CS168
Introduction to the Internet: Architecture and Protocols

Rishabh Iyer

Spring 2026

Slide credits: Sylvia Ratnasamy, Rob Shakir, Peyrin Kao

Today

- **Introductions**
- **Class logistics**
- **What is (this course on) the Internet about?**

NEW

Rishabh Iyer (he/him)

- **Background**
  - PhD from EPFL, Switzerland in 2023
  - Joined the UCB faculty in 2025
  - Research focus: Computer systems

TAs!

Jonah Bedouch
(head TA)

Dev Bali

Jaewan Hong

Jocelyn Tao

Zoir Imomaliev

Abhi Nambiar

Owen Ye

Today

- Introductions
- **Class logistics**
- **What is (this course on) the Internet about?**

Course Website

- All course logistics are available on our website: https://sp26.cs168.io/
- Policies page: https://sp26.cs168.io/policies/
- Spring 2026 FAQs page: https://su25.cs168.io/sp26-faqs/
- If you have questions, please read our FAQs page first!
- If your question is not answered on that page, please email cs168@berkeley.edu with your question. Do not email individual instructors or TAs; it is far less likely that you will get a response.

Enrollment, Ed, bCourses, & Gradescope

- Class size will expand to subsume the waitlist.
- Please do not email us if you are a concurrent enrollment student with a pending application; you will be added automatically within 3–4 days of submitting your application.
- If you just enrolled in the class, please don't email us about being added; we will sync the roster and add you within 3–4 days.

Discussions, Office Hours, and Exams

- Discussions and office hours start next week.
- You can attend any discussion section. Attendance is not taken.
- Project 1 starts **today** and the deadline is Friday Jan 30.
- Exam dates and details about alternate exams are on the website.

Accomodations

- If you are registered with the Disabled Students' Program (DSP), please send us your letter of accommodations through the DSP portal as soon as possible.
- Your well-being is more important than this class. The website has a link to a form to request extensions.

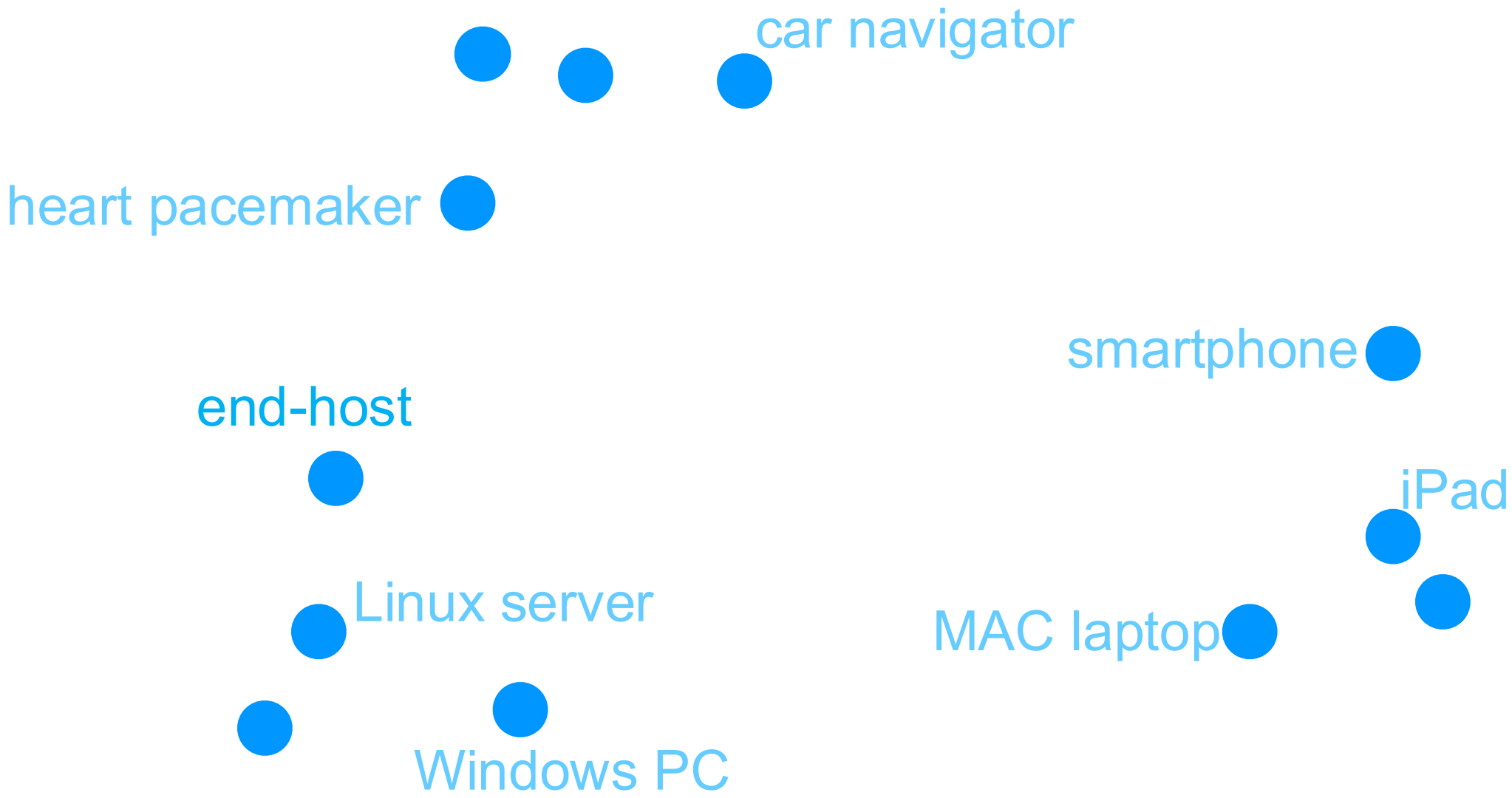
Today

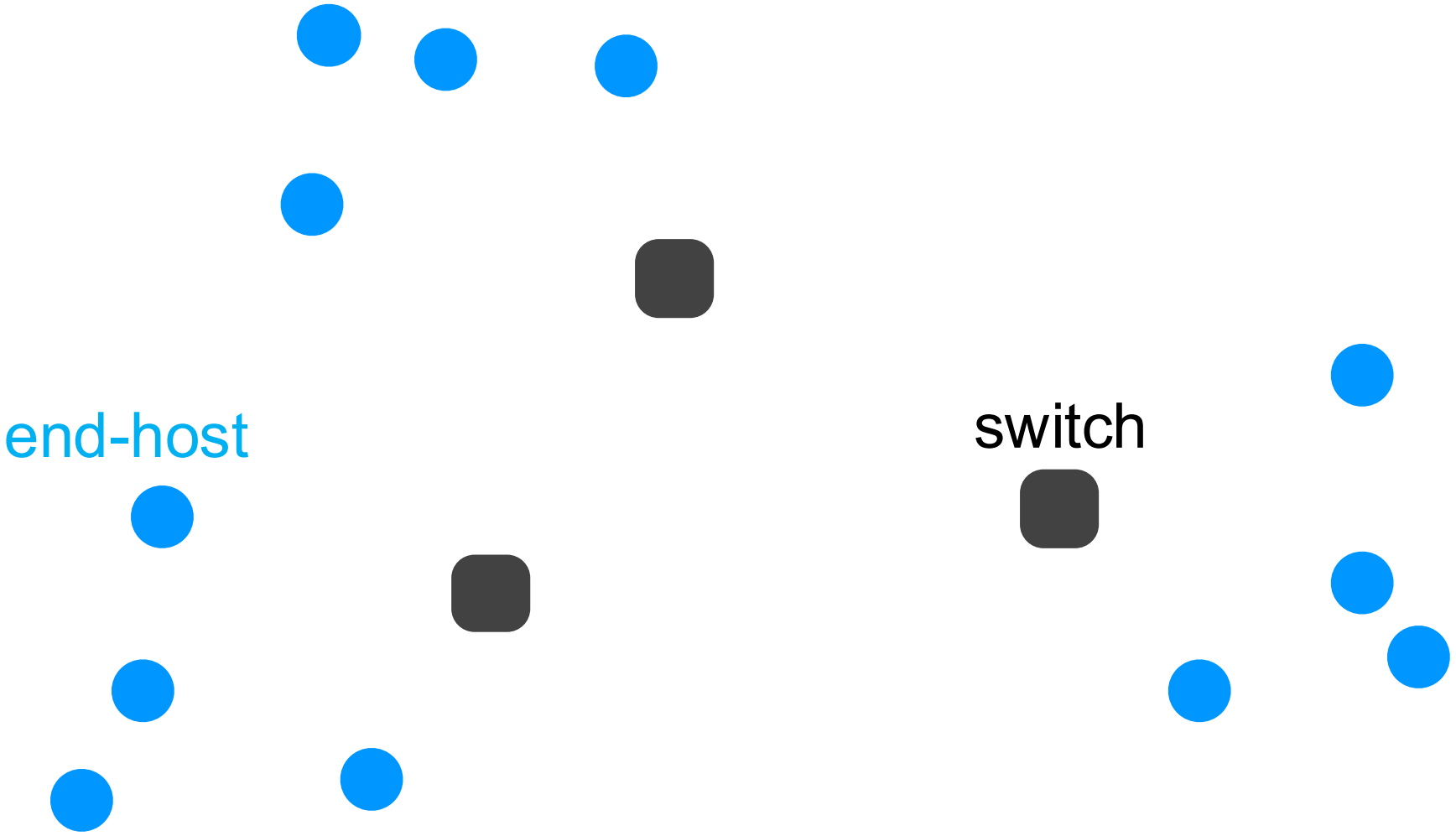
- Introductions
- Class logistics
- **What is (this course on) the Internet about?**

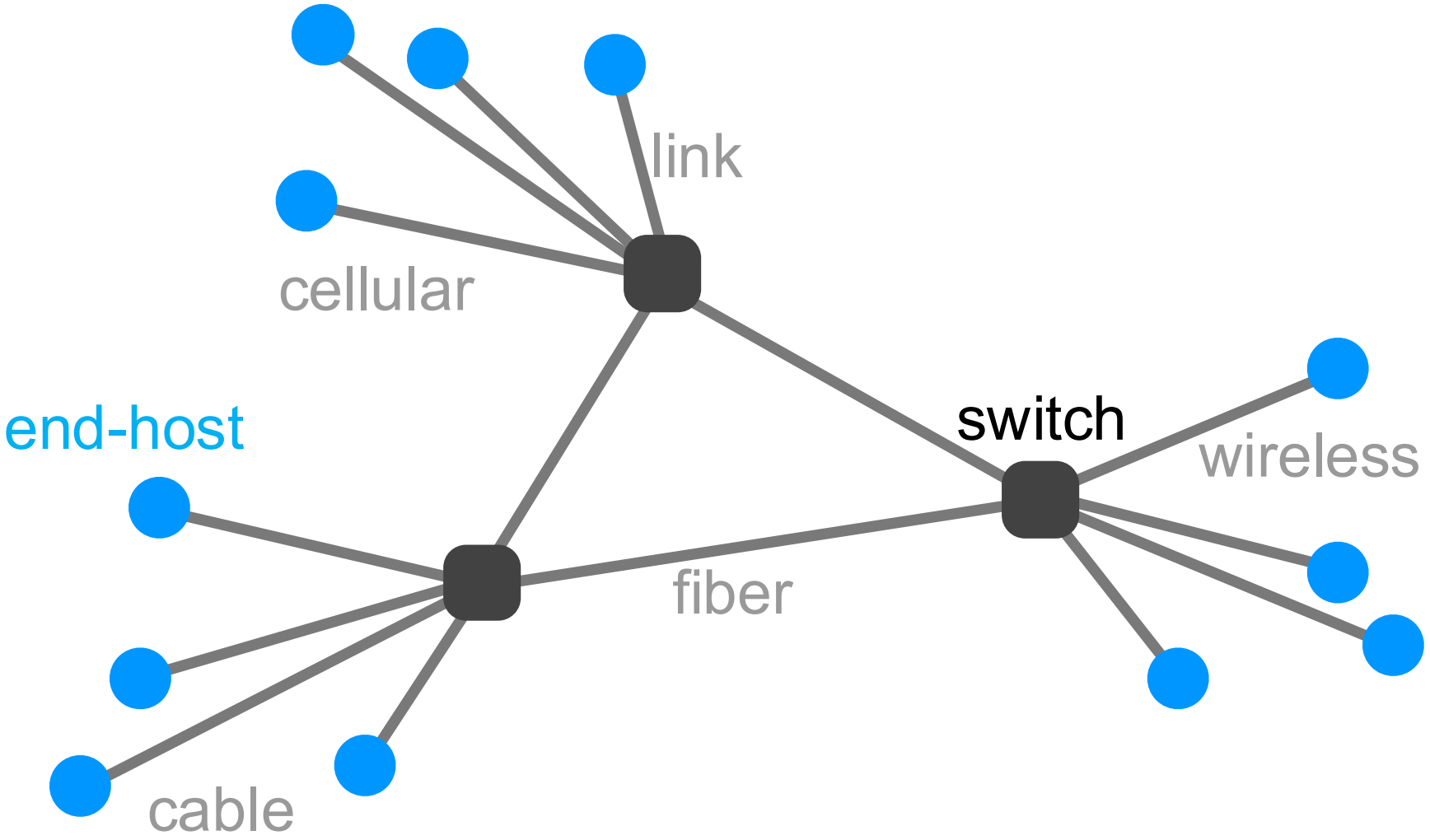
Introduction to the Internet: Protocols and Architecture

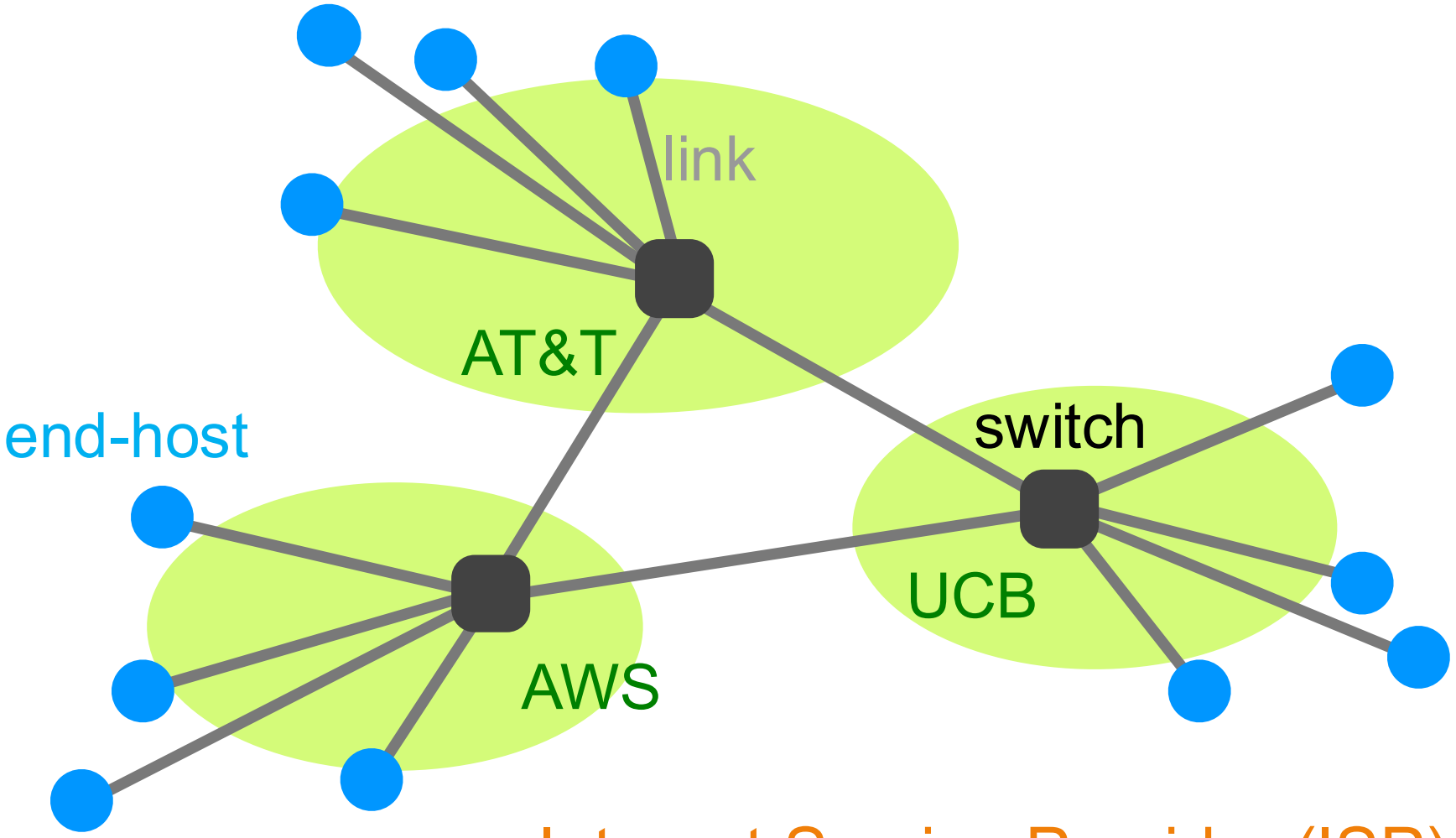
Two Meanings of "Internet"

- **The infrastructure that ties together computing devices**
  - TCP, IP, BGP, DNS, OSPF, …
- **The ecosystem of applications built on top of the above infrastructure**
  - Amazon, Google, ChatGPT, ….
- **In this class, we use the first definition!**


car navigator
heart pacemaker
smartphone
end-host
iPad
Linux server
MAC laptop
Windows PC

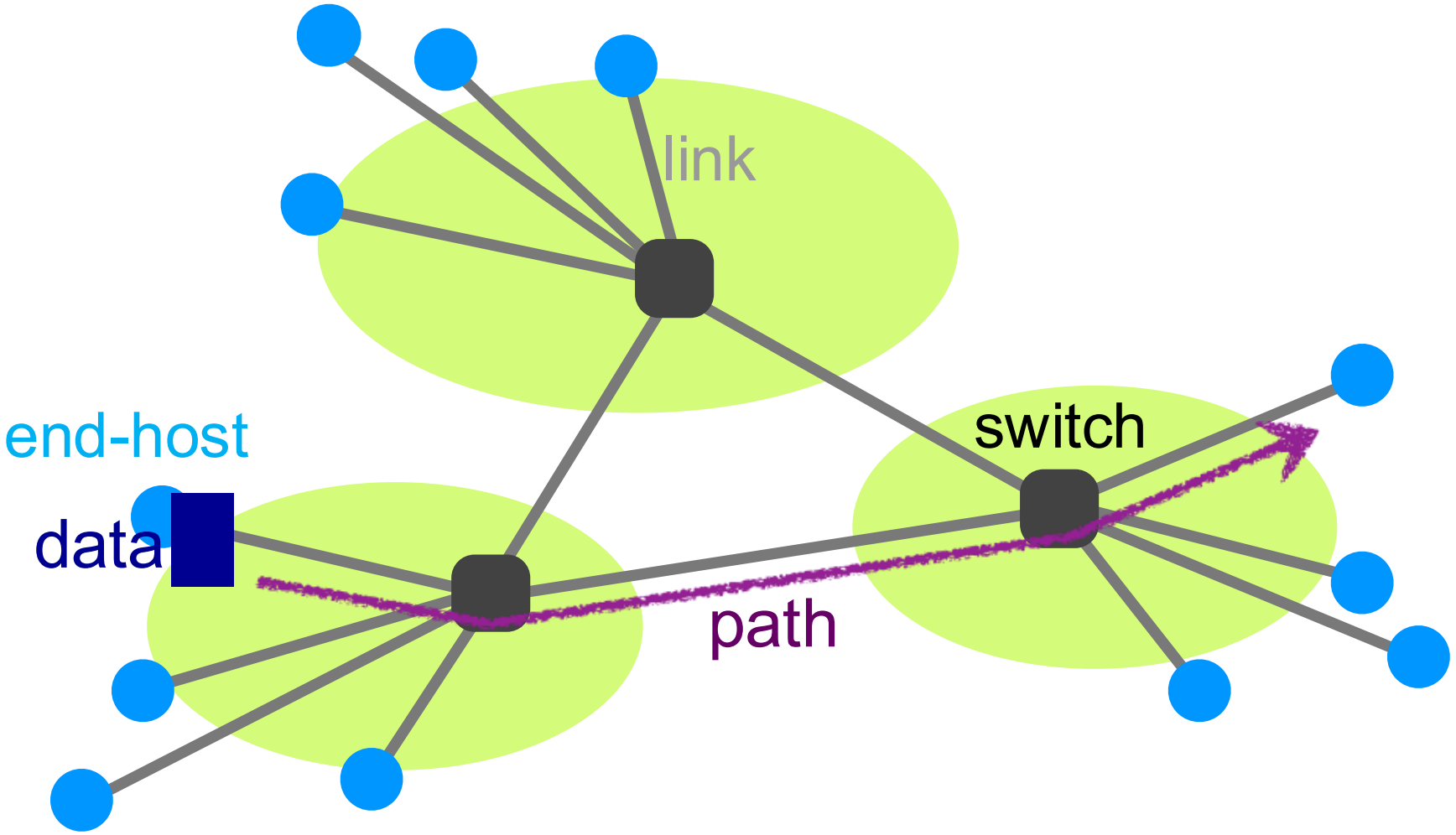

end-host
switch


link
cellular
end-host
switch
wireless
fiber
cable

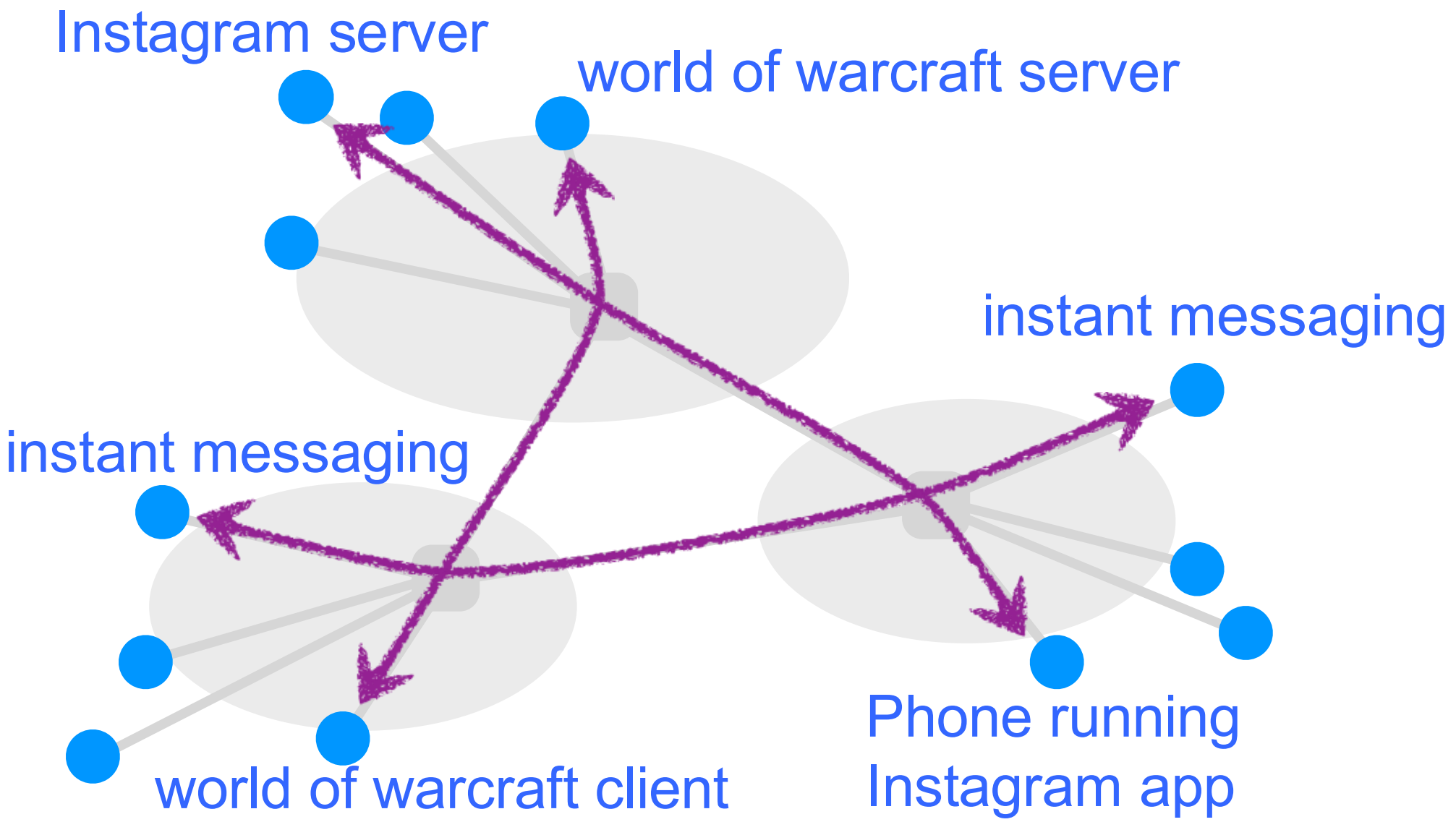


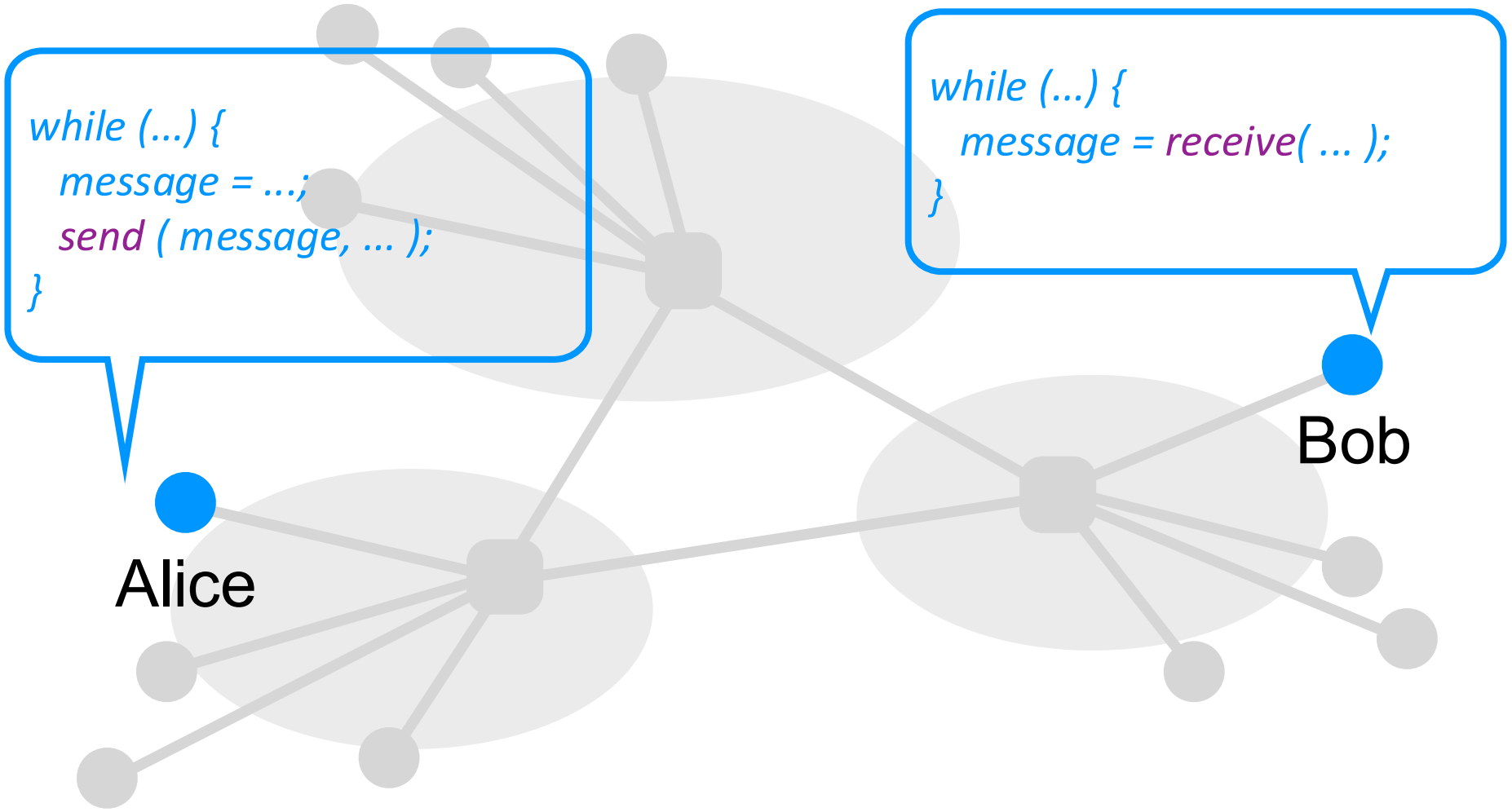
Internet Service Provider (ISP)

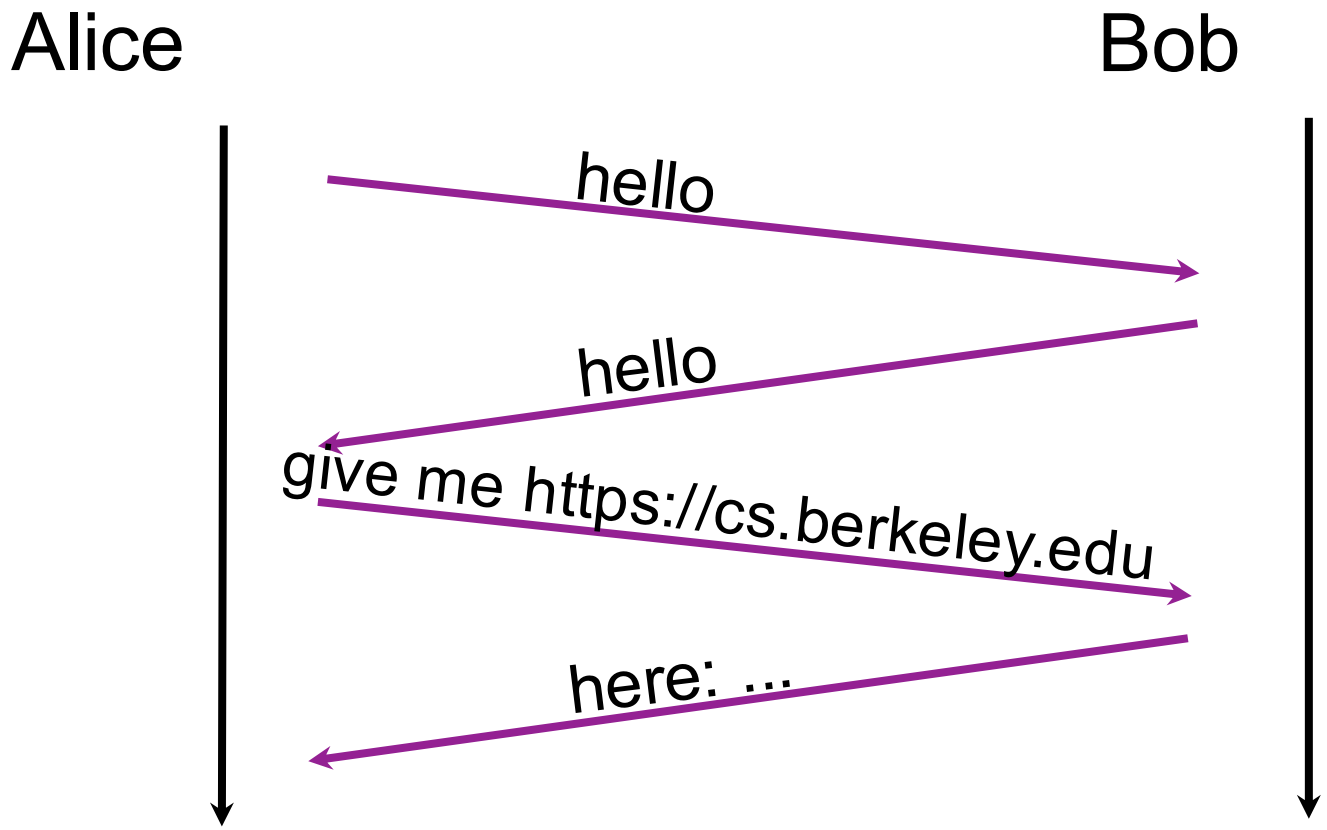
The Internet transfers data between end hosts



- Internet
- **Protocols**
- **Architecture**


Instagram server
world of warcraft server
instant messaging
instant messaging
Phone running
Instagram app
world of warcraft client


while (…) {
message = …;
send (message, …);
}
while (…) {
message = receive(…);
}
Alice
Bob


Alice
Bob
hello
hello
give me https://cs.berkeley.edu
here: ...


Alice
Bob
hello
give me https://...
give me https://...
give me https://...
give me https://...
give me https://...
give me https://...

Protocol

- A specification of the messages that communicating entities exchange
    - their syntax and semantics

- Very much like conversational conventions … determining who should talk next and how they should respond

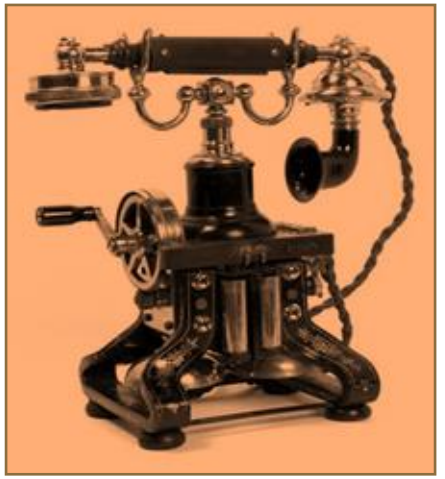
- Designing a good protocol is harder than it first seems!

- Internet
- Protocols
- **Architecture**

Why study the Internet?

The Internet has and is transforming everything

- **The way we do business …**
  - retail, advertising, cloud computing
- **The way we have relationships**
  - Twitter, chat
- **The way we learn**
  - Wikipedia, ChatGPT, AR/VR
- **The way we govern**
  - E-voting, censorship, cyber-warfare
- **The way we cure disease**
  - digital health, remote surgery



What's your formal model for the Internet? -- theorists

You don't have performance benchmarks??? – hardware folks

But why is the Internet *interesting*?

Aren't you just writing software for networks? – OS community

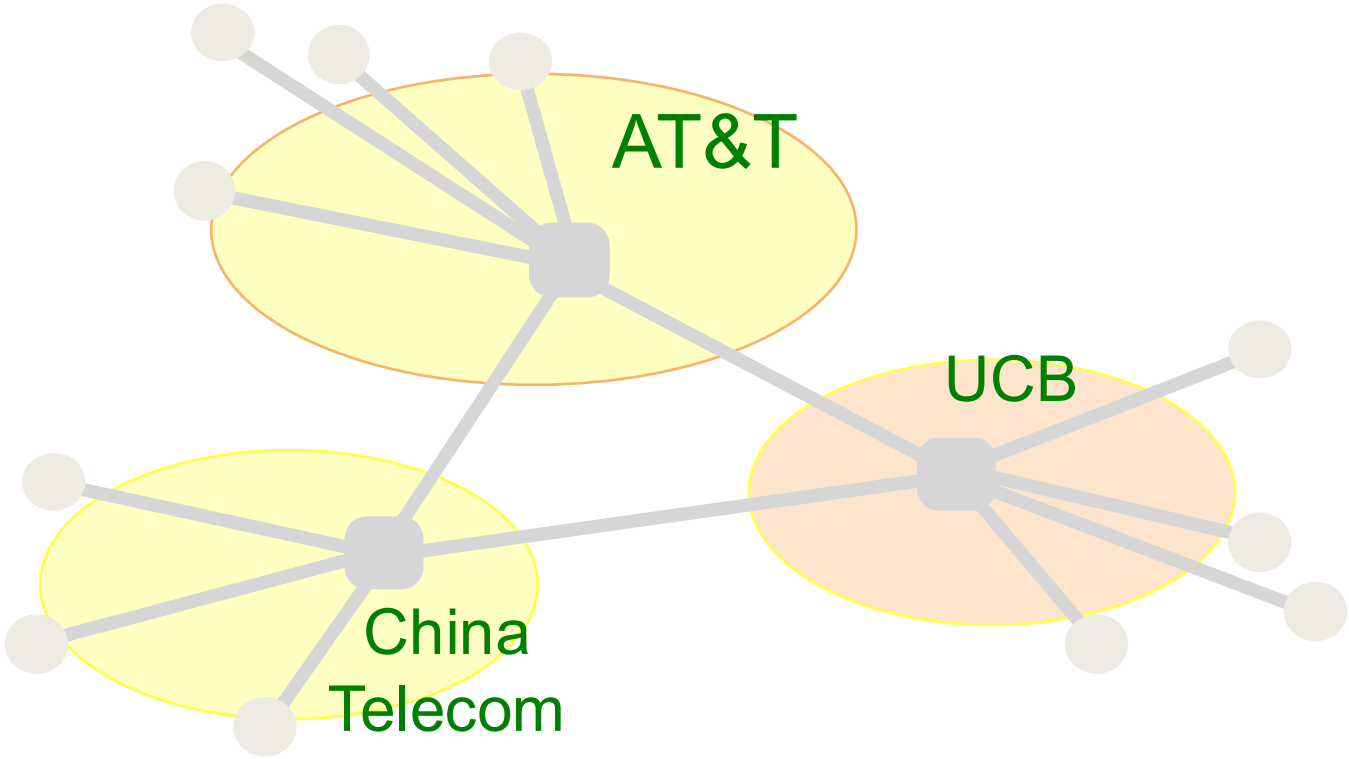
A few defining characteristics of the Internet…

Network versus "The Internet"

- **There are many kinds of network technologies (switches and links)**
  - Ethernet, optical, wifi access points, DSL modems, Infiniband switches, …
- **The Internet is not a new/particular kind of network technology**
- **Instead, the Internet ties different networks together**
  - The Internet

A federated system

Interoperability is the Internet's most important goal!



The Internet interconnects over 100,000 independently operated networks

A federated system

- **Fundamental challenge: how do you interconnect competing entities?**
  - Competing network providers must cooperate to serve their customers!
- **Leads to a constant tussle between business and technical factors**
  - Real-world incentives determine topology, path selection, diagnostics, and more
- **And complicates innovation**
  - How do you differentiate when interoperability relies on supporting a common protocol?
  - Upgrading “the Internet” is not an option

Tremendous scale

- > 5 Billion users
- 1.24 Trillion unique URLs (web pages)
- Every second, we generate >10000 tweets, >100,000 Google queries, >3M emails

Asynchronous Operation

- Fundamental constraint: **speed of light**

- Consider: how many cycles does your 3GHz CPU in Berkeley execute before it can possibly get a response for a message it sends to a server in NY?
  - Berkeley to New York: 4,125 km
  - Traveling to NY and back at 300,000 km/s: 27. 5 milliseconds
  - 3,000,000,000 cycles/sec * 0.0275 = 84,000,000 cycles!

- Thus, communication feedback is always **dated**

Prone to Failure

- Many components along a path
  - software, switches, links, network interface cards, wireless access points, modem,…
- Consider: 50 components, that work correctly 99% of time → 39.5% chance communication fail
  - Plus asynchrony → takes a long time to hear (bad) news

Enormous diversity and dynamic range

- **Technologies**: optical, wireless, satellite, copper, …
- **Communication latency:** microseconds to seconds (10^6 operating range)
- **Bandwidth:** 1Kbits/second to 1 Terabit/second (10^8 operating range)
- **Reliability**: 0 – 90%
- **Devices:** sensors, cell phones, datacenters, …
- **Users**: you and me, governments, operators, malicious users, …
- **Applications:** ChatGPT, live video, gaming, remote medicine, …

Constant evolution

1970s:

- 10^4 bits/second links
- < 100 computers in the US
- File transfer is the “killer” app

Today

- 10^{14} bits/second links
- 10B+ devices, all over the globe
- 3B+ facebook users; self-driving car

Yet change must be backward compatible, incremental, and “in place”

Recap: The Internet is …

- A federated system …
- of enormous scale …
- with tremendous dynamic range and diversity …
- that is asynchronous in operation …
- failure prone …
- **and constantly evolving**

Recap: The Internet is …

- Too complex for theoretical models
- "Working code" needn't mean much
- Performance benchmarks are too narrow

The Internet required a new design paradigm, which was a radical departure from systems at the time, but is the de-facto blueprint today for scalable services

Why Study the Internet?

- **The Internet poses a design challenge like no other**
- **From its creation emerged a new design paradigm**
- **That shaped how we reason about the design of scalable systems**
  - What's the right prioritization of goals?
  - What are fundamental constraints?
  - How do we decompose a problem?
  - What abstractions do we need?
  - What are the tradeoffs?
- **In short, a lesson in how to <u>architect</u> a (networked) system**

- Internet
- Protocols
- **Architecture**

Network architecture

- More about thinking rigorously than doing rigorous math
- More about understanding tradeoffs than running benchmarks
- More about practicality than optimality

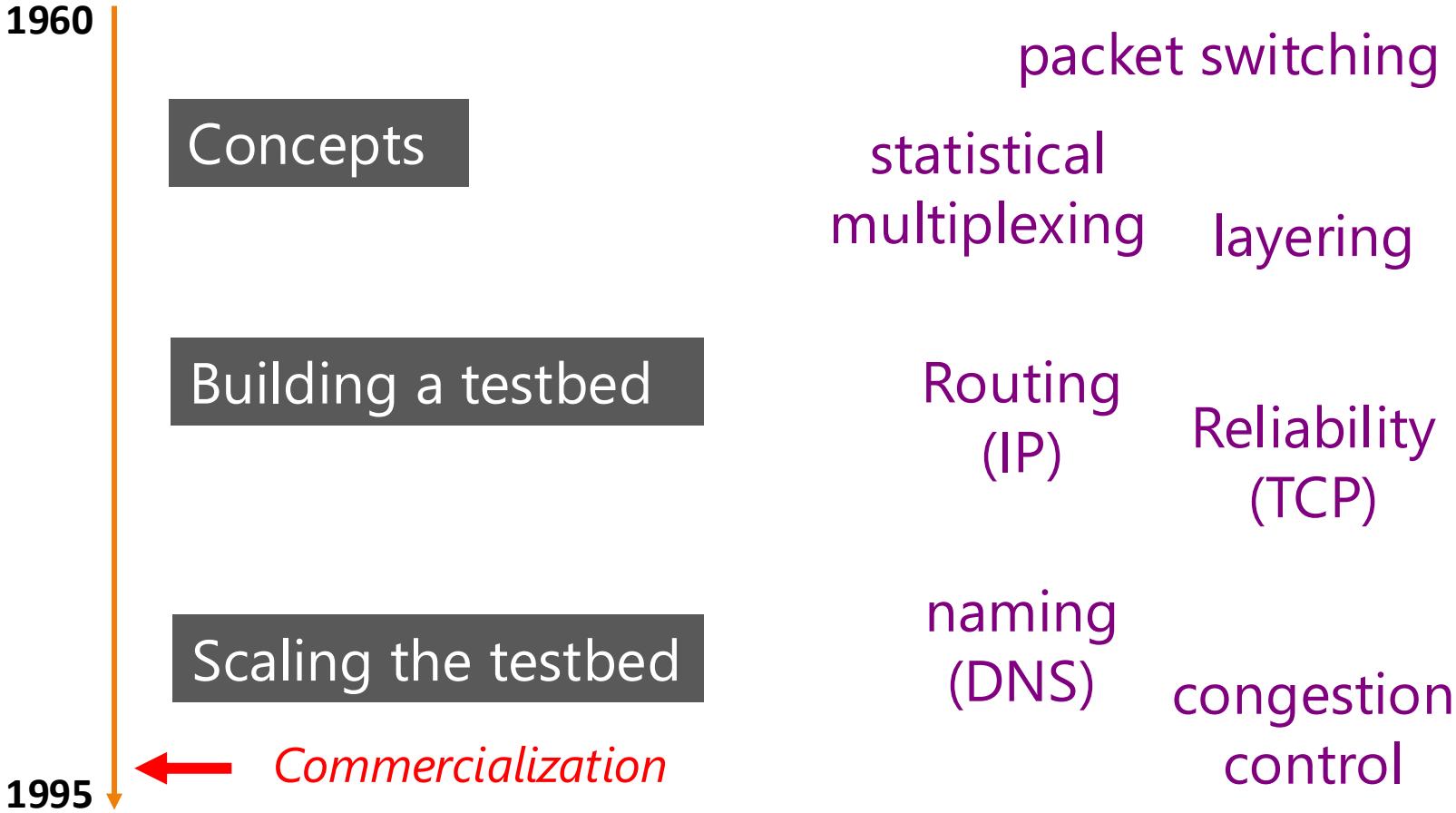
Done right, can be a powerful thing!

Class topics, more concretely

Reflect three broad phases in the Internet's evolution

1. Building a global data communication network
2. Scaling communication; and the emergence of a commercial ecosystem
3. (Networks that enable) scaling data; and a shifting commercial ecosystem

Phase 1: Building a global data communication network



Military interest in a communication infrastructure to withstand a nuclear attack

Scientists want to share data

Impact: transformed how humans communicate

Phase 2: Scaling & the emergence of a commercial ecosystem

"Content is king" – *Bill Gates*

Proliferation of PCs

Commercialization

Exponential scaling

Policy (BGP)

Content retrieval (HTTP)

Security (firewalls, DoS)

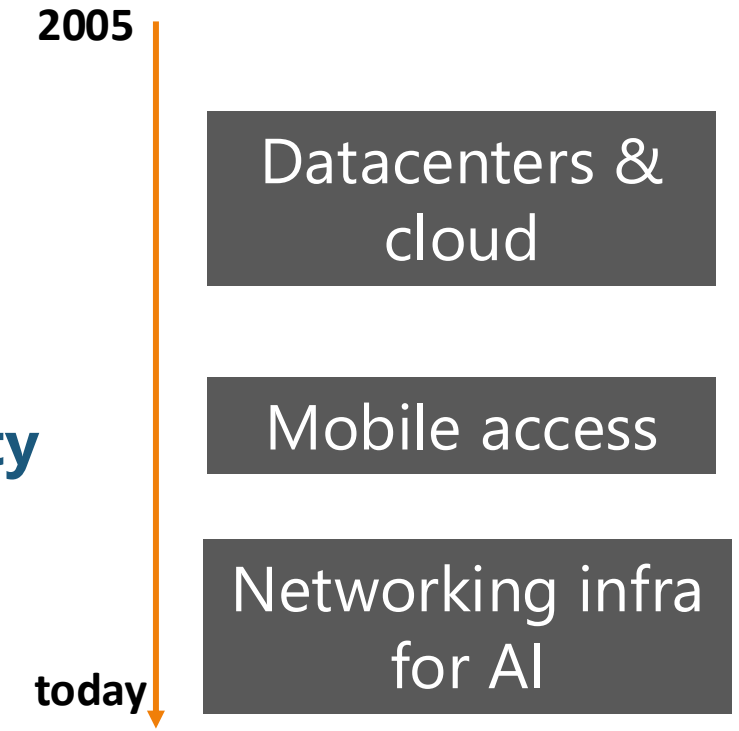
Caching (CDNs, load balancers)

Scalable addressing (NAT)

High-speed routers

Impact: everything moves to the Internet (content, brick-and-mortar businesses, banks, *etc.*)

Phase 3: Data and a shifting ecosystem



Big Data & AI

24/7 connectivity

Datacenters & cloud

Mobile access

Networking infra for AI

Low-latency commn. (RDMA)

Fat-tree networks

Network virtualization

Software-defined networking (SDN)

WiFi

Cellular networks

Communication collectives

Impact: The Internet is everywhere, transforming everything

To recap, what we hope CS 168 will teach you

- How the Internet works
- Why it works the way it does
- How to reason through a complex (networking) design problem