CS4450

Computer Networks: Architecture and Protocols

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Acknowledgment

- I have learnt computer networks from some of the great teachers
    - Sylvia Ratnasamy, UC Berkeley
    - Ion Stoica, UC Berkeley
    - Scott Shenker, UC Berkeley
    - Jen Rexford, Princeton
    - Nitin Vaidya, UIUC
    - Brighten Godfrey, UIUC
    - Matthew Caesar, UIUC

- These slides have been shamelessly stolen from their courses

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

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? And, what do I expect from you?**
10. **Is CS4450 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**:
  - **Core infrastructure:**
    - A set of network elements connected together
  - **Protocols:**
    - Needed to use the network
- **Purpose:**
  - Sharing resources at the end hosts (computing devices)

What is a computer network?

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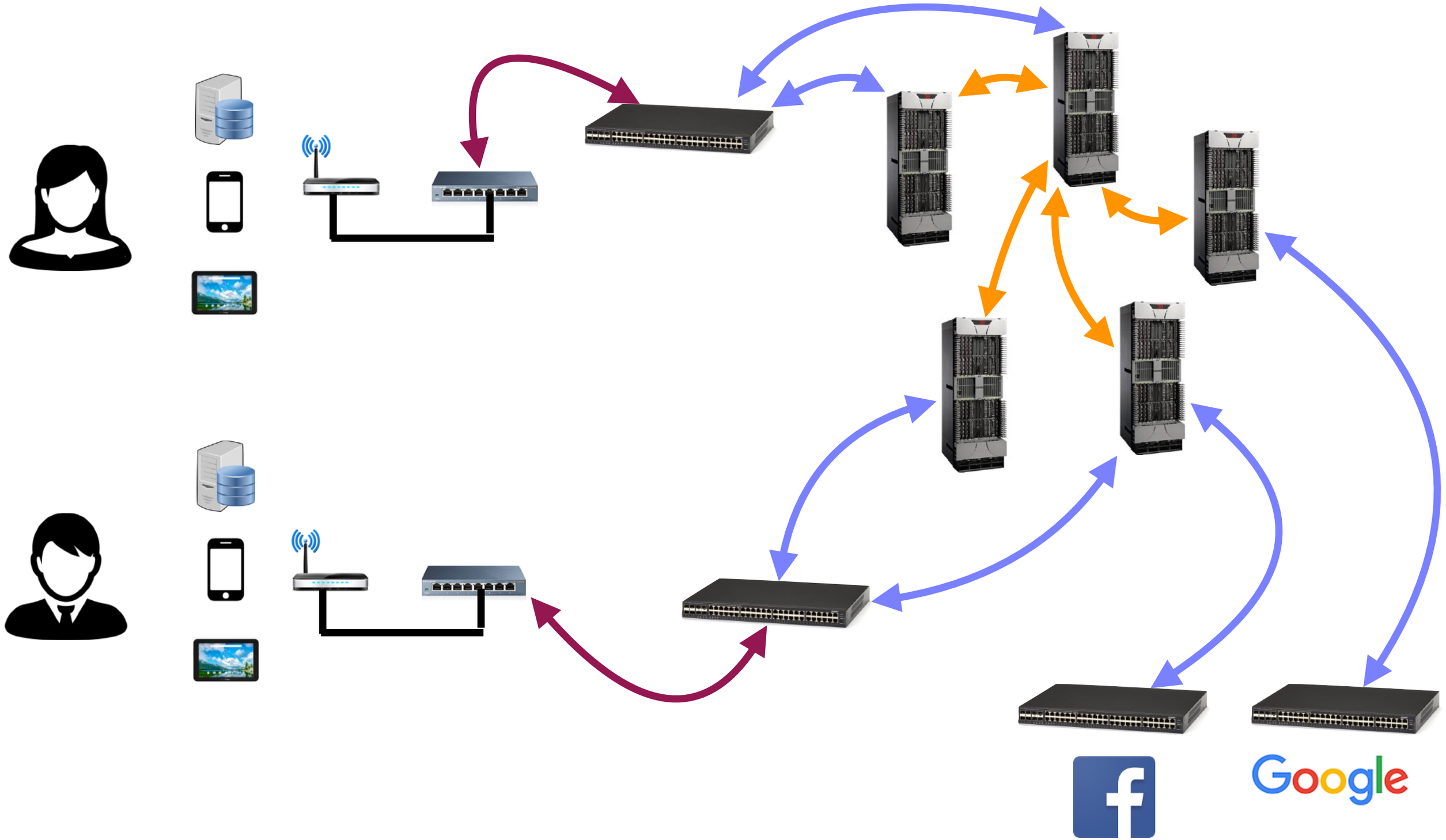

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Questions?

#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 40 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?

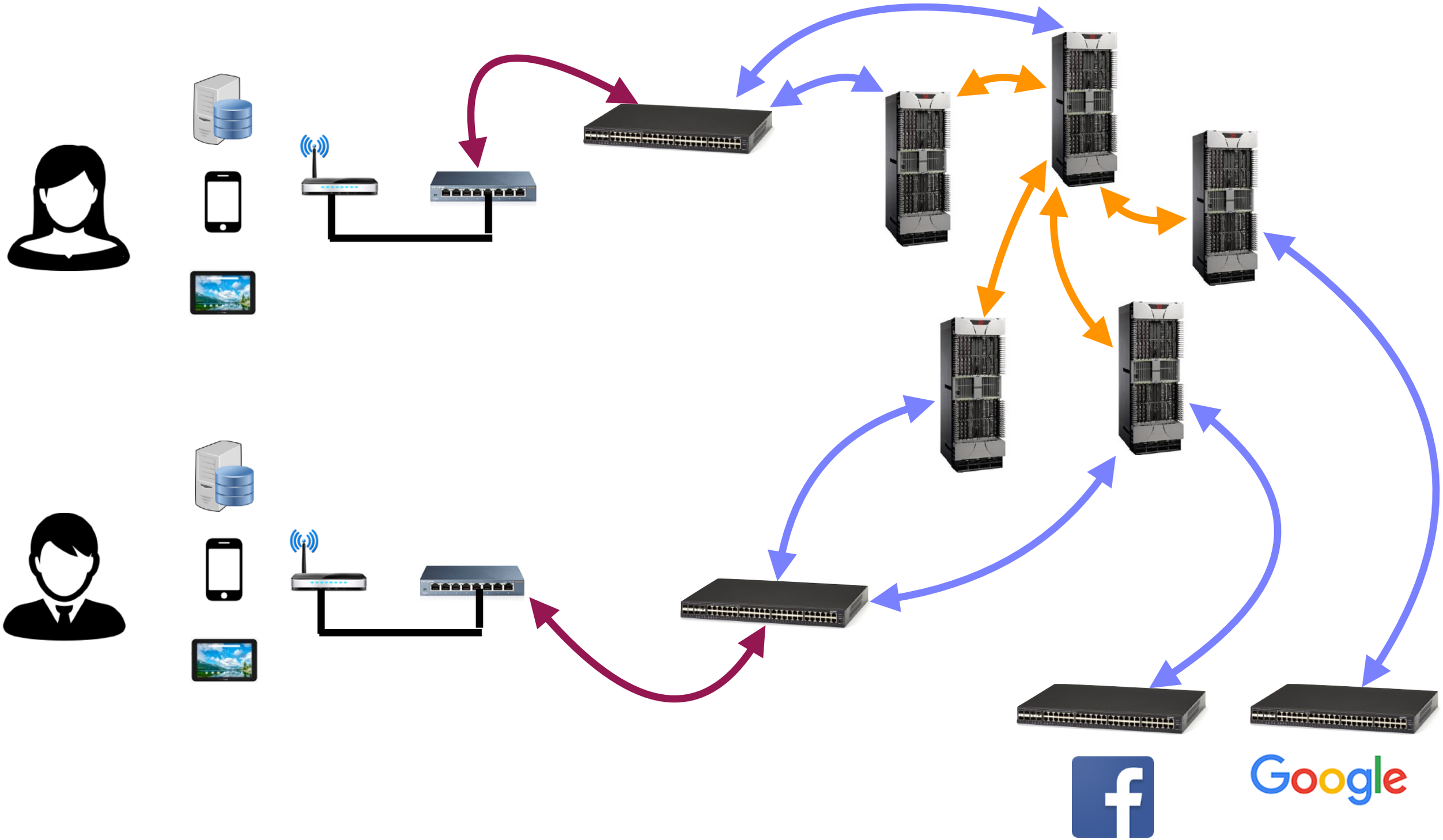
What do computer networks look like?

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, Facebook, 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 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 <u>scale</u>!

- **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 2020 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 do end hosts interface with network elements?
  - How do different network elements interface with each other?
- **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 (0%)**
    - For you to practice questions; solutions available after one week

- **In-class surprise quizzes (20%)**
    - There may be no quiz, or there may be a quiz per lecture
    - Pay attention, regularly read material, attend lectures

- **One prelim (30%)**
    - 03/29, 7:30PM, Gates G01
    - Everything covered in class until 03/15

- **Final (45%)**
    - 05/22, 9AM (location to be announced)
    - Everything covered in the course

- **Class feedback (5%)**

Course workload

- **My courses tend to be "heavy": require <u>regular attention</u>**
    - You have been warned!

- **My exams tend to be hard**
    - For those who miss lectures and do not care about problem sets!
    - But easy for people who attend lectures and solve problem sets.
    - 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 OS, algorithms, probability, algebra
    - Review your past courses as needed

- **Textbook**
  - **Computer Networks: A systems approach (5th edition)**
    - We will not follow its order of presentation
    - Instead, use it as a reference for individual topics
  - e-version of the book available via Cornell library

- **Advanced readings**
  - If you get curious about a topic and want to read more
  - Anything in these readings 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; **fill the poll (check email)**
    - We will announce regular office hours (time/location) next week
        - More hours by appointment

- **LOST sessions**
    - We understand that students sometime lose track of the course
        - Spend the rest of the semester “catching up”
    - Send us an email; we’ll help you catch up in 1-1 sessions
        - No need to give us a proof; we are here to help
        - But we will keep track to avoid abuse
    - Secure, private email address: cs4410lost@gmail.com

#8: Who am I?

Instructor — Rachit Agarwal

- **Assistant Professor, starting Fall 2016**
- **Previously**: UC Berkeley, UIUC
- **Office:** 411c, Gates Hall
- **Proud of: my students**
  - Two PhD students (Saksham Agarwal, Justin Miron — your TAs)
  - Graduated four undergraduate researchers so far
    - 2x now PhD students at MIT (Akshay Narayan, Yannan Wu)
    - 1x now PhD student at UC Berkeley (Zongheng Yang)
    - 1x Microsoft research (Alana Marzoev; applying for grad school)

Instructor — Rachit Agarwal

- **Research interests**: **problems that excite me**
    - Publish in top conferences of several areas:
        - **Operating systems (OSDI)**
        - **Networking (NSDI, SIGCOMM)**
        - **Databases (SIGMOD)**
        - **Theory (SODA)**
        - **Information Theory (ISIT)**
    - **Diversity reflects my learning and teaching style!**
    - Competitive advantage: ignorance (and curiosity)!

- **Non-research interests:**
    - Food: Chocolate
    - Activity: Flying planes (still training; rarely get time)
    - Skill: Mixing cocktails (sorry, you'll never get to see, unless …)
    - Sleeping hours: 2-3

#9: How do I teach? And, what do I expect from you?

My teaching style not for everyone …

- **I am not a great educator**
- I have not refined the mechanics of teaching
- I sucked as a teacher when I taught the first time
- Now I suck a little less, but only a little less
- My style is highly idiosyncratic, reflects who I am
    - It won’t change, so either deal with it, or drop …

First and foremost …

- **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 my way

- I should never have to ask for quiet during lecture
    - If things get bad, I'll start asking people to leave

Two, 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?

Two, 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 "how" networks are implemented
    - Focus on "why" the networks work the way they work

- **The best way to learn about networks:**
    - First think about how you would solve the problem
    - Then, the solution used by networks would make a lot more sense

Three, I am not satisfied by “good enough”

- Everything looks good, but I am always thinking about:
    - How to **improve** the course
    - How to explain a concept **better**
    - How to **make you think** more conceptually

- **Result:**
    - My slides are always evolving
    - My course will always be evolving
    - I have no idea what next lecture will be about
        - There is a tentative schedule on the website
        - It might change arbitrarily

Four, the best way to learn from me?

- **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

Fifth, 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**

The Bottom Line

- I hate the set of tasks leading to the classroom …
    - I hate managing TAs, giving exams, the inevitable failure ..
- But I love communicating once I am up here …
    - I want to reach each and every one of you
- And I care about you(r learning)
    - If you show interest, I'll give you as much attention as you need
- **"The Bottom Line":**
    - **I will work to make every lecture and every meeting useful for you**
    - **All I ask is that you do too ….**

#10: Is CS4450 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

- Read the webpage for course policies, etc.
- If you enroll starting today, send us an email to add you to Piazza
- Fill out the office hour poll, so that we can decide on timings
- Find a partner to sit with in the class
  - Not necessary, but will help you!
  - You will solve a lot of questions with them
  - You will discuss a lot of design issues with them

If you decide to stay …

Next lecture

- The beautiful concept of packets and flows
- Why would one even think of packets and flows?
- What is statistical multiplexing?
- How long would it take for you to send a message to destination X?