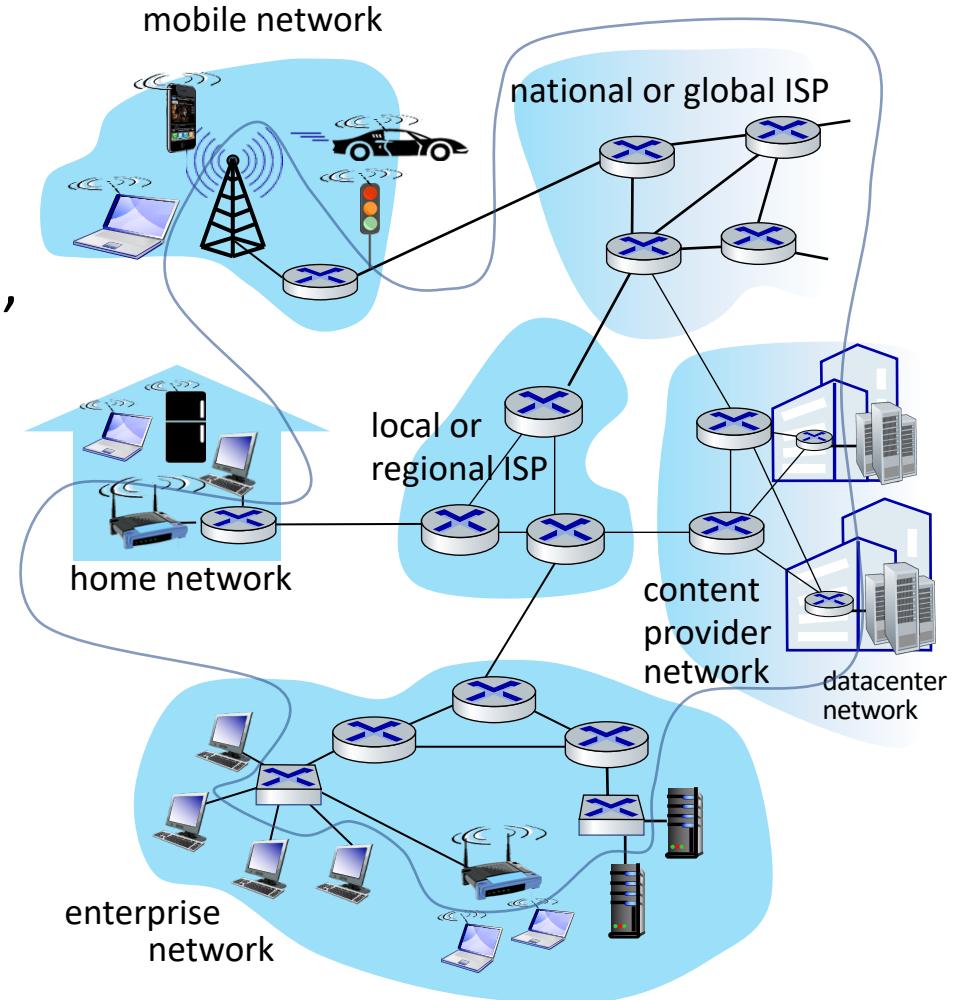


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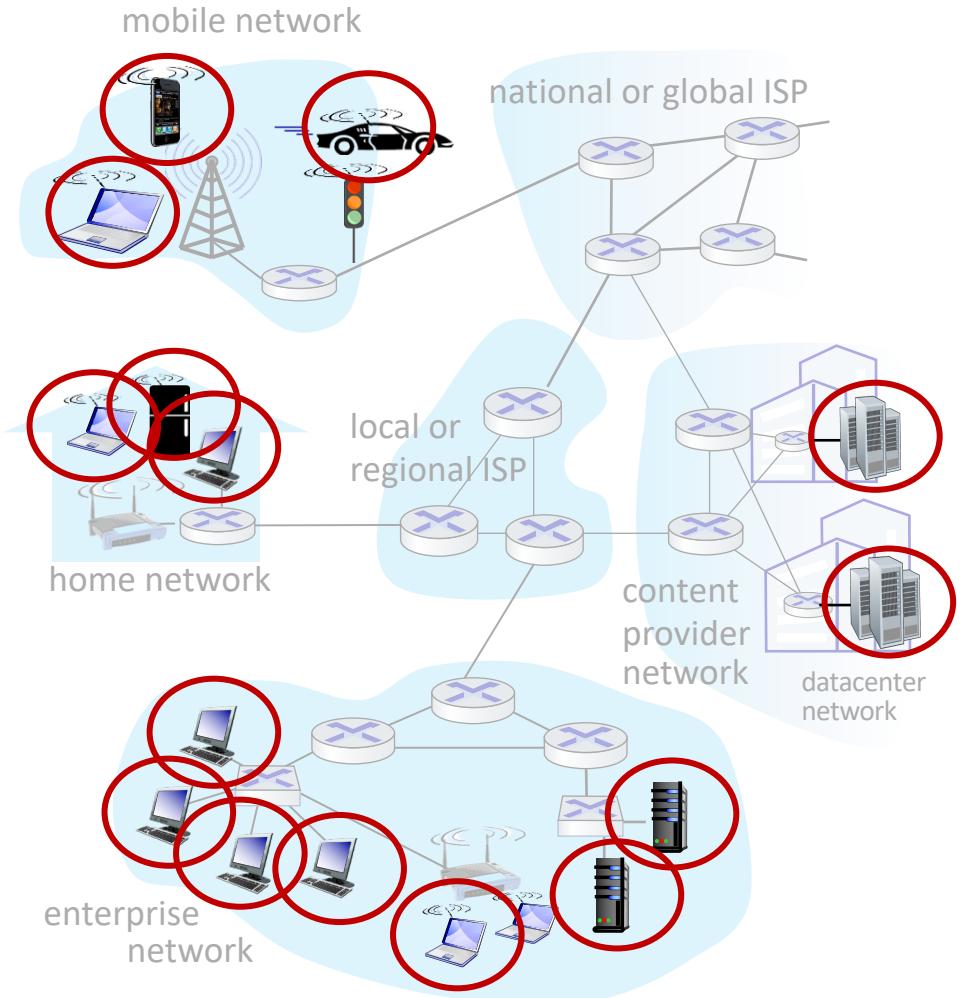
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# The network edge

- The end systems connected to the network.
  - Running applications that communicate with applications on other end systems.
- Commonly referred to as hosts, end hosts, or end points.



# “Fun” Internet-connected devices



Amazon Echo



Internet refrigerator



Security Camera



Internet phones



IP picture frame



Slingbox: remote control cable TV



Gaming devices



sensorized, bed mattress



AR devices



Fitbit



diapers



Pacemaker & Monitor



Tweet-a-watt:  
monitor energy use

bikes



cars



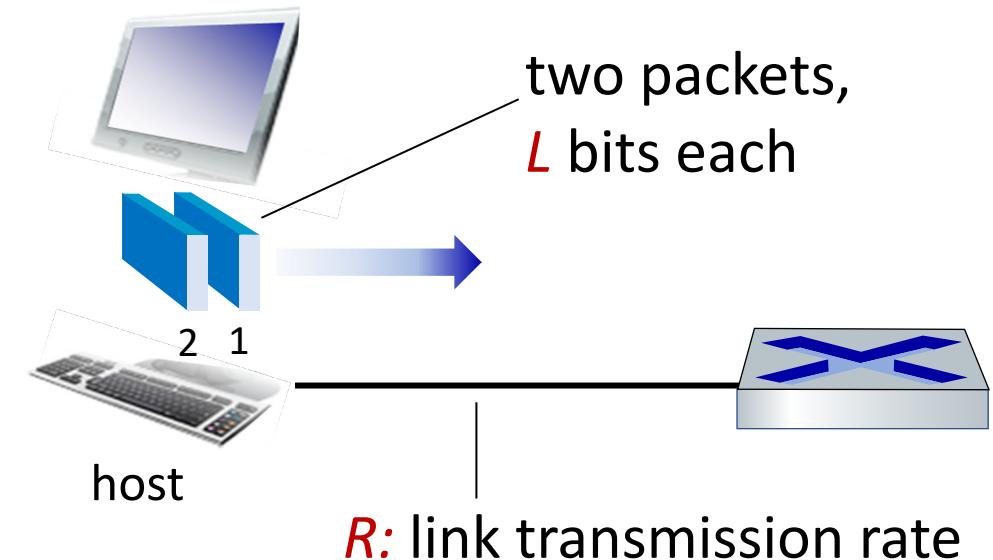
scooters

Others?

# Hosts send *packets* of data

host sending function:

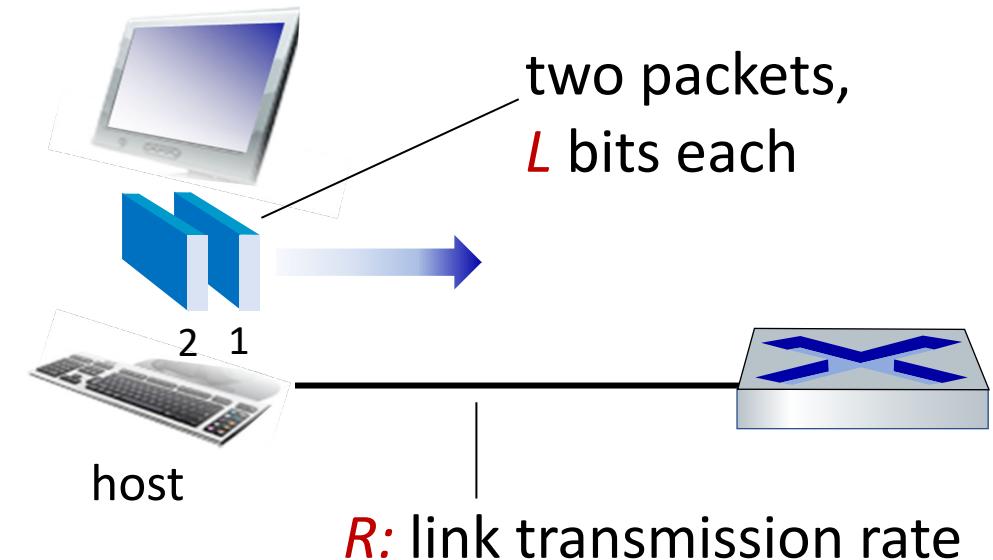
- takes application message
- breaks into smaller chunks, known as *packets*, of length  $L$  bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate is also known as link capacity or link bandwidth



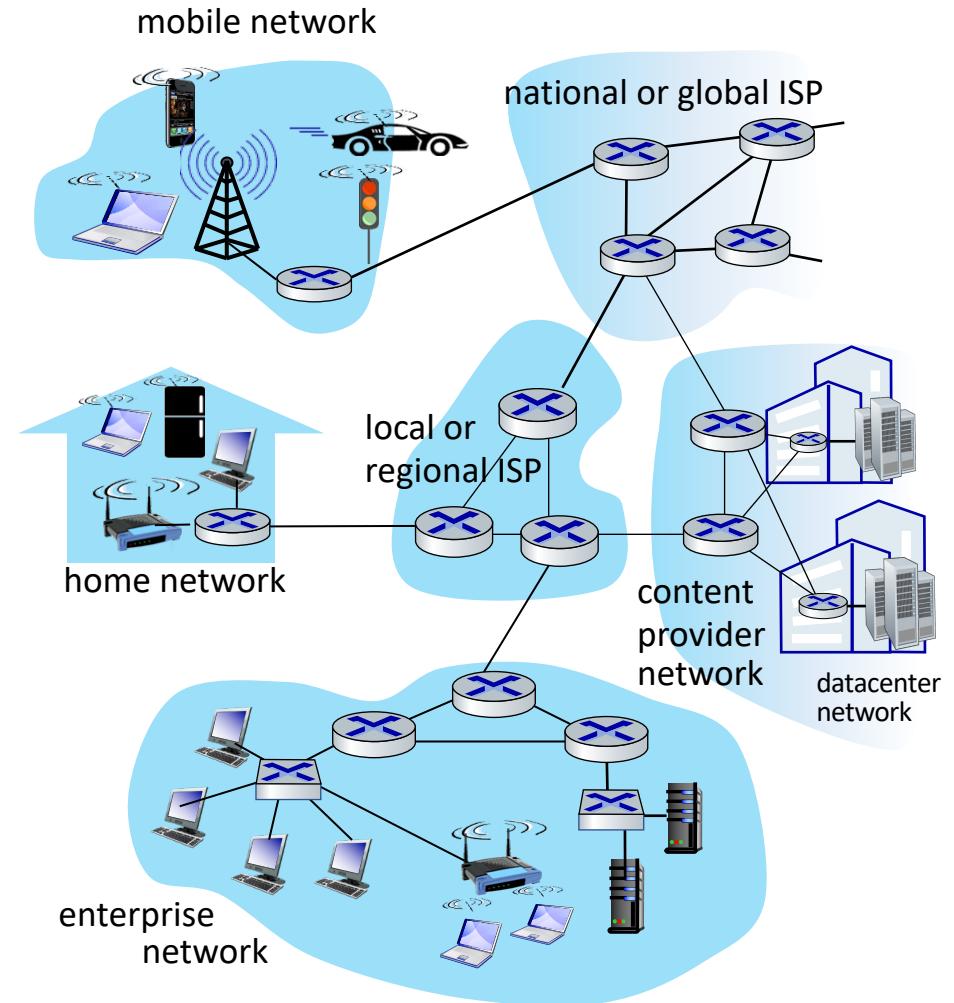
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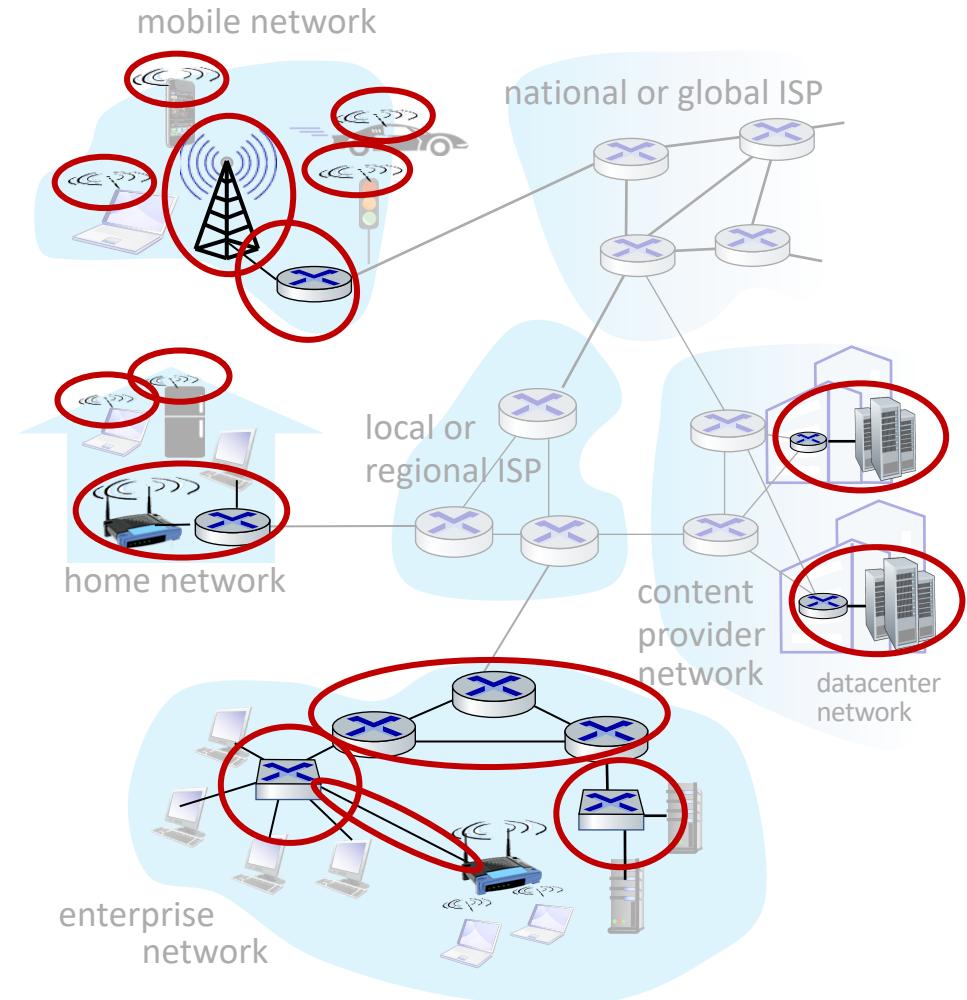


# Access networks



# Access networks

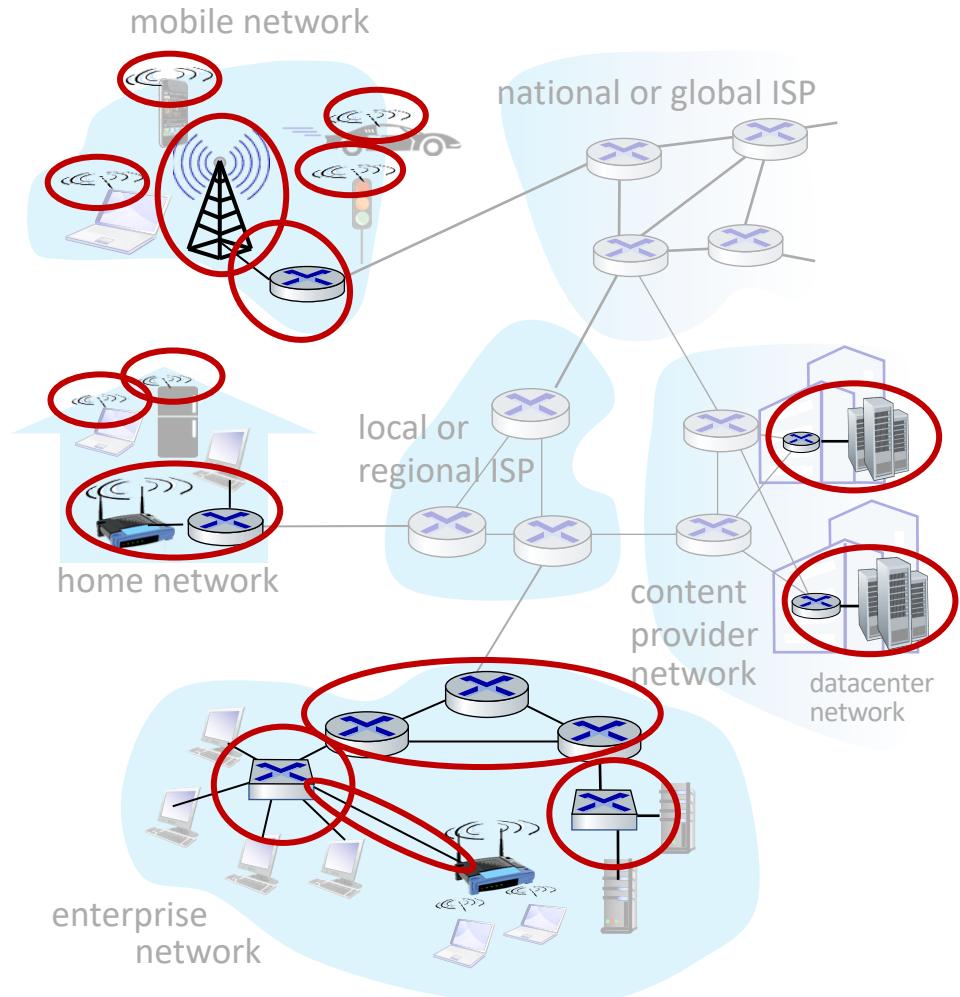
- Access networks connect end systems to the edge routers.
- edge router = entry point to the Internet.



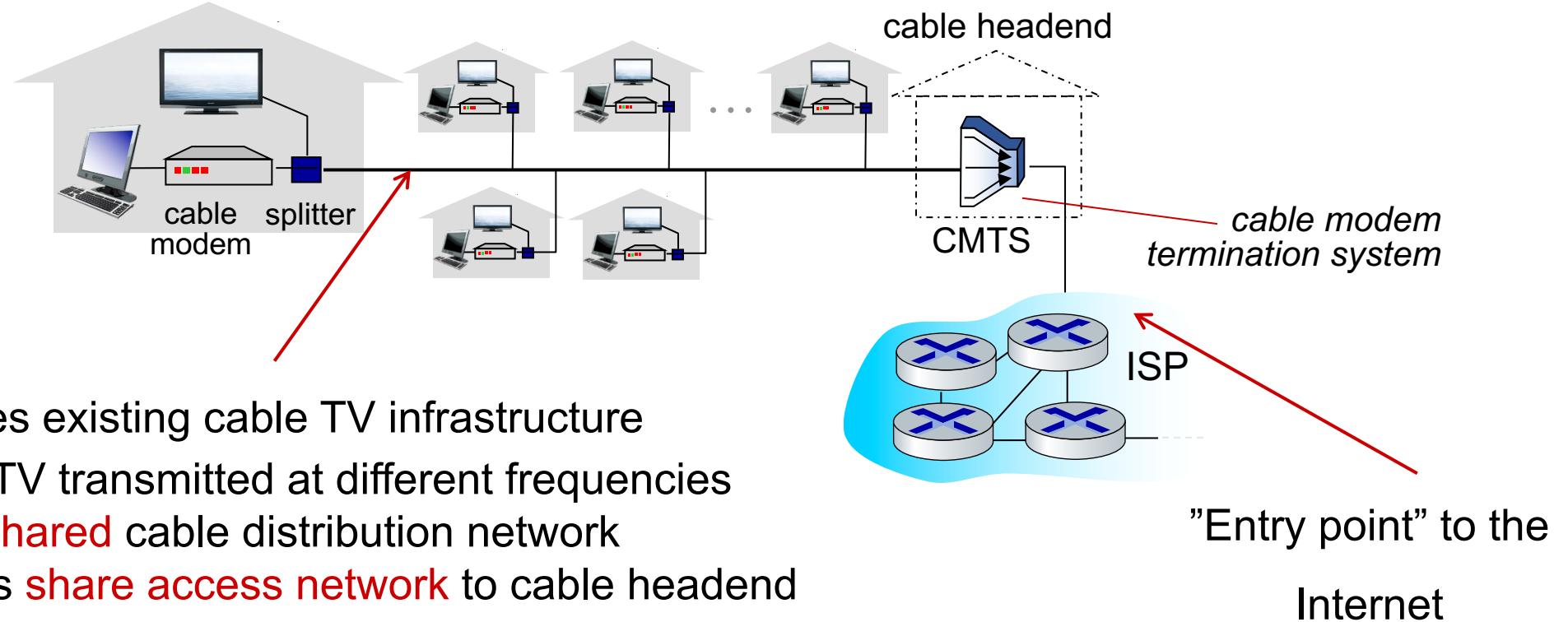
# Access networks - continued

There are different kinds of access networks:

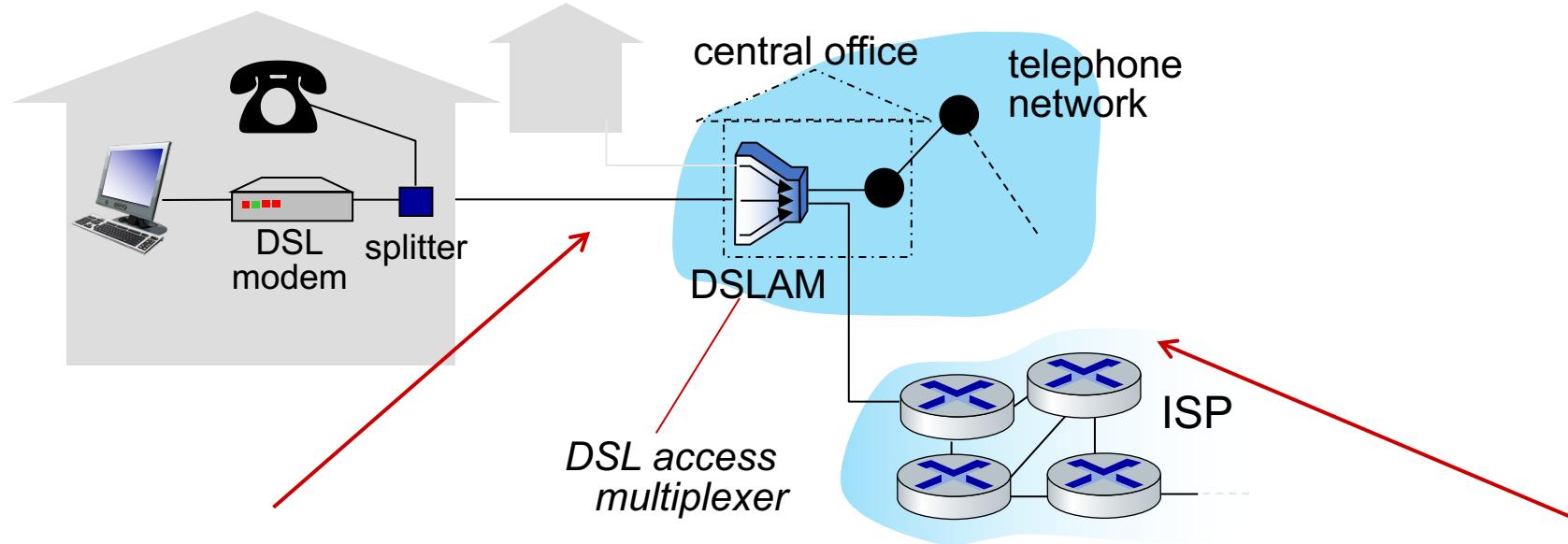
- residential access networks
- Wireless access networks (WiFi, 4G/5G)
- Enterprise (Institutional) access networks
  - school, company, etc.
- Data center networks
- ...



# Residential access networks: cable-based access



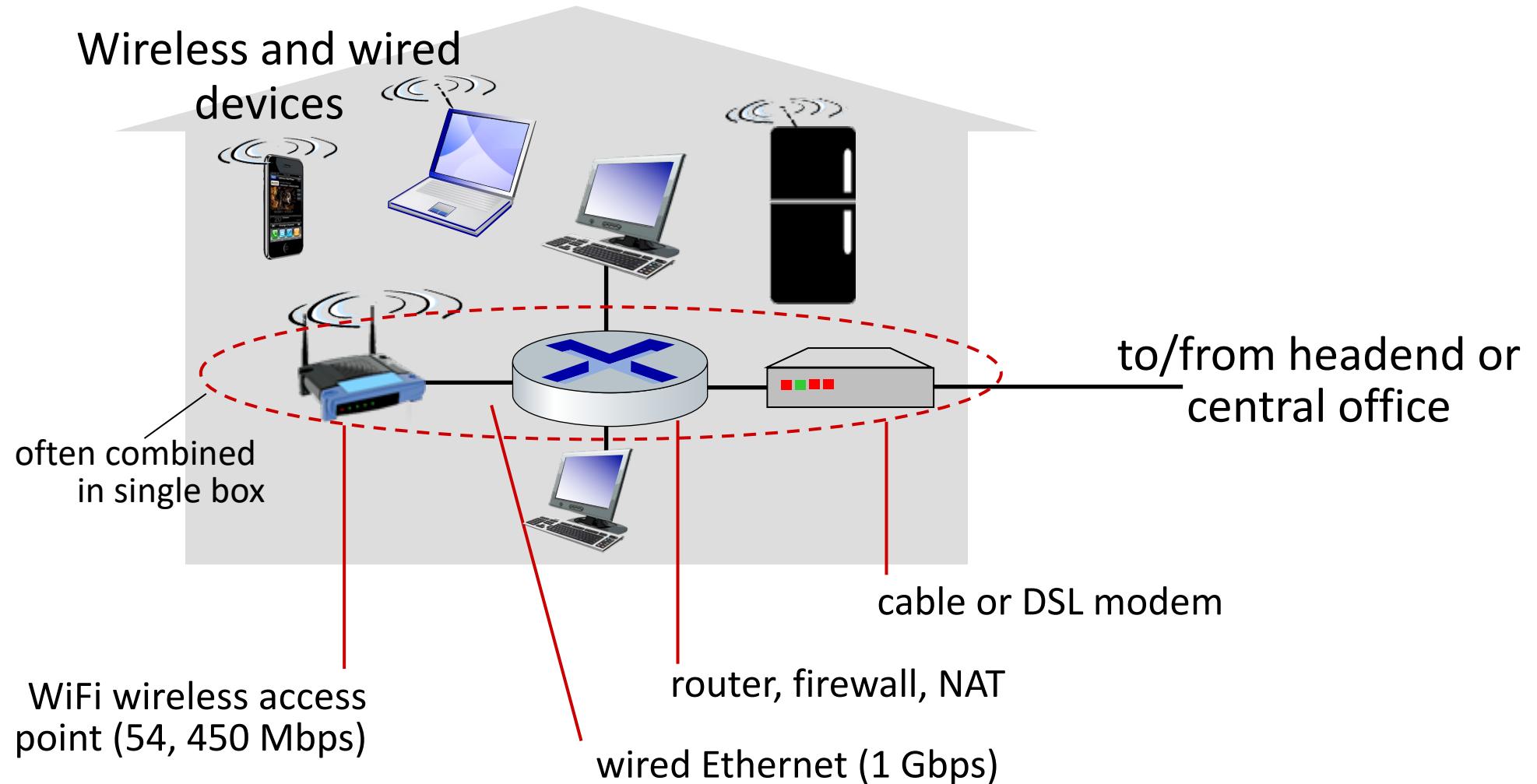
# Residential access networks: Digital Subscriber Line (DSL)



- Use existing telephone line to the central office.
- Data and voice transmitted at different frequencies over **dedicated** line to central office.
- Data over DSL phone line goes to the Internet
- Voice over DSL phone line goes to the telephone network

"Entry point" to the  
Internet

# Residential access networks: home networks



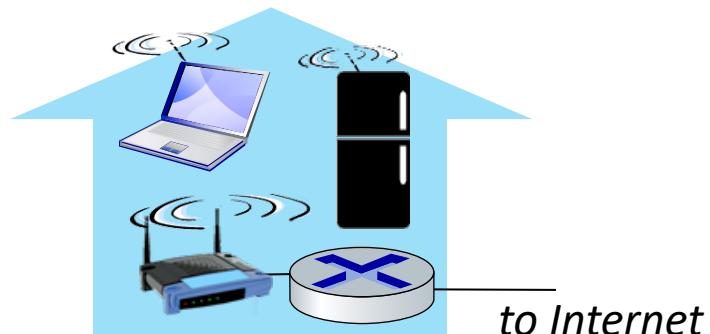
# Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

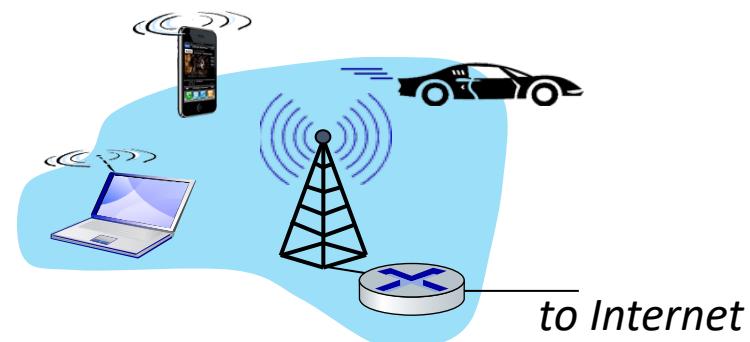
## Wireless local area networks (WLANs)

- typically within or around building (~30 m)

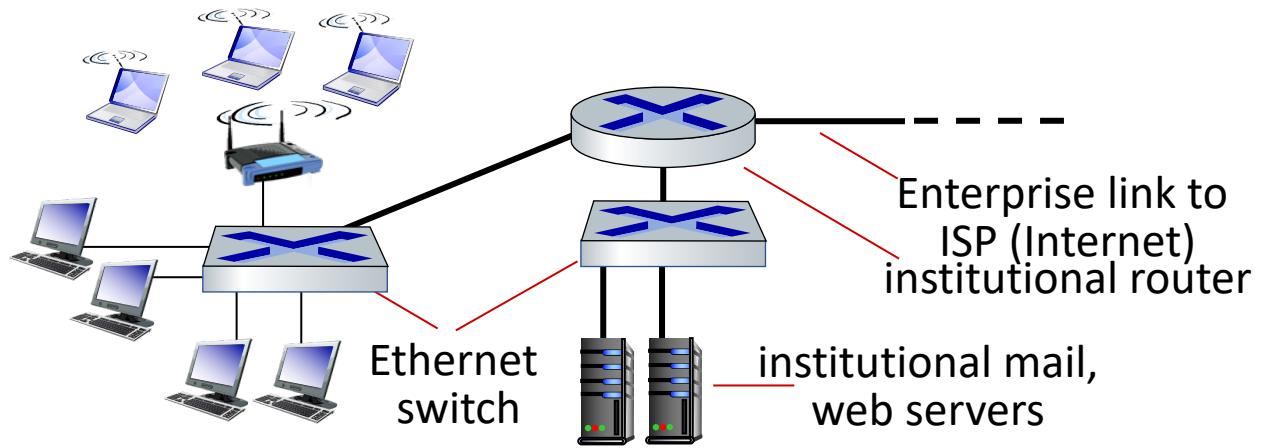


## Wide-area cellular access networks

- provided by mobile, cellular network operator (10's km)
- 4G/5G cellular networks



# Enterprise access networks



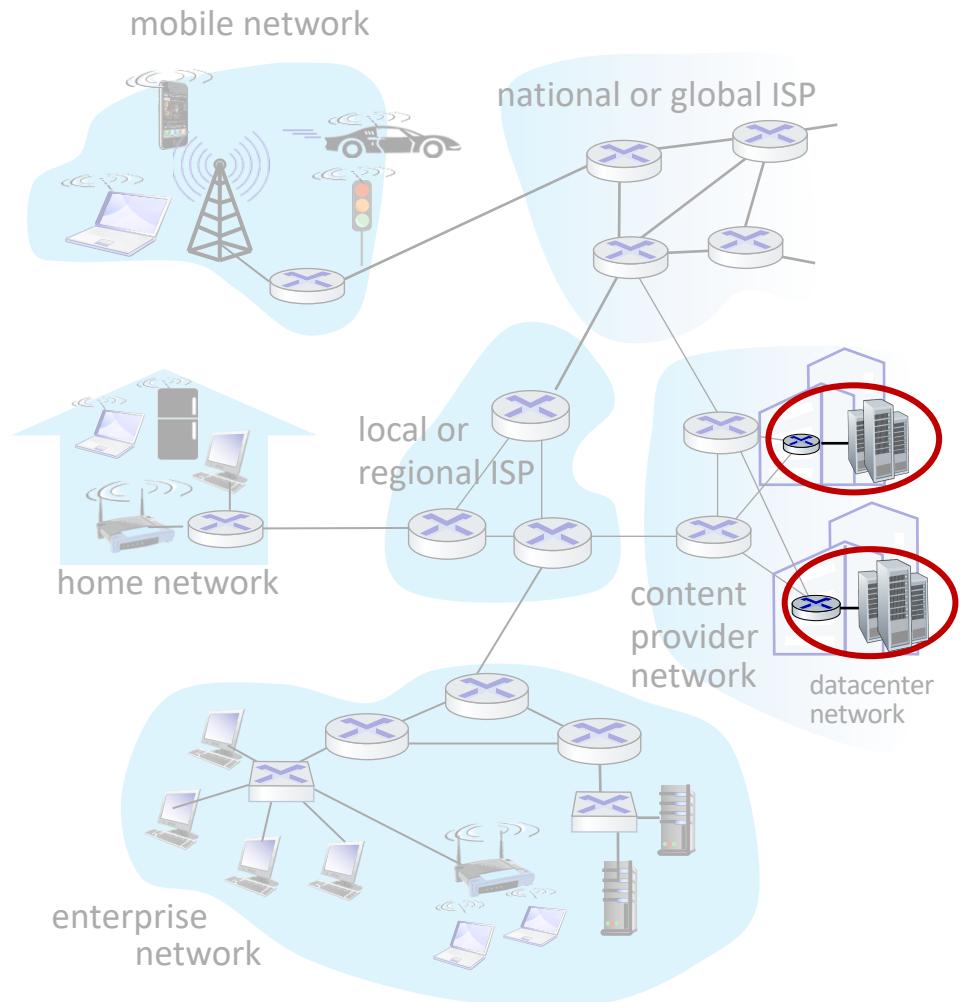
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers.

# Data center networks

- high-bandwidth links (10s to 100s Gbps) connect hundreds to thousands of servers together, and to Internet



Courtesy: Massachusetts Green High Performance Computing Center ([mghpcc.org](http://mghpcc.org))



# Links: physical media

- We just talked about different kinds of access networks.
- They have all kinds of different devices and components that have to physically connect to each other.
- What kind of physical media is used in today's networks to connect these components?

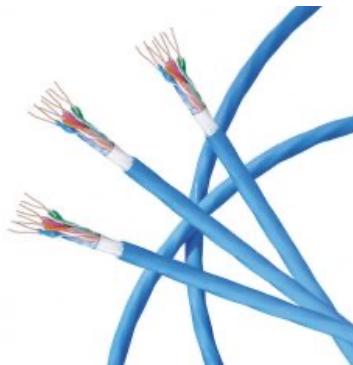
# Links: physical media

- Guided media:
  - signals propagate in solid media: copper, fiber, coax
- Unguided media:
  - signals propagate freely, e.g., radio

# Guided media examples

## Twisted pair (TP)

- two insulated copper wires



## Coaxial cable:

- two concentric copper conductors



## Fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit



# Unguided media examples

## Wireless radio

- signal carried in various “bands” in electromagnetic spectrum
- no physical “wire”
- propagation environment effects:
  - reflection
  - obstruction by objects
  - Interference/noise

## Radio link types:

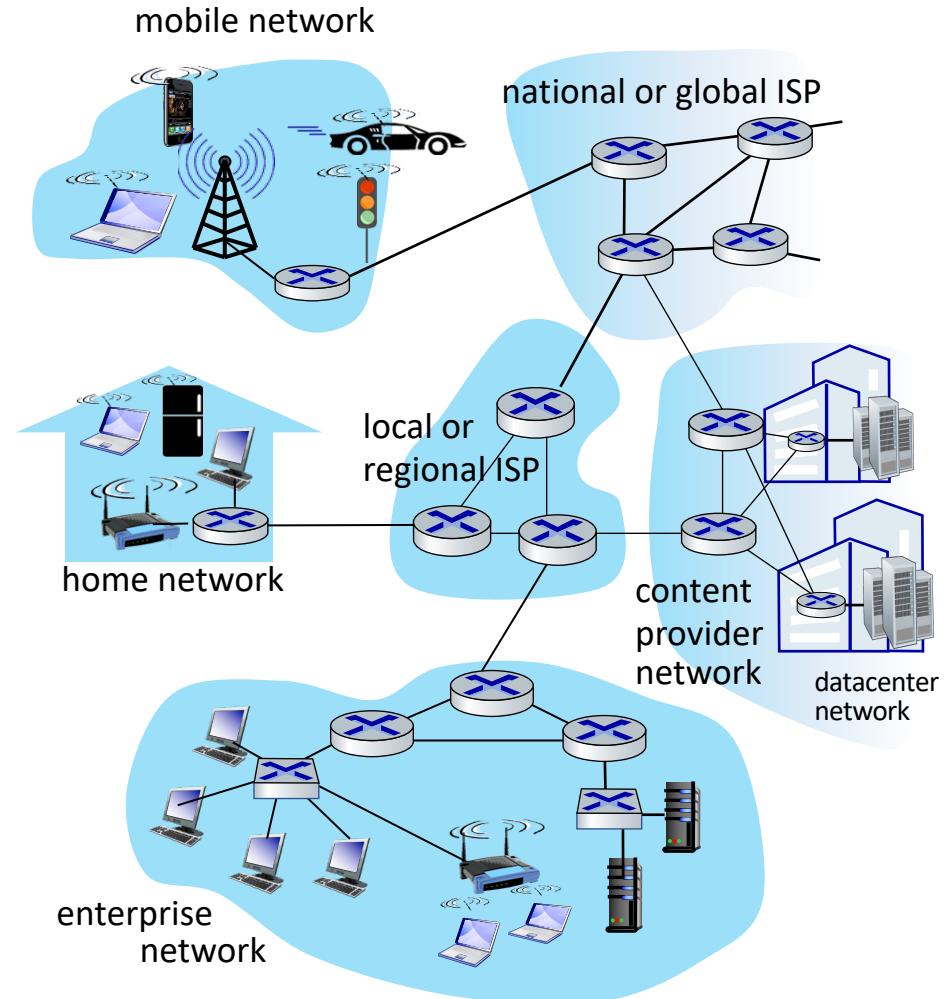
- Wireless LAN (WiFi)
- wide-area (e.g., 4G/5G cellular)
- Bluetooth
- terrestrial microwave
- Satellite

Differ in bandwidth, latency, error rate, range, etc.

# The Internet: a “nuts and bolts” view

So far, we have discussed

- The network edge
  - End systems or hosts
- Access networks
  - Networks connecting hosts to the “Internet”

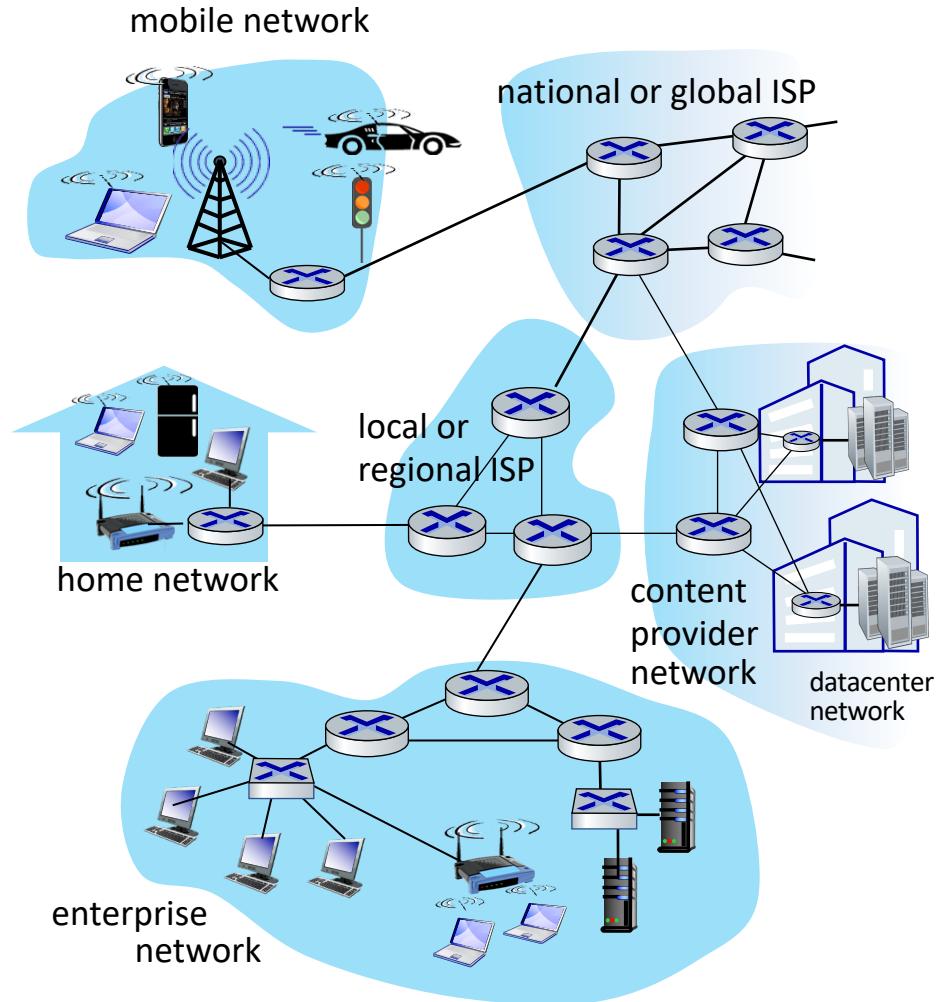


# The Internet: a “nuts and bolts” view

So far, we have discussed

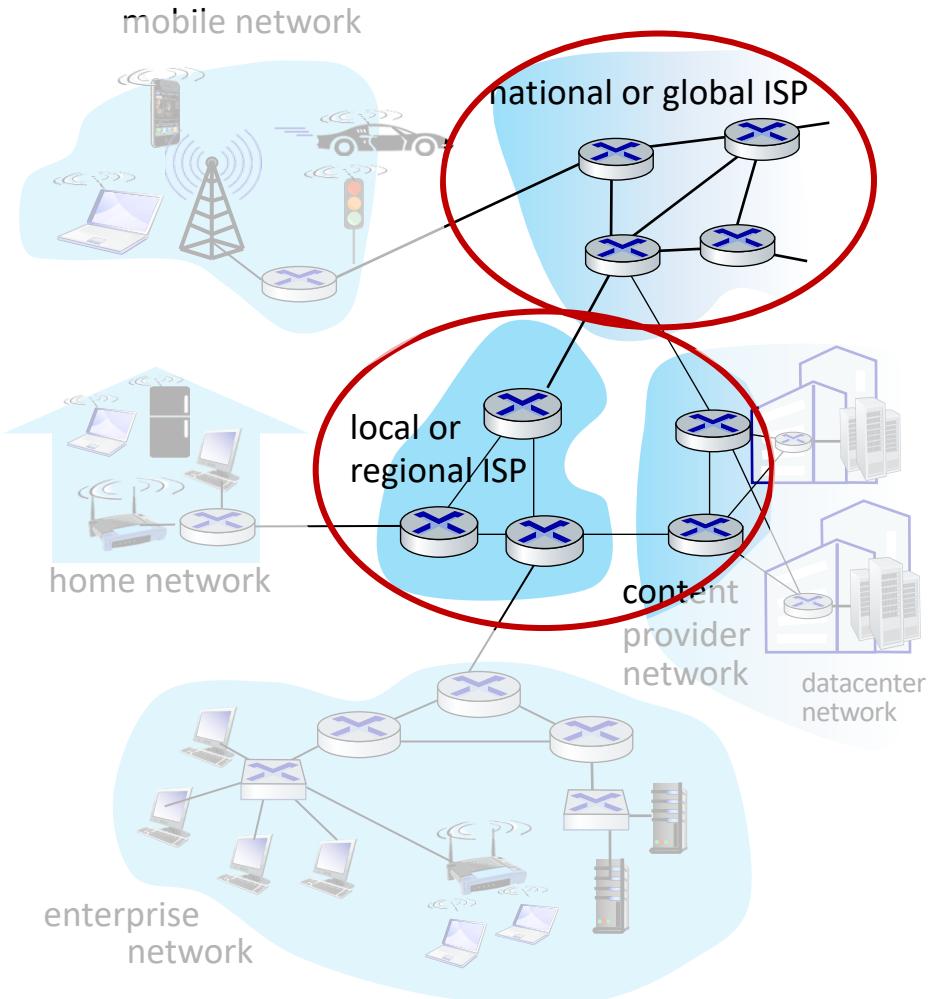
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network core



# The network core

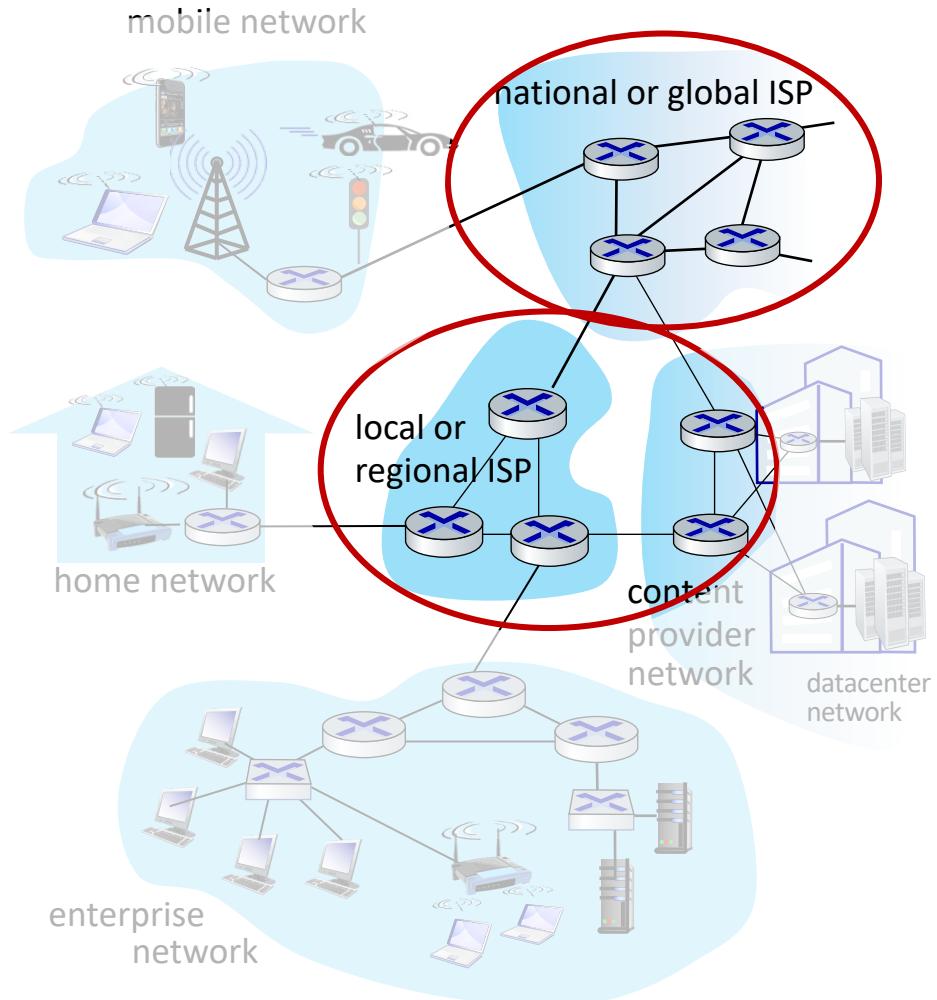
- mesh of interconnected routers
- Network of networks
- **packet-switching:** hosts break application-layer messages into *packets*
  - network forwards packets from one router to the next, across links on path from source to destination



# The network core

- mesh of interconnected routers
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How does packet switching work?  
We'll get to that, and other overview topics, in the next lecture



# Questions?

# Course logistics – where to get what 😊

- The course webpage
  - <https://mina.arashloo.net/courses/CS456-F23/index.html>
  - Course outline, tentative schedule, slides, policies, and references
- Waterloo outline
  - Course outline, policies
- LEARN
  - Announcements, slides, quizzes, assignments
- Piazza
  - Questions and discussions

# Course logistics – Lectures and office hours

- There are two sections in the course.
  - They will cover the same overall material by the end of the term.
  - But they may not be fully in sync.
  - Try to attend lectures of the same section throughout the term.
- Instructor office hours are generally for questions about the lectures and other topics related to computer networks
  - Tuesdays and Thursdays, 4-5pm, in DC 3510.
- TA office hours are generally for questions about the assignments
  - Time and location will be announced on LEARN and the course website.

# Course logistics – Readings

- Readings are optional and from the following sources
  - Computer Networking, A Top-Down Approach, James Kurose & Keith Ross, Pearson, 8th Edition (7th Edition is also fine).
  - Research papers, blog posts, and platforms related to computer networks.
- Links to the latter will be posted on the course webpage

# Course logistics – Assessment

	<b>CS 456</b>	<b>CS 656</b>
<b>Quizzes</b>	10%	10%
<b>Programming Assignments</b>	30%	10%
<b>Midterm</b>	25%	25%
<b>Final</b>	35%	35%
<b>Research Project</b>	-	20%

# Course logistics – Quizzes

- Helps you assess your understanding of the course material
- Help us as your instructors to pinpoint subjects that need extra discussion in the class.
- Every week that we have lectures, a quiz will be posted on LEARN on Thursday that week at 8PM EST.
- You have until Saturday at noon (40 hrs) to complete the quiz.

# Course logistics – Quizzes

- Questions are multiple-choice and are about the material covered in class that week.
- You will have unlimited attempts. Hopefully, this helps you focus on your learning of the material without having to worry about your grade.
- A missed quiz cannot be retaken and doctor's note is not accepted for missed quizzes.
- You can miss two quizzes without it affecting your grade.

# Course logistics – Programming Assignments (CS 456)

- There are three programming assignments, each counting as 10% of your final grade.
- Assignment specifications will be posted on LEARN.
- Assignments are to be completed individually and submitted to the appropriate Dropbox on LEARN.
- You have a total of four late days for the whole term.

# Course logistics – Programming Assignments (CS 456)

- Use your late days to accommodate unexpected situations. No questions will be asked.
  - Examples of unexpected situations include your internet connection being down right before the deadline or forgetting or missing the deadline.
- Your four late days are for the whole term, not per assignment.
  - E.g.: If you use 2 late days for assignment 1, you have only 2 late days left to use for the rest of the assignments.

# Course logistics – Programming Assignments (CS 456)

- Late days are tracked daily, not hourly.
  - E.g.: If an assignment is due on Thursday at 11:59pm, and you turn it in the next day (Friday) at noon, you have used one of your late days.
- No extensions are granted if you have no late days left, so plan ahead and use them carefully.
  - E.g.: If you have no late days left and submit the assignment after the deadline, you will not receive any points for the assignment

# Course logistics – Programming Assignments (CS 656)

- Choose two of the three to complete.
- Each will count as 5% of your grade.
- The rest of the logistics is the same as CS 456.

# Course logistics – Exams

- Exams will be solely based on the materials presented in the class
  - this includes the parts that may not necessarily be covered in the textbook.
- Exams are closed-book.
- The midterm exam will be during class time, on Tuesday, Oct 24. Location will be announced on LEARN.
- Date, time, and location of the final exam will be announced by the Registrar's Office.

## Course logistics – Exams

- Midterm and final have to be passed, in the aggregate, in order to pass the course. That is,  $[(\text{Midterm} * 25) + (\text{Final} * 35)] / 60 \geq 50\%$
- In the case of a missed exam, a medical certificate or doctor's note must be uploaded to the university's online portal.
  - Please refer to the course outline for information about acceptable certificates and doctor's notes.

# Course logistics – Research Project (CS 656)

- Students taking CS 656 are expected to work individually on original research projects related to computer networks.
- There are three deliverables:
  - **Proposal (5%)**: One page, due by the end of week 3. Please reach out to set up a time to discuss project ideas.
  - **Progress Report (5%)**: Two pages, due a month after the proposal
  - **Final Report (10%)**: 6-page conference-style paper, due at the end of the term

# Course logistics – Generative AI

- Like any other tool, it should be used carefully and in a mindful, responsible manner.
- If you decide to use it in your programming assignments, it needs to be with proper documentation, citation, and acknowledgement.
  - Details will be outlines in the assignment instructions.
- You can find pointers to university guidelines and recommendations about using generative AI in the course outline.

# Course logistics – Generative AI

- At the end of the day, you are accountable for the content and accuracy of your work, including any supported by generative AI.
- So, be mindful about where, how, and to what extent you use generative AI in your work.

# Course logistics - Other

- Please make sure to read the outline carefully regarding
  - Mental health
  - Diversity
  - Academic integrity
  - Special accommodations
- No quiz this week.

# Final remarks

- It gets quite boring to have a one-way conversation for 80 minutes 😊
- Your questions and thoughts are always welcome!
- Computer networks are a corner stone of modern society and I'm looking forward to go over the in and outs of how they work with all of you this term.