CS/ECE 4457

Computer Networks: Architecture and Protocols

Qizhe Cai

Context for today's lecture

- This will be my first time teaching this class
- I'm really looking forward to it!
- Good dynamics, from the very beginning
- Explicit about my expectations
    - Knowing exactly what you expect to do …
    - Going above and beyond to meet those expectations …
    - …

Goal of Today's Lecture

- Tell you about the course
    - What we will cover
    - How I teach
    - What I expect from you
- You can then decide whether you want to take the course
- If you stay:
    - you have been forewarned, and
    - you are agreeing to my conditions

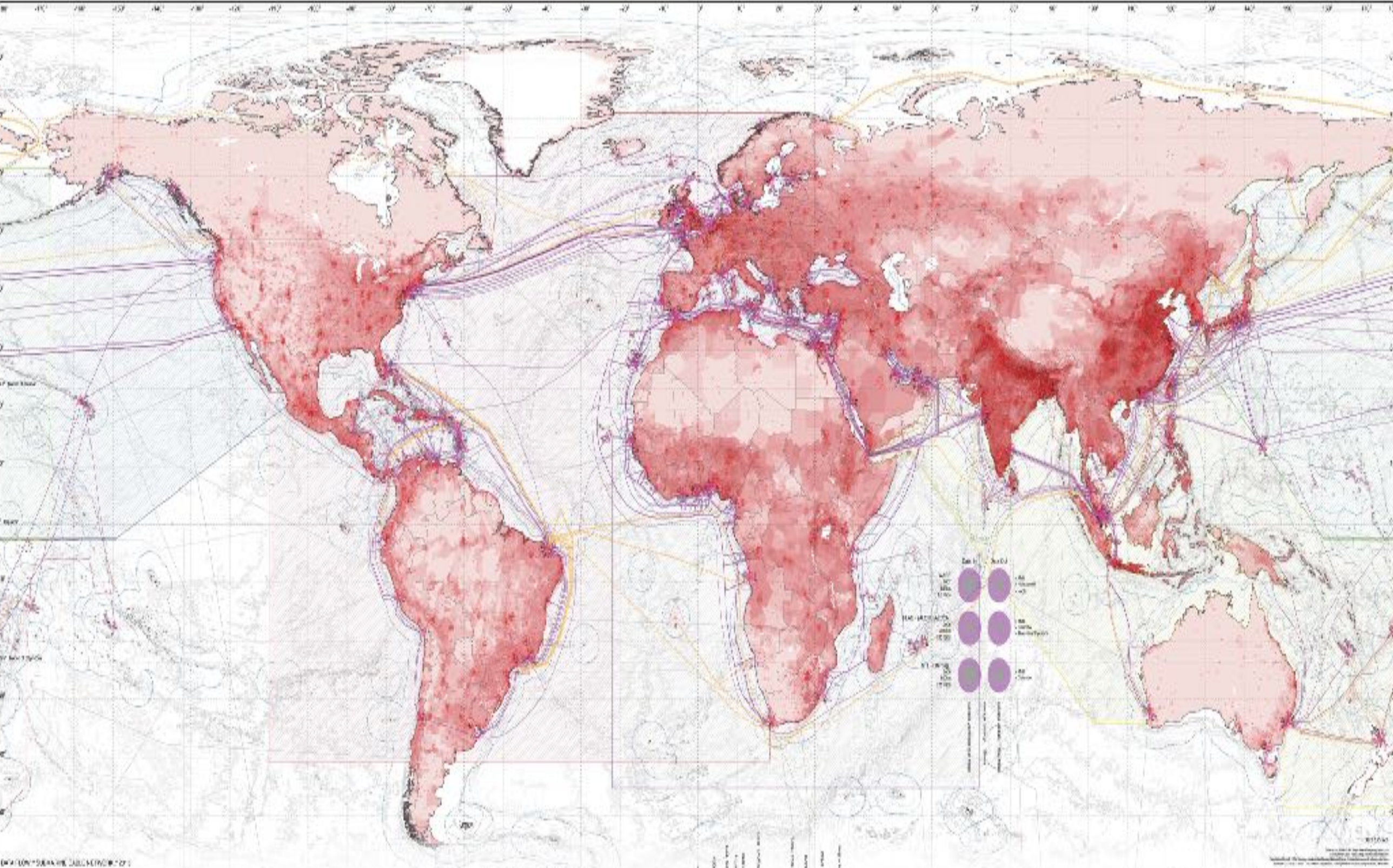
The “contract”

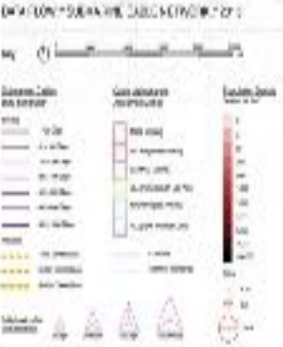
- **You will try to attend every class**
- You will not treat Piazza/ as a substitute for class attendance
- **You will not talk in the class, unless I ask you to**
- You will not complain if slides do not capture everything I have said
- You will not complain that my slides look like they were made in PowerPoint ’97.
- **You will try to laugh at my jokes, even if they are terrible**

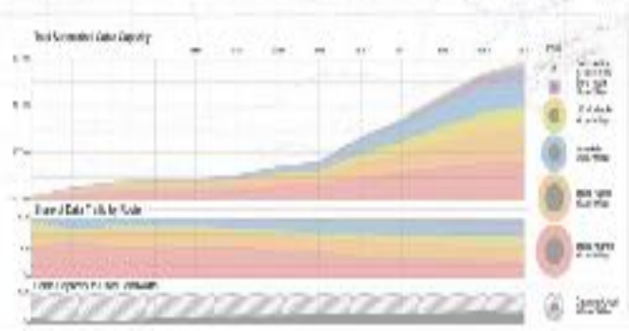
Today's lecture: 10 basic questions

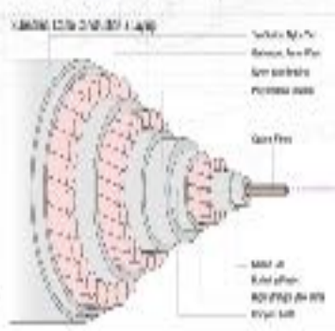
1. **What do I mean by "computer networks"?**
2. **What do computer networks do?**
3. What do computer networks look like?
4. Why study computer networks?
5. **What is this course about?**
6. What is the course workload, grading policies, etc.?
7. How will this course be organized?
8. Who am I?
9. **How do I teach?**
10. **Is CS4457 the right class for you?**

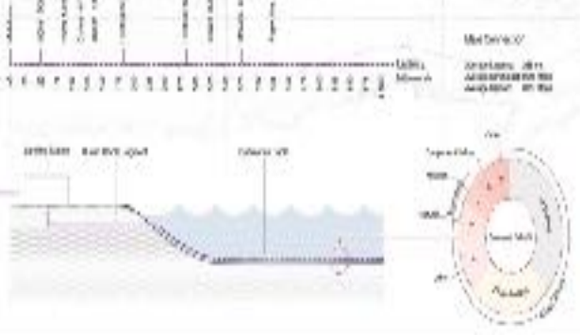
#1: What do I mean by “computer networks”?











What is a computer network?

A set of network elements connected together, that implement a set of protocols for the purpose of sharing resources at the end hosts

- **Three important components**:
  - **Set of network elements, connected together:**
    - Core “infrastructure”
  - **Protocols:**
    - Needed to use the network
- **Purpose:**
  - Sharing resources at the end hosts (computing devices)

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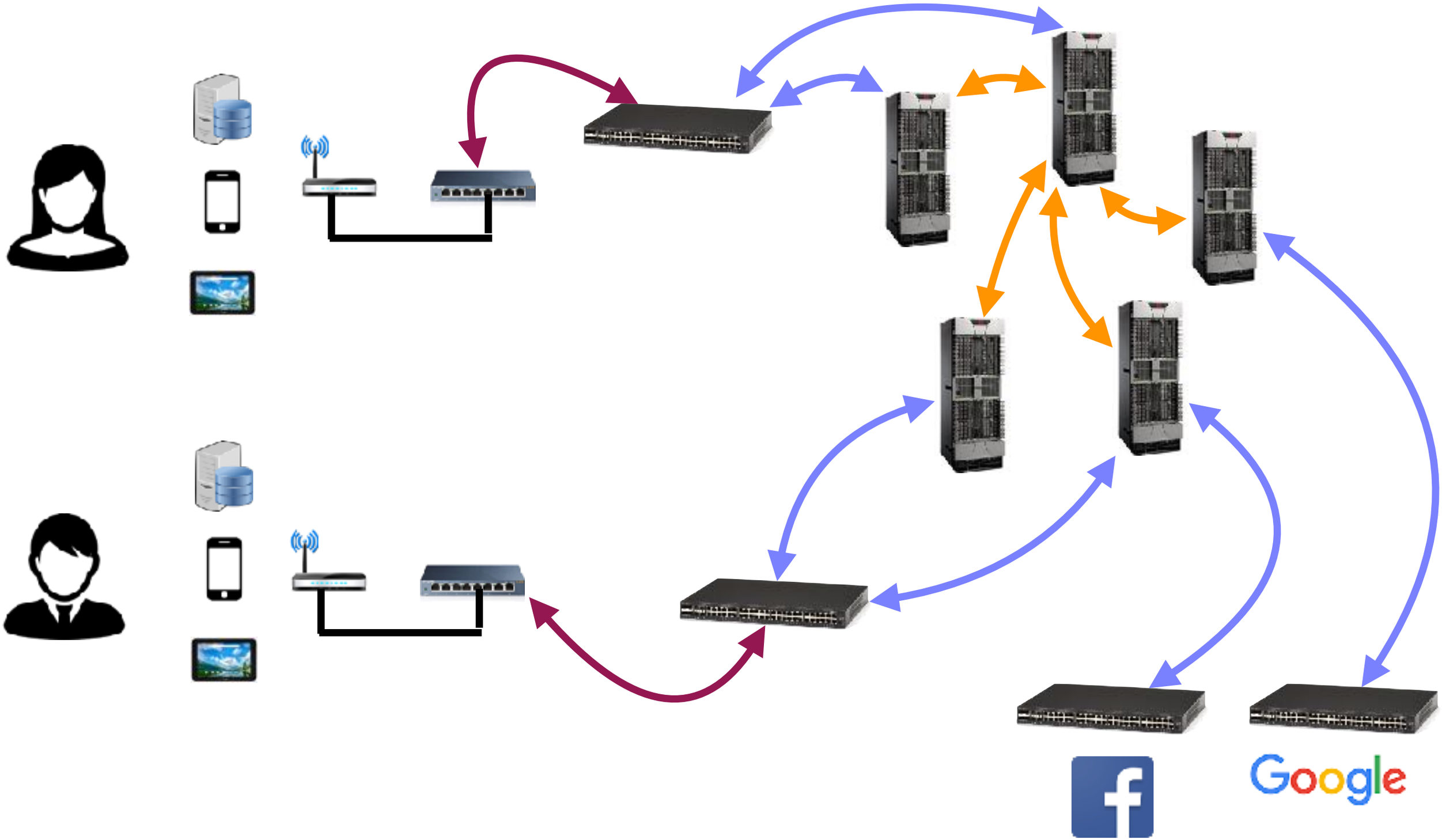

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Questions?

#2: What do computer networks do?

What do computer networks do?

A computer network delivers data between the end points

- **One and only one task**: Delivering the data
- **Read that sentence again. Remember it forever.**

- This delivery is done by:
    - Chopping the data into **packets**
    - Sending individual packets across the network
    - Reconstructing the data at the end points

- **That is all! This course:**
    - Evolution of three components of computer networks!
        - Infrastructure, protocols, purpose
    - Why the *&#@ has it taken 50 years of research (and counting) to design a data delivery system

Data delivery as a fundamental goal

- **Support the logical equivalence of <u>Interprocess Communication (IPC)</u>**
    - Mechanism for “processes on the same host” to exchange messages
- **Computer networks allow “processes on two different hosts” to exchange messages**
- **Clean separation of concerns**
    - Computer networks deliver data
    - Applications running on end hosts decide what to do with the data
- **Keeps networks simple, general and application-agnostic**

Questions?

#3: What do computer networks look like?

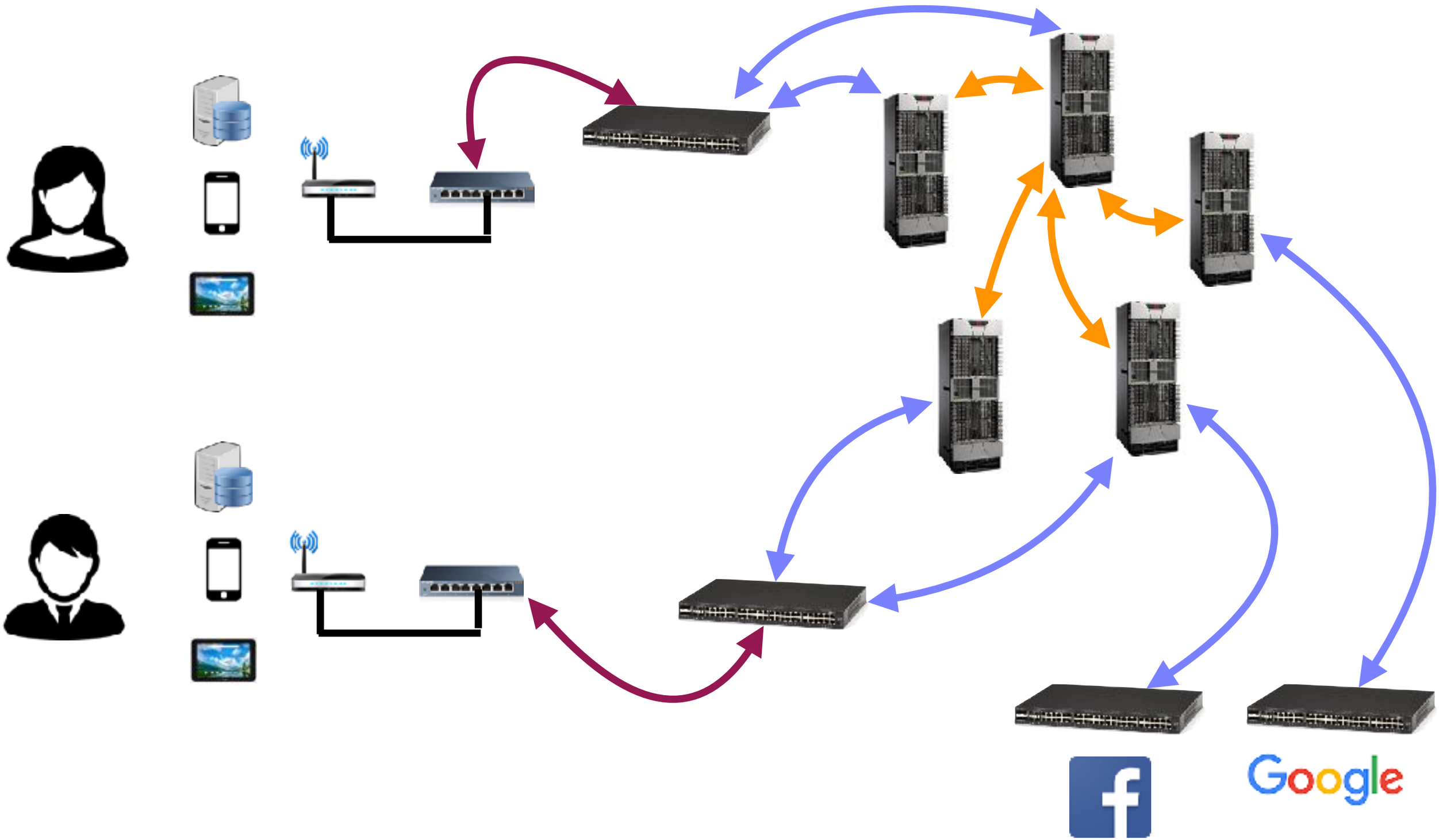
What do computer networks look like?

Three Basic components

- **End hosts**: they send/receive packets
- **Switches/Routers:** they forward packets
- **Links:** connect end hosts to switches, and switches to each other

What do computer networks look like?

End hosts, switches/routers, links



#4: Why study computer networks?

Why study computer networks?

What would the world look like without the Internet?

- **Lets see**

Why study computer networks?

#1: Has transformed and more importantly, <u>is transforming everything</u>!

- **Industry: core to and creator of many large and influential companies**
    - Google, Meta, Apple, Cisco, Broadcom, AT&T, Verizon, Akamai
- **Communication**
    - Email, messenger, phones, VoIP, …
- **Travel**
    - Airbnb, Uber, Maps, …
- **Health**
    - Digital health, remote diagnostics, ….
- **Entertainment**
    - Netflix, news
- **Relationships**
    - Okcupid, Tinder, …

Why study computer networks?

#2: To learn how to design for tussle!

- **Federated System**
  - The Internet interconnects different networks
    - >18000 Internet Service Providers (ISPs)
  - How do you interconnect distrustful and competing entities?
  - Constant tussle between business and technical factors!

Why study computer networks?

#3: To learn how to design for scale!

- **Tremendous scale**
    - 51% of world population
    - 1.24 trillion unique web pages
    - Every **second**, approximately
        - > 2 million emails
        - > 40000 Google search queries
        - > 6000 Tweets
- **Introduced the phrase “Internet-scale”**

Why study computer networks?

#4: To learn how to design for <u>diversity</u>!

- **Communication latency:** Microseconds to seconds
- **Bandwidth:** 1Kilobits/second to 100Gigabits/second
- **Packet Loss:** 0-90%
- **Technology:** Wireless, satellite, optical, copper, …
- **End hosts:** Sensors, cell phones, computers, servers, datacenters, …
- **Applications:** www, voice, video, gaming, remote medicine
- **Trust models:** selfish (users), malicious (attackers), greedy (companies), …

And yet, everything needs to work in tandem!

Why study computer networks?

#5: To learn how to design for <u>evolution</u>!

	1970	Today
Bandwidth	50 kbps	100+ Gbps
#End hosts	< 100 computers	8 billion +
Applications	Telnet and File transfer	!!

We have no clue what 2035 would be like!

Why study computer networks?

#6: To learn how to think <u>"architecture rather than engineering"</u>!

- **The early pioneers came up with a solution that has lasted for 40 years!**
    - Almost unchanged!!! A true success story of "thinking differently"!!
    - Brilliant in conception; sometimes weak in execution
    - Several **architectural principles** emerged
        - Decentralization [All lectures]
        - "Packets" [Lecture #2]
        - Statistical multiplexing [Lecture #2]
        - The end-to-end principle [Lecture #3, #6+]
        - Layering [Lecture #3, #6+]
        - Best effort service [Lecture #4, #6+]
        - Narrow waist interface [Lecture #6]

Why study computer networks?

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Computer networks offer us a lesson on how to "reason" through the design of a complex, diverse, ever-evolving, failure-prone system

- What are our goals and constraints? How to prioritize them?
- How do we decompose a problem into smaller components?
- How to partition the functionality across multiple components?
- What are the design tradeoffs?

In short, how to architect a system!

#5: What is this course about?

What is this course <u>not</u> about?

- **There are many kinds of computer networks (and technologies)**
  - Telephone (landline) networks
  - Cellular networks
  - Wireless networks
  - Optical networks
  - Infiniband
  - ….
- **And many applications of these computer networks**
  - World Wide Web
  - Multimedia streaming
  - Social networks
  - Email/audio/video messaging
  - Search
  - ….

What is this course about?

Architectural principles, design goals and performance objectives in wired networks

- **What tasks get done?**
  - What is delivered (packets, files, …)?
  - What are the semantics (reliability, ordering, …)?
- **Where do tasks get done?**
  - At the network elements? At the end-hosts?
- **How tasks get done?**
  - What protocols and algorithms do each of these use?
  - How to achieve various performance objectives (latency, etc.)?

What is this course about?

Architectural principles, design goals and performance objectives in wired networks

- **Mostly drawing examples from the Internet**
  - Not a particular kind of network
  - Not just another technology on the list
  - **Ties different networks together**

- **Why Internet?**
  - Has similar goals as individual network technologies
    - Speed, Cost, Reliability, …
  - Has an additional fundamental goal
    - **Ability to connect all computer networks (and technologies)**
    - **Leads to myriad of new challenges**

Questions?

#6: What is the course workload, grading policies, etc.?

Course workload

- **Problem set, one every two weeks**
    - For you to practice questions; solutions available after one week
- **In-class surprise quizzes**
    - There may be no quiz, or there may be a quiz per lecture
    - Pay attention, regularly read material, attend lectures
- **Three exams**
- **Class feedback**

Course grade

- **We will assign you 2 preliminary grades**

	Grade1	Grade 2
Exam 1	20	20
Exam 2	25	30
Exam 3	40	45
Quizzes	10	0
Course eval	5	5

- Your **final grade** will be the **best out of the 2** preliminary grades
- **I am perfectly happy to assign everybody an A grade**

Course workload

- **My courses tend to be "heavy": require <u>regular attention</u>**
    - You have been warned!
- **My exams tend to be hard**
    - You have been warned!
- **Quizzes will be simple**
    - Pay attention, regularly read material, attend lectures
    - Solve problem sets regularly

#7: How will this course be organized?

Course organization

- **Prerequisites**
  - This is a senior-level course
  - We expect knowledge of algorithms, probability, data structures
    - Review your past courses as needed
- **Textbook**
  - **Computer Networks: A systems approach**
    - 6th edition, but others are fine too (translate sections, etc.)
    - We will not follow its order of presentation
    - Instead, use it as a reference for individual topics
  - e-version of the book available online
- **Advanced readings**
  - If you get curious about a topic and want to read more
  - Anything not covered in the class will not be in exams/quizzes

Interaction with course staff

- **Piazza**
    - Not a substitute for classes
- **Office hours**
    - We want to choose timings that suit you;
    - We will announce office hours (time/location) on Piazza
- **Website:**
    - https://www.qizhecai.com/cs4457-sp26/

Interaction with course staff

- **Piazza**
    - Not a substitute for classes
- **cs4457staffsp26@virginia.edu**
    - For time-sensitive matters

5 minute break

#8: Who am I?

Instructor — Qizhe Cai

- **Assistant Professor**
- **Previously**: Cornell
- **Office:** 102, Rice Hall
- **Proud of: my students**
  - One PhD student: Tianyu

Instructor — Qizhe Cai

- **Research interests**: **problems that excite me**
    - Publish in top conferences of several areas:
        - **Networking (NSDI, SIGCOMM)**
        - **Operating systems (OSDI,SOSP)**

- **Non-research interests:**
    - Video games
    - Sports: soccer, football (mainly watching these days)

#5: How do I teach?

My teaching style not for everyone …

- **I am not a great educator**
- **I teach the old-fashioned way — I talk, you listen**
- If you want to be online, or talk to your friends
    - Then please pick another class …
    - … and leave the class for those who want to learn
- I should never have to ask for quiet during lecture
    - If things get bad, I'll start asking people to leave

Second, my teaching style not for everyone …

- **I ask more questions than I answer**
    - Ask questions before telling you a concept/algorithm
    - This is a key part of my teaching style
    - Why do I ask questions …
        - I probably know the answer
        - I can probably explain the answer better than most of you
        - So, why I ask?

Second, my teaching style not for everyone …

- **I ask questions so you can think!**
    - The pause after the question is the only time you get to think
    - When I ask a question, I don't care if you answer
    - But please, **think about the question**!
- **The discussion is more important than the answer**
    - Do **not** focus on <u>how</u> networks are "implemented"
    - Focus on <u>why</u> the networks are "architected" the way they are
- **The best way to learn about networks:**
    - Cannot "follow the logic", have to try designing yourself
    - First think about how you would solve the problem
    - Then, the solution used by networks would make a lot more sense

Third

- **Focus on the big picture**
    - **What is the conceptual question?**
    - **What is the key insight?**
    - **What is the basic answer?**

- Learn the details later
    - But only when they make sense in the larger context

- Don’t start by focusing on details
    - I am bad at them
    - Course will be boring
    - We will both be wasting our time

Fourth, I know exactly what I expect of you

- **Show up**

- Ask questions when you don’t understand
    - Or when you want to understand better

- Answer (or think about) questions when I ask them
    - Even if you aren’t sure of the answer

- **Be quiet during the lecture**

- Laugh at my jokes

#10: Is CS4457 the right course for you?

Ask yourself four questions…

- **Agree with the contract?**
  - No violation to the agreement
- **Want to understand the "concepts" and the "why" of networking?**
  - Not just looking for definitions, techniques and pseudo-codes
- **Willing to work regularly**
  - Attend lectures regularly
  - Work on problem sets regularly
- **Ready to have fun?**

If you decide to stay …

Announcements

- The webpage is up
    - Your first stop for all questions
    - **Read the webpage for course policies, etc.**

- Check for exam dates on webpage
    - If you have a conflict, let us know before 01/20
        - Sending emails to **cs4457staffsp26@virginia.edu**
    - We will not be able to accommodate ANY request after that date

If you decide to stay …

Next lecture

- The beautiful concept of packets and flows
- Why packets and flows?
- What is statistical multiplexing?
- How long does it take for a packet to go from source S to destination D?