Fall 2018-2019: EE471/CS471/CS573
Computer Networks: Principles & Practices
Slide set 01

Tariq Jadoon and Zartash Afzal Uzmi
SBA School of Science and Engineering
LUMS

Material taken from Jennifer Rexford, Sylvia Ratnasamy, Kurose and Ross, Ion Stoica, Scott Shenker, Dave Anderson and others.

Today

- Intro and Course information
- What is networking about?
- Basics of networking

Networking courses at LUMS

- Networking Systems is the strongest research area at LUMS
  - Basit, Fareed, Hamad, Ihsan, Mobin, Nadeem, Tariq, Yasir, Zafar, Zartash
- Introductory courses
- Specialized courses (in allied areas)
  - Measurements, security, IoT, data science, multimedia
- Topical courses (very useful for research)

Basic Networking courses

- CS382 Network Centric Computing (Spring)
- CS4713/EE474 Intro to the Internet: Protocols and Architecture (Fall)
- CS471/EE471/CS573 Computer Networks: Principles and Practices (Fall)

- All three courses:
  - Serve as the first course in the Computer Networking Systems
  - Cover the basic networking concepts

- NetCen focused on networked and distributed applications (core for CS)
- IntInt places an increased focus on emerging topics (wireless, for example)
- CompNets covers protocols / fundamental principles in more detail (subs CS core)

Course Staff

- Zartash (zartash@lums.edu.pk)
  - Office hours: 4-5pm Mon/Wed (or by appointment)
- Tariq (jadoon@lums.edu.pk)
  - Office hours, TBD
- Teaching Assistants:
  - TBD

Grading

- Homework/Quizzes/Programming 35%
- Midterm(s) 30-35% (30% if one MT, 35% if two)
- Final Exam 30-35% (35% if one MT, 30% if two)

- Contests and grading revisions — After the grades are reported, you can contest within following timelines:
  - Homework, Quizzes, Programming: 2 days
  - Midterm(s) and Final: 3 days

Prerequisites + **Textbook**

- Computer Networking: A Top Down approach by James F. Kurose and Keith W. Ross (6th Edition)

- Prerequisites
  - Basic knowledge of Probability, Digital Logic, Signals, Computer Organization
  - Basic problem solving and computer programming at the level of CS-200 (using C and C++)

Goals and Learning Objectives

- Understand the anatomy of the Internet
- Grasp the mechanisms for data transfer over the Internet
- Understand the design of networking stack
- Learn how to design support protocols for Internet applications
- Acquire skills for end-to-end design of Internet applications
- Be able to write simple applications/protocols in C/C++

- Create foundation for taking more advanced courses in computer networks
- This course will provide you the foundation for becoming an effective networking researcher

Attendance

- If there is one thing to be re-emphasized, it has to be this!

Cooperation

- The next thing to be emphasized…
- Think about the real answer to:

Why are we here?

Today

- Course information
- What is networking about?
- Basics of networking

It's hard to name an area of computer science that has produced more tangible changes for the average person over the last 25 years than networking

What is *Networking*?

Networking is…

the Internet

Networking is…

the World-Wide Web

Networking is…

Skype

Networking is…

Facetime

Networking is…

Google Hangouts

Networking is…

Netflix

Networking is…

YouTube

Networking is…

Tor

Networking is…

Napster

Networking is…

BitTorrent

Networking is…

Bitcoin

Networking is…

World of Warcraft

Networking is…

Google Search

Networking is…

NFS

Networking is…

Dropbox

Networking is…

Facebook

Networking is…

Snapchat

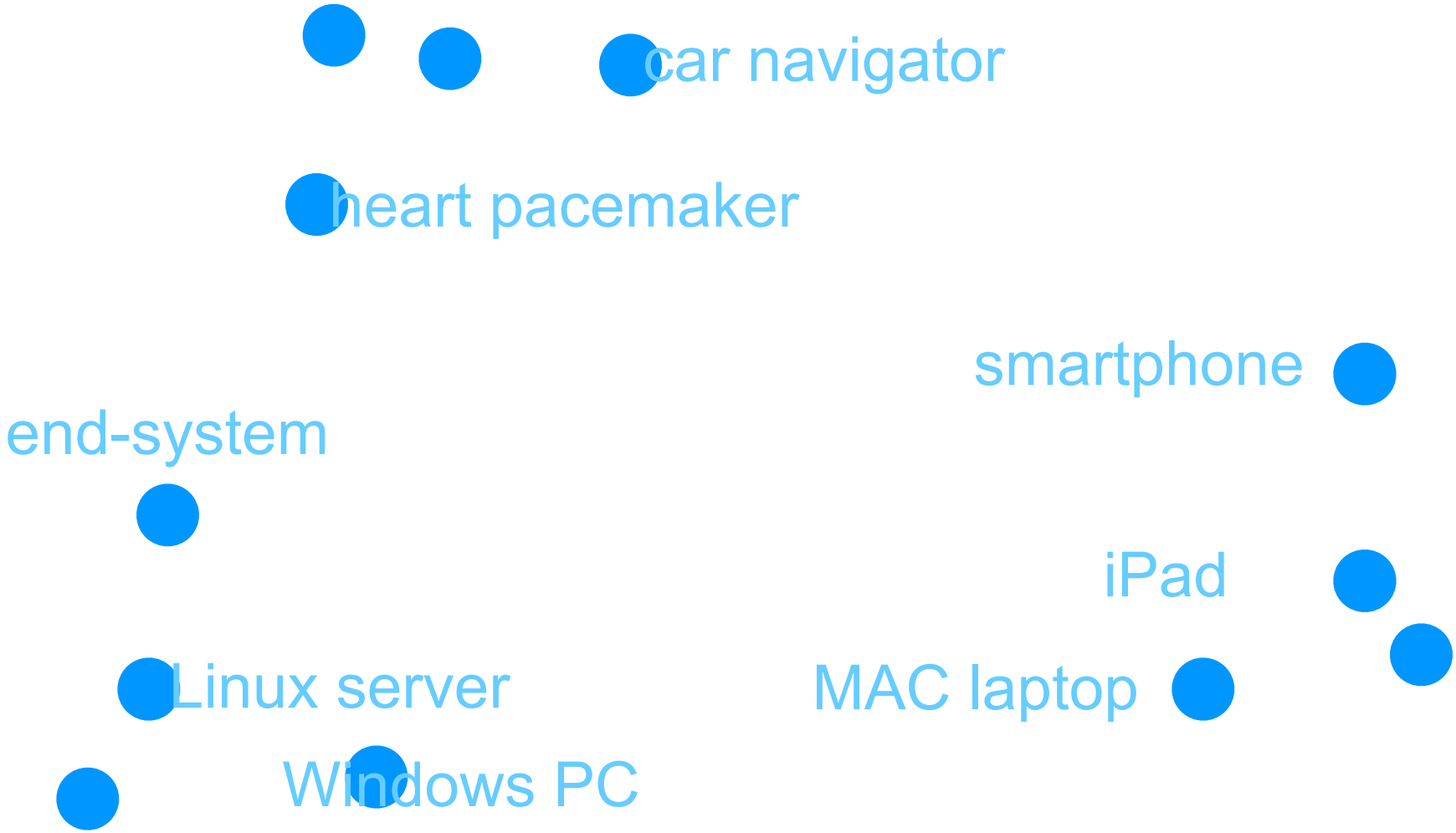
Networking is…

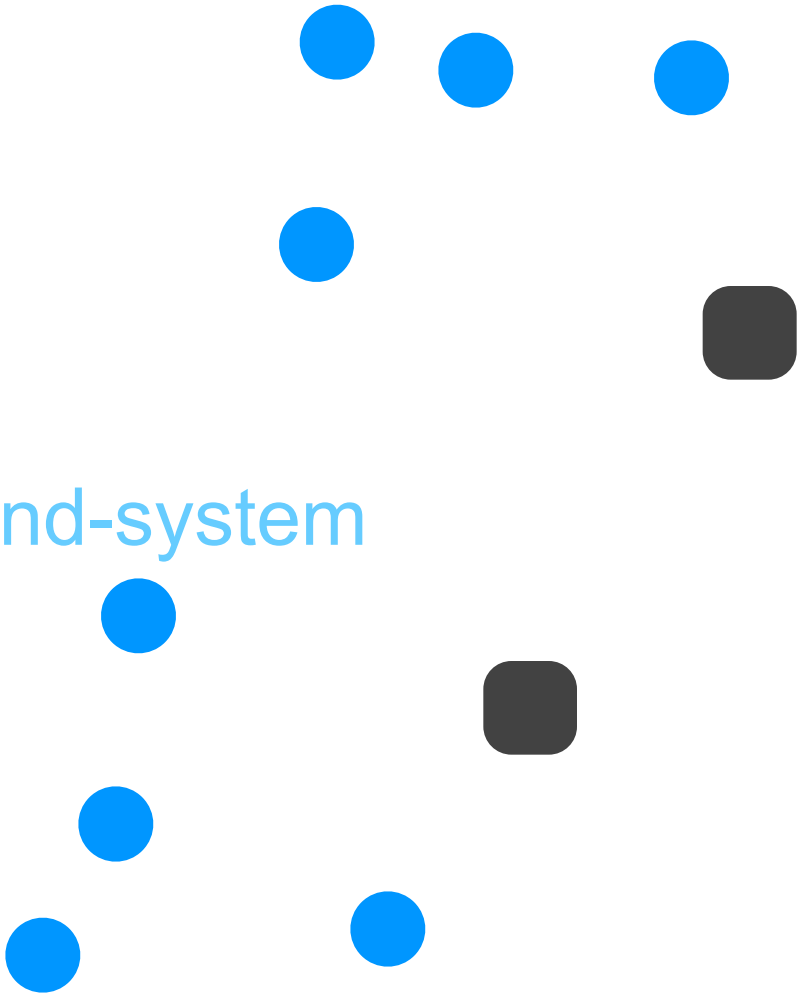
MapReduce, Spark

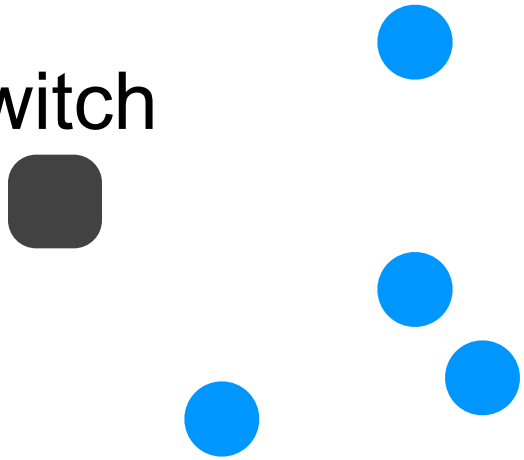
Networking is…

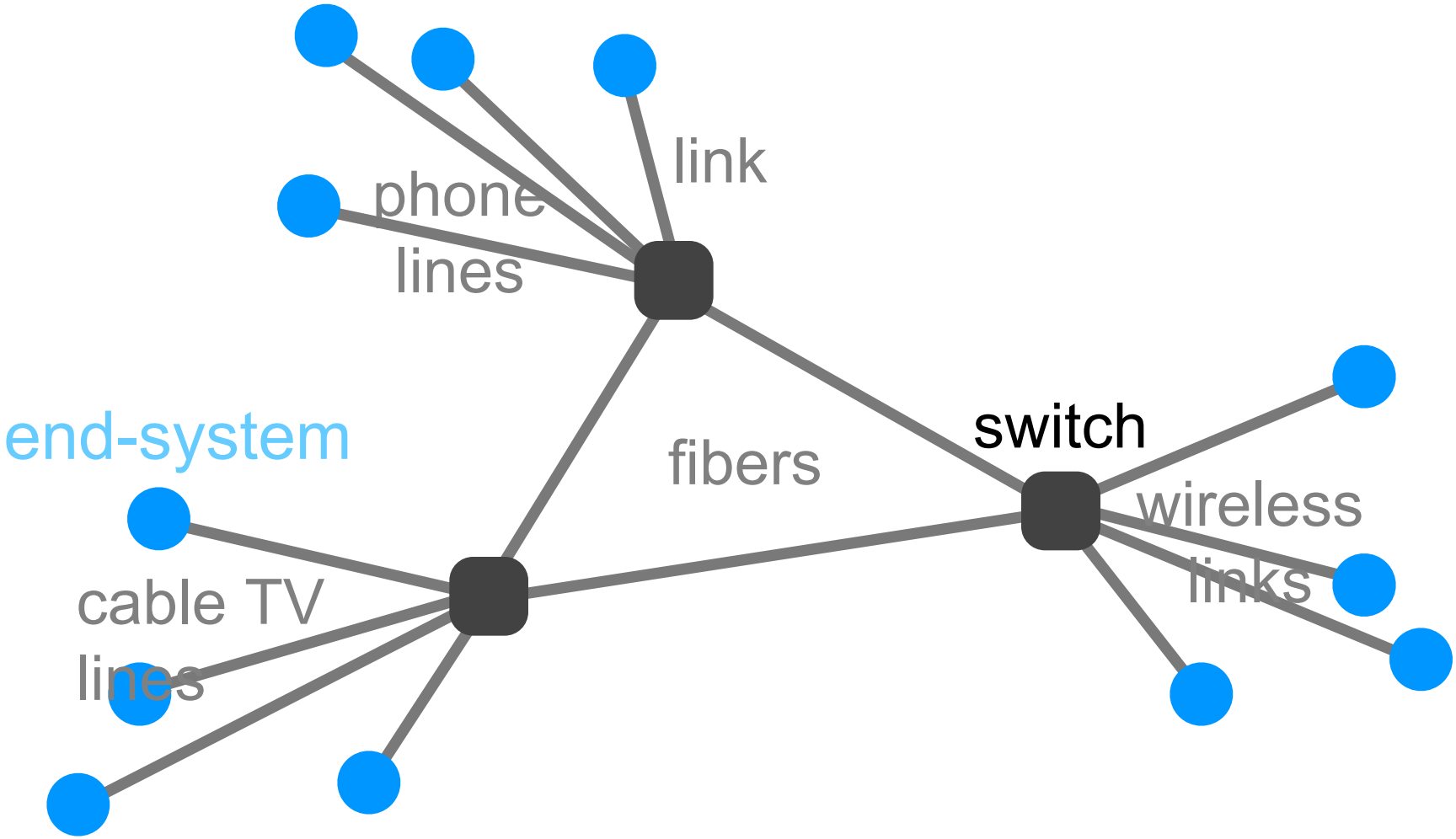
Wi-Fi, LTE, SDN, BGP, MIMO,
mesh-networking, full-duplex,
IoT and medical devices,
datacenter networks,
undersea, deep space. . .

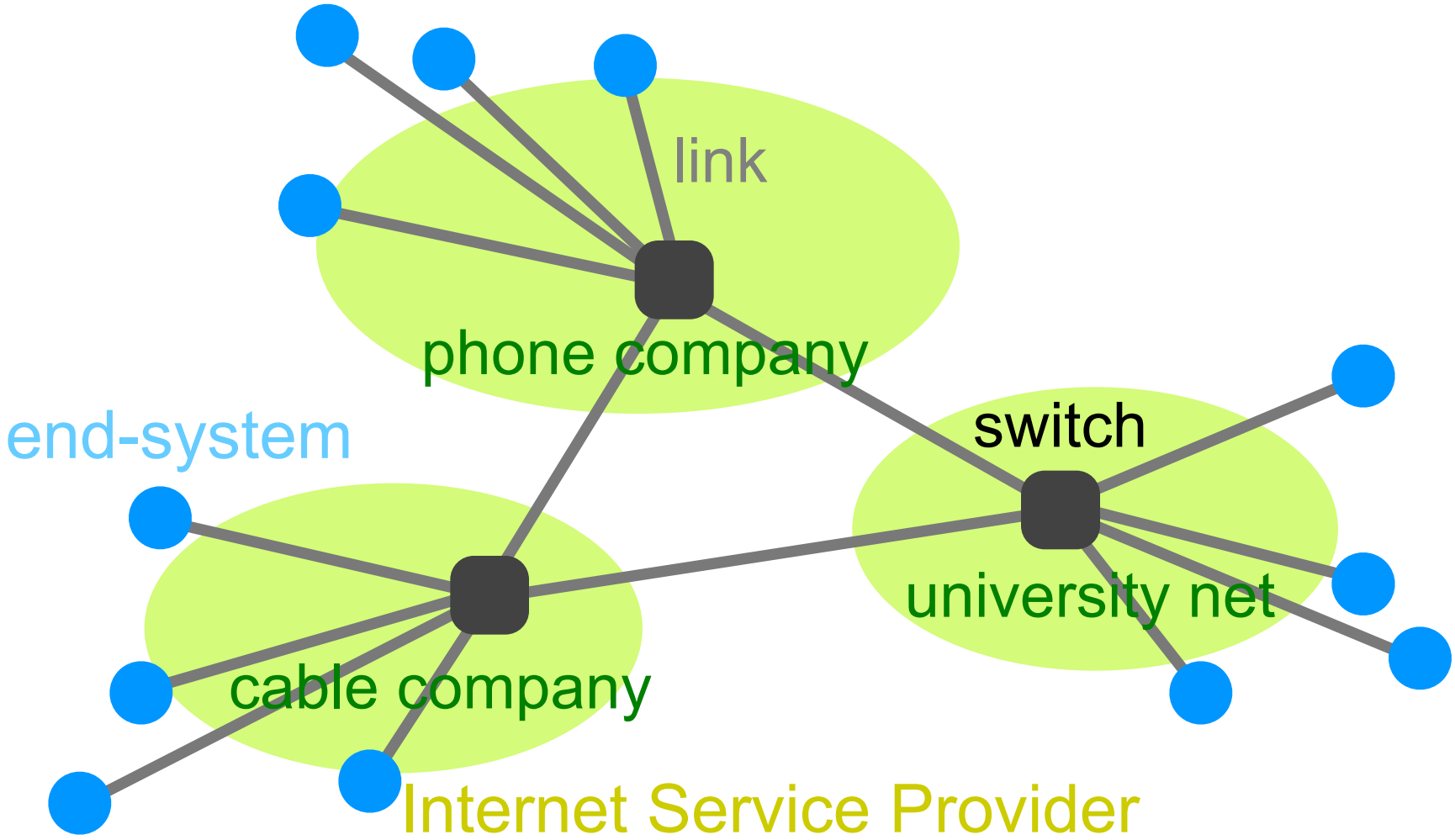
What is *Networking* about?

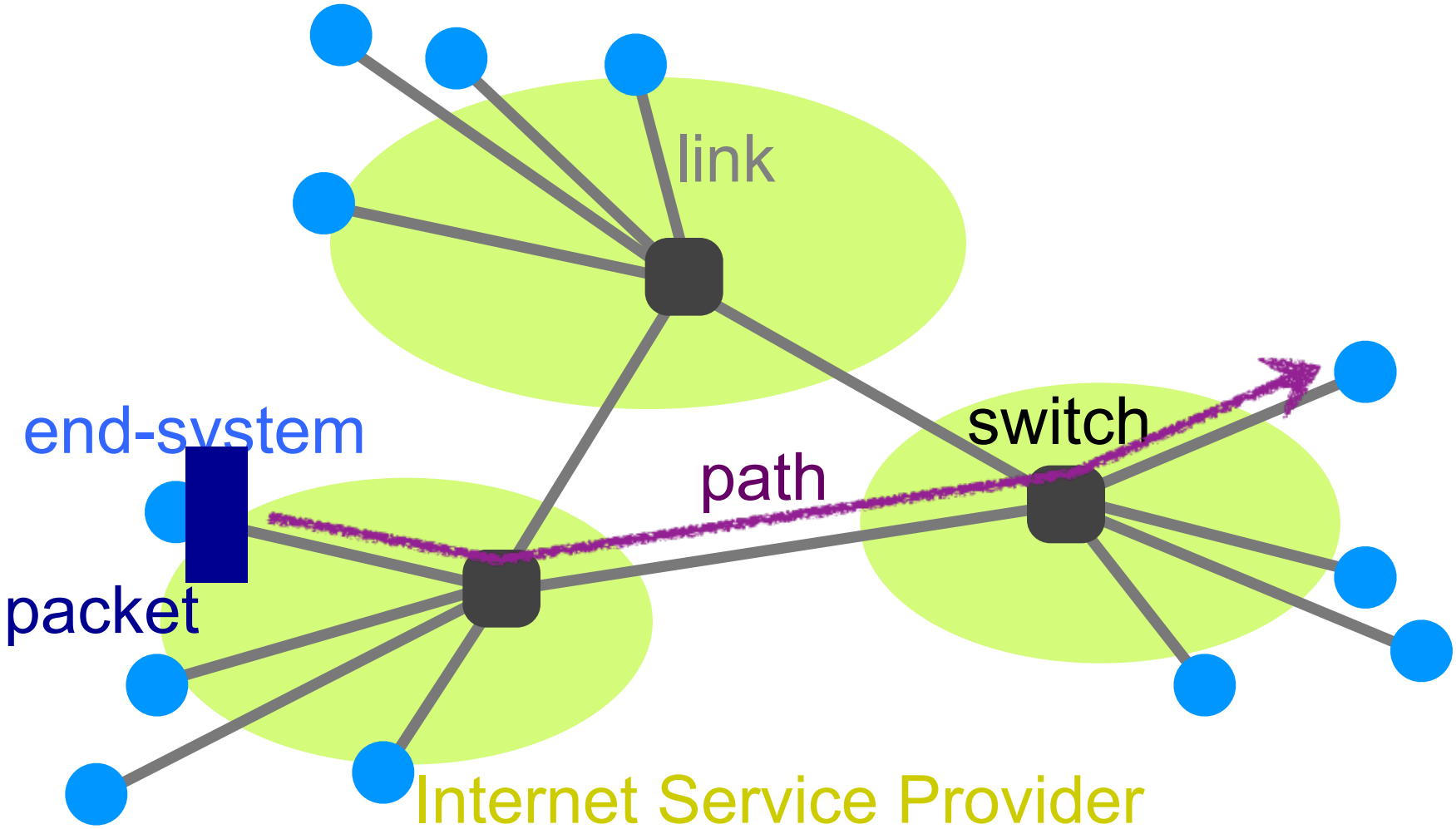

car navigator
heart pacemaker
smartphone
end-system
iPad
Linux server
MAC laptop
Windows PC

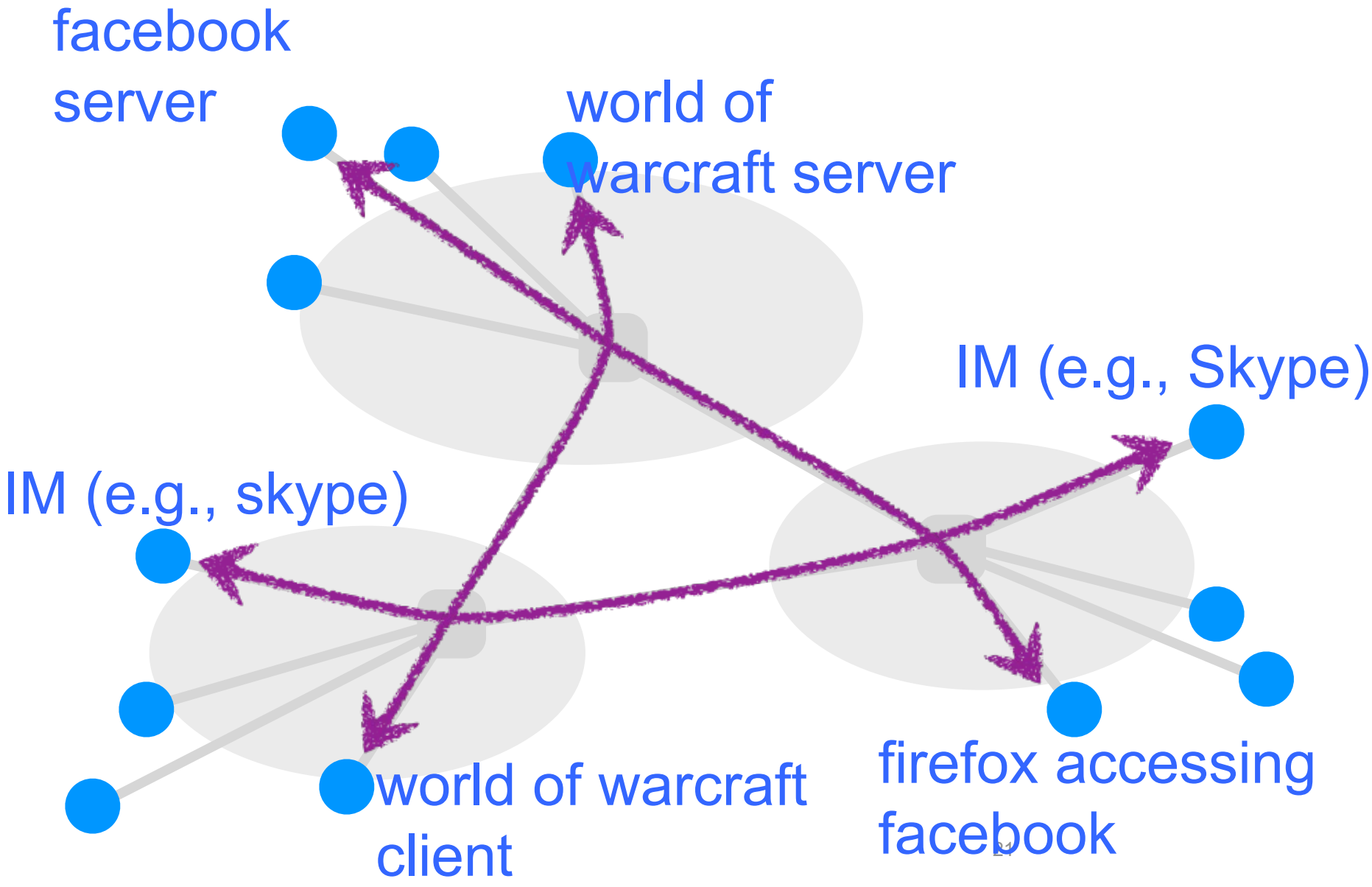

end-system

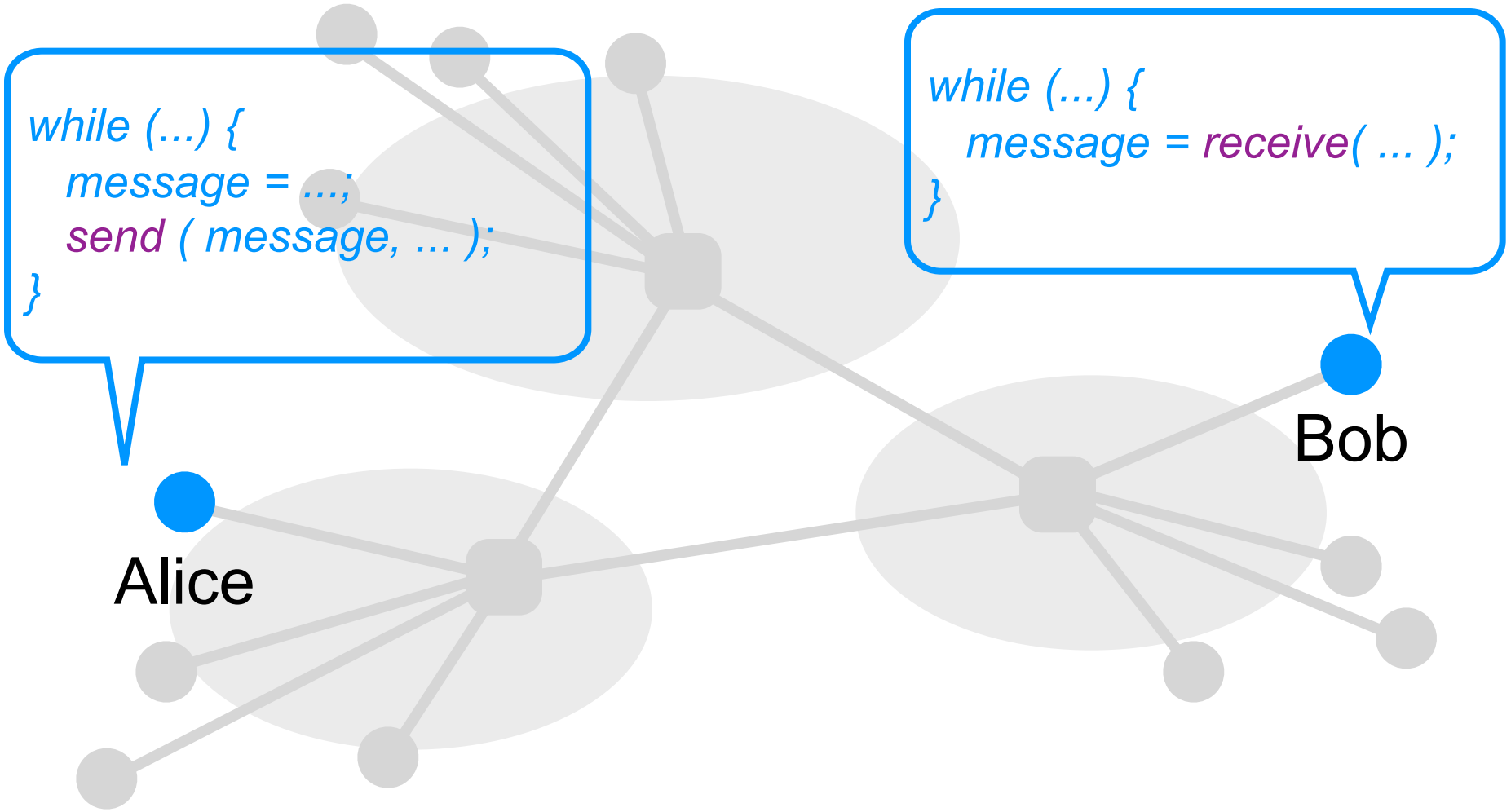

switch

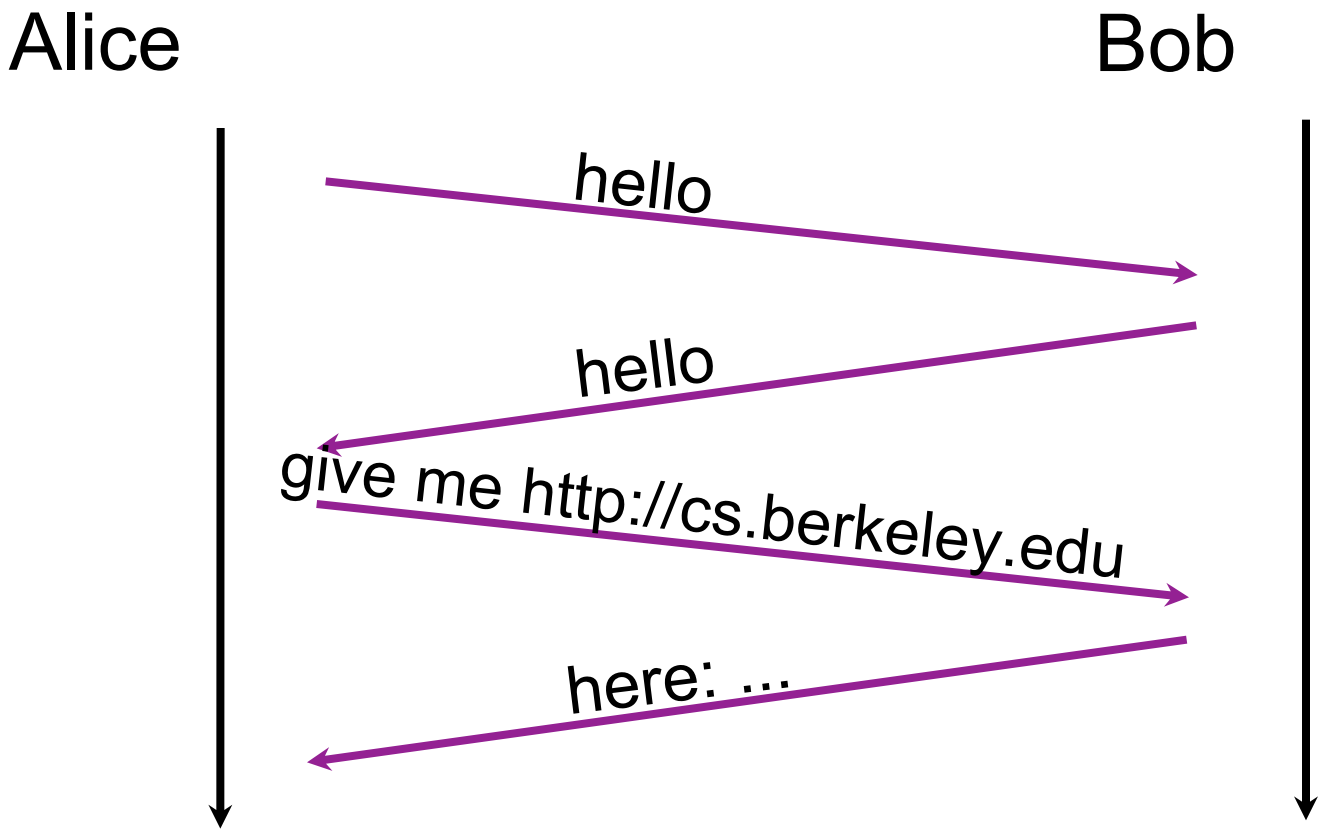

link
phone
lines
end-system
fibers
switch
wireless
links
cable TV
lines


link
phone company
end-system
switch
university net
cable company
Internet Service Provider


link
end-system
switch
path
packet
Internet Service Provider


facebook server
world of warcraft server
IM (e.g., Skype)
IM (e.g., skype)
world of warcraft client
firefox accessing facebook


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


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


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

Internet design challenges?

Basics design considerations

- Connectivity structure
- Addressing
- Data forwarding
- Common language (protocol)
- Flow and congestion control

Why study the Internet?

The Internet is transforming everything

- The way we do **business**
  - *E-commerce, advertising, cloud-computing*
- The way we have **relationships**
  - *Facebook friends, E-mail, IM, virtual worlds*
- The way we **learn**
  - *Wikipedia, MOOCs, search engines*
- The way we **govern** and view **law**
  - *E-voting, censorship, copyright, cyber-attacks*
- The way we cure **disease**
  - *Digital health, remote diagnostics*

The Internet is big business

- Many large and influential networking companies
  - Cisco, Broadcom, AT&T, Verizon, Akamai, Huawei, …
  - $200B+ industry (carrier and enterprise alone)
- Networking central to most technology companies
  - Google, Facebook, Microsoft, HP, Dell, VMware, …

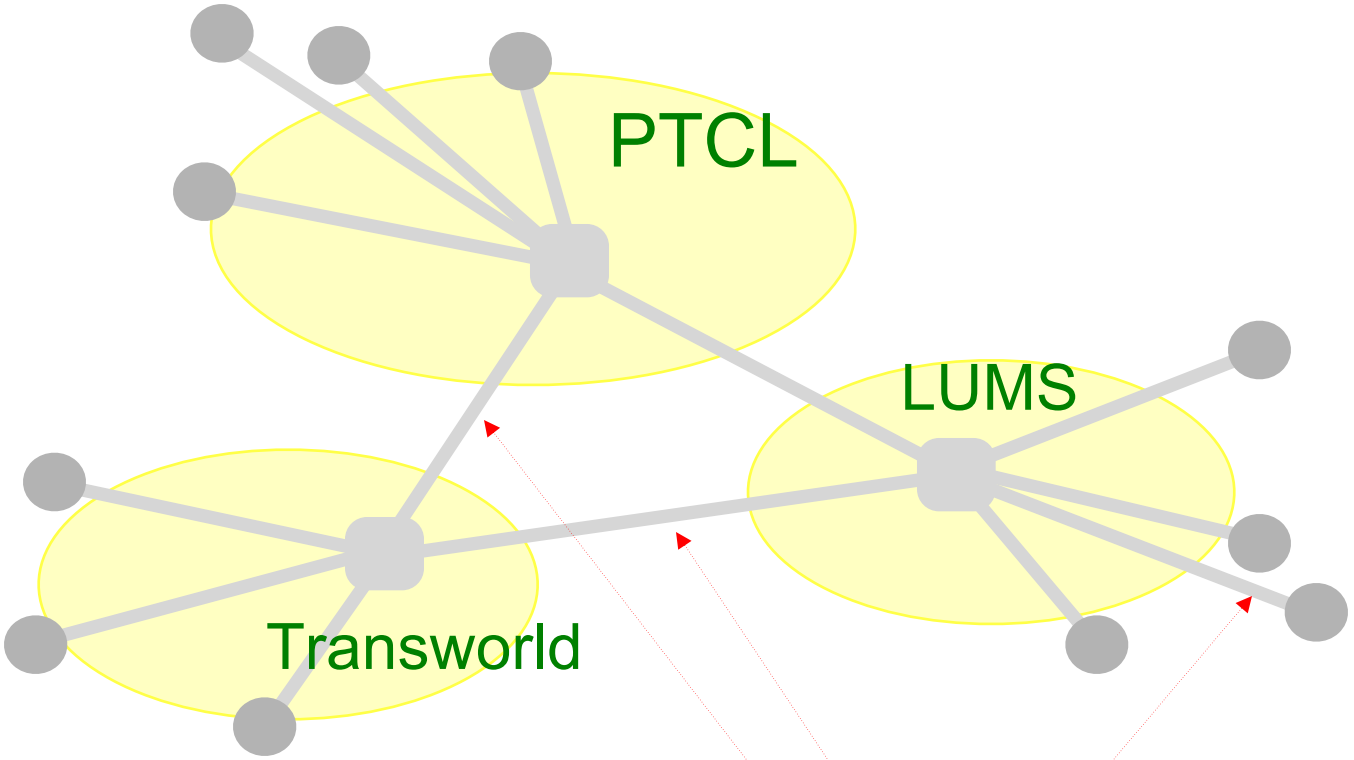
Internet research has impact

- The Internet started as a research experiment!
- 4 of 10 most cited authors work in networking
- *Many* successful companies have emerged from networking research(ers)

A few defining characteristics of the Internet

A federated system

The Internet interconnects different networks (>18,000 ISPs)



One common protocol — the "Internet Protocol (IP) — between users and the network and between networks

A federated system

- Interoperability is the Internet's most important goal

- Leads to a constant tussle between business and technical factors
  - competing ISPs must cooperate to serve their customers
  - practical realities of incentives, economics and real-world trust determine physical topology and path selection
  - a common protocol is great for interoperability …
  - … but complicates innovation

Tremendous scale

- ~3.2 Billion users (almost half of world population)
- 1.2 Billion online websites (a lot more unique URLs)
- 210+ Billion emails sent per day
- More than 2 Billion smartphones
- 2+ Billion Facebook monthly active users
- >400 hours of video uploaded to YouTube every minute
- Switches that move 300Terabits/second
- Links that carry 100 Gigabits/second

Enormous diversity and dynamic range

- Communication latency: microseconds to seconds (10^6)
- Bandwidth: 1Kbits/second to 100 Gigabits/second (10^7)
- Packet loss: 0 – 90%
- Technology: optical, wireless, satellite, copper
- Endpoint devices: IoT, sensors, cell phones, datacenters
- Applications: skype, live video, gaming, remote medicine,
- Users: the governing, governed, operators, selfish, malicious, naïve, savvy, embarrassed, paranoid, …

Constant Evolution

1970s:

- 56kilobits/second “backbone” links
- <100 computers, a handful of sites in the US
- Email, Telnet and file transfer are the “killer” applications

Today:

- 100+Gigabits/second backbone links
- 5B+ devices, all over the globe
- Millions of apps (from stores) installed per day

Asynchronous Operation

- Fundamental constraint: speed of light
- Consider:
  - How many cycles does your 2.8GHz CPU execute before it can possibly get a response against a message it sends to a server in Karachi?
    - Lahore to Karachi: 1,225 km
    - Traveling at 300,000 km/s: 4.0833 milliseconds
    - Then back to Lahore: 2 x 4.0833 = 8.1666 milliseconds
    - 2,800,000,000 cycles/sec * 0.0081666 = 22,866,480 cycles!
- Thus, communication feedback is always *dated*

Prone to Failure

- To send a message, all components along a path must function correctly
  - software, modem, wireless access point, firewall, links, network interface cards, switches,…
  - Including human operators
- Consider: 50 components, that work correctly 99% of time → 39.5% chance communication will fail
- Plus, recall
  - scale → lots of components
  - asynchrony → takes a long time to hear (bad) news

An Engineered System

- Constrained by limits of available technology
  - Link bandwidths
  - Switch port counts
  - Bit error rates
  - Cost
  - …

Recap: The Internet is…

- A federated system
- Of enormous scale
- Dynamic range
- Diversity
- Constantly evolving
- Asynchronous in operation
- Failure prone
- Constrained by what's practical to engineer

What we know

- The early Internet pioneers came up with a solution that was successful beyond all imagination
- Several enduring architectural principles and practices emerged from their work

Architectural principles

- Decentralization [lectures: all]
- Packets [lecture# 1,2]
- Statistical multiplexing [lecture 1,2,3]
- Best effort service [lecture 3+]
- The “end to end” design principle [lecture 3+]
- “Layered” decomposition [lectures: all]
- IP as “narrow waist” interface [chapter 4]

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

What (we hope) this course will teach you

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

Topics we will cover

- Basic concepts
  - packets, circuits, delay, loss, protocols
- How the “insides” of the Internet work
  - IP, DV/LS routing, BGP
- How endpoints use the network
  - TCP, DNS, HTTP
- Crucial lower-level technologies
  - Ethernet, wireless
- Some important new(er) topics
  - management, security, WiFi, datacenters

Any questions?

Thanks!