CS 4450, 5456

Computer Networks: Architecture and Protocols

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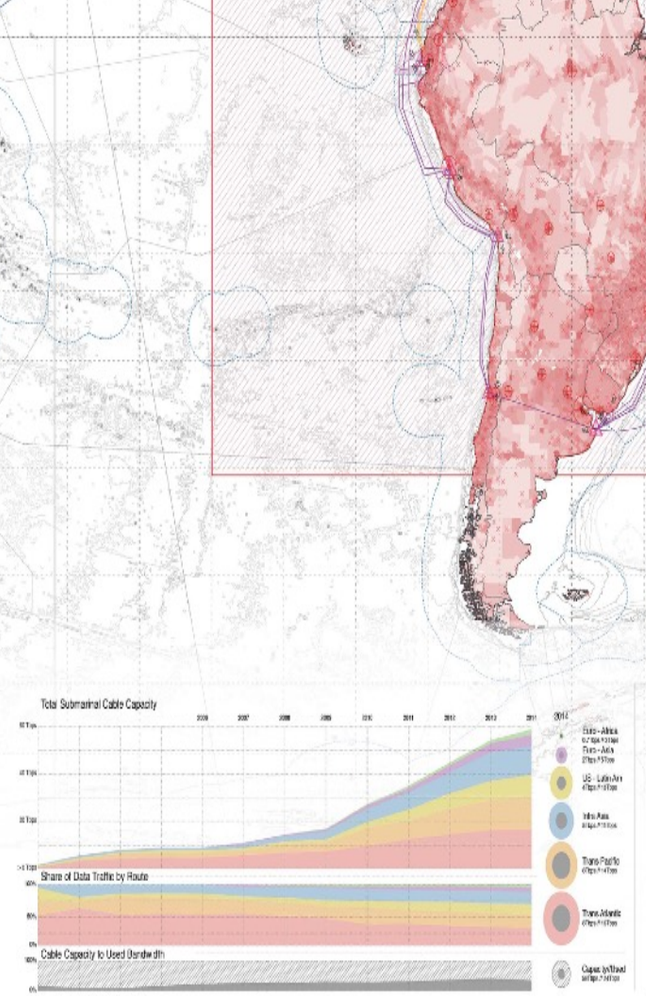
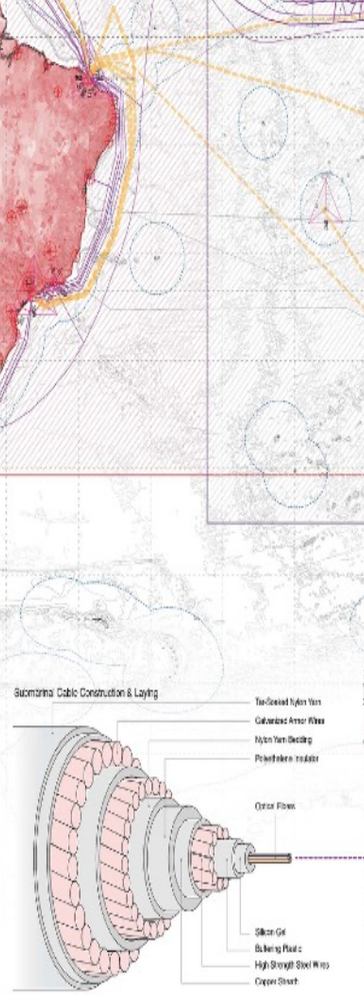
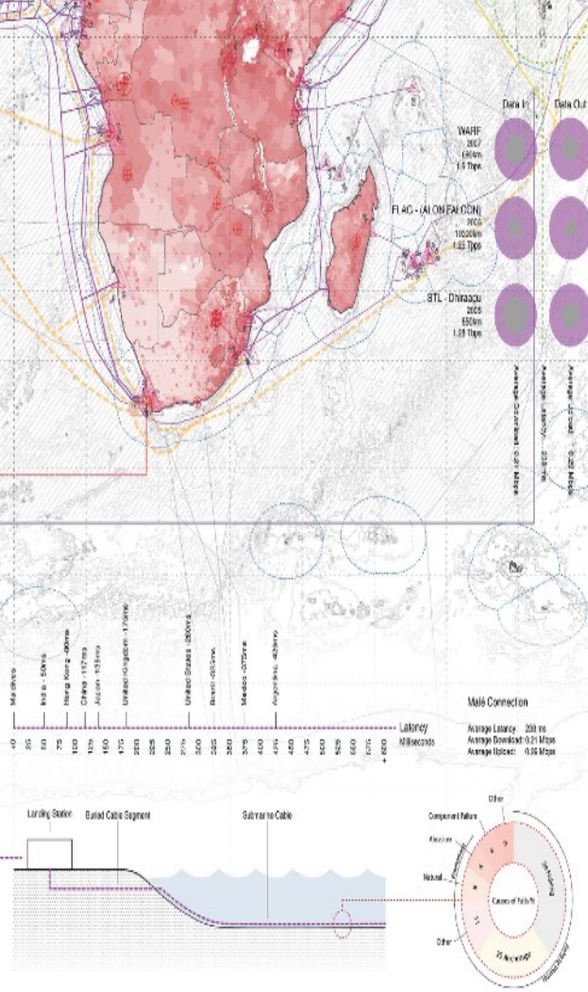
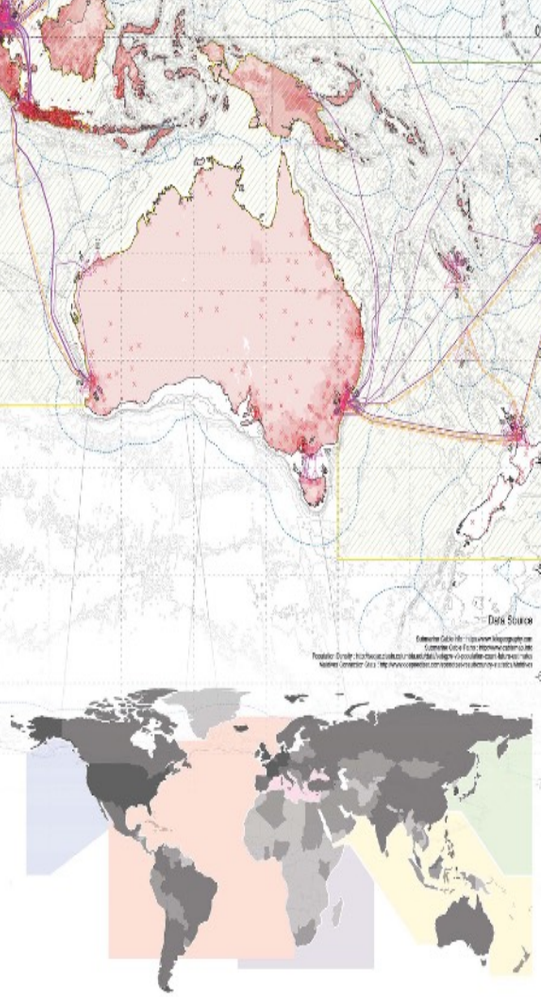
DATA FLOW // SUBMARINE CABLE NETWORK // 2015









#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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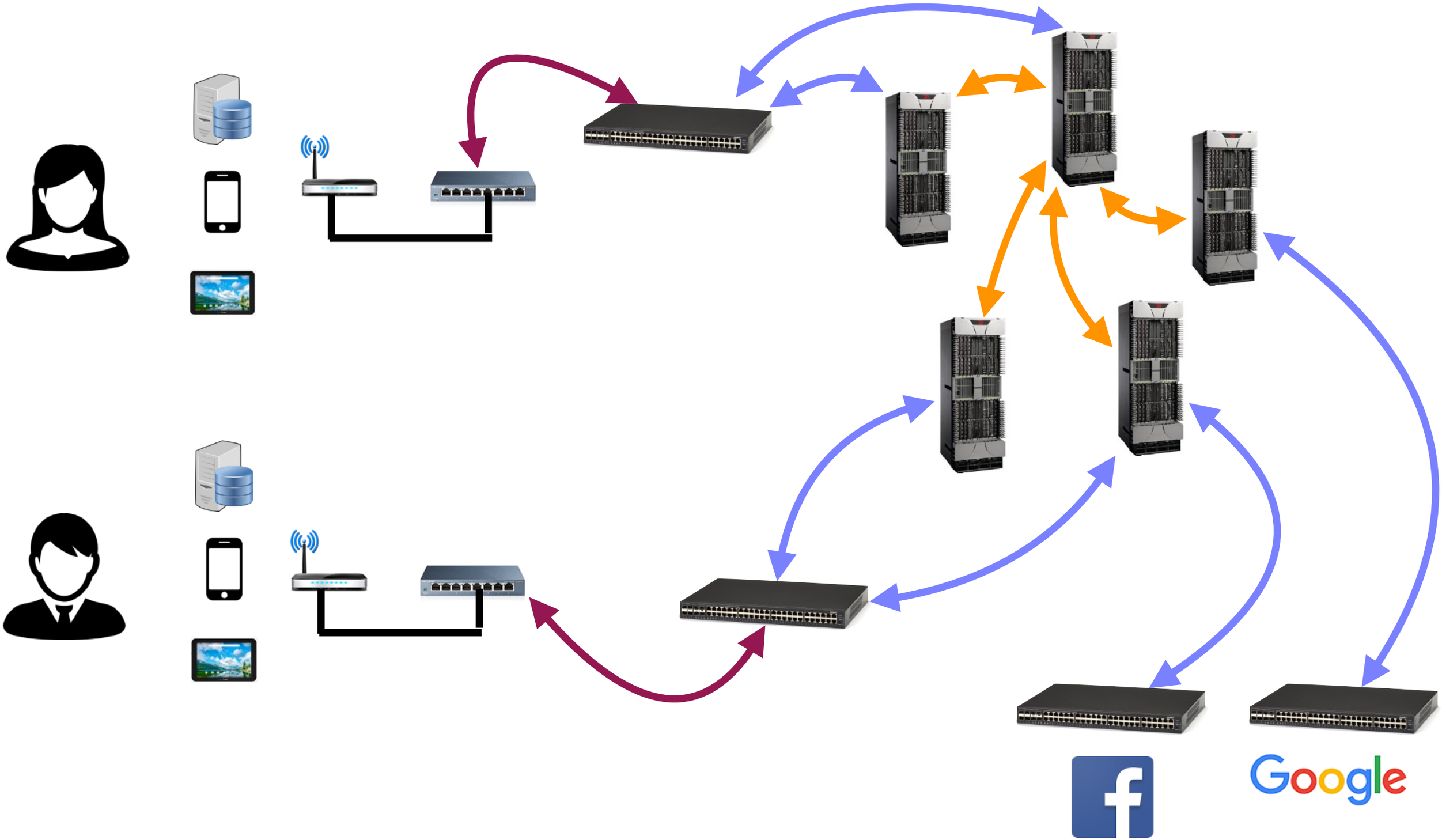

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Questions?

#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?

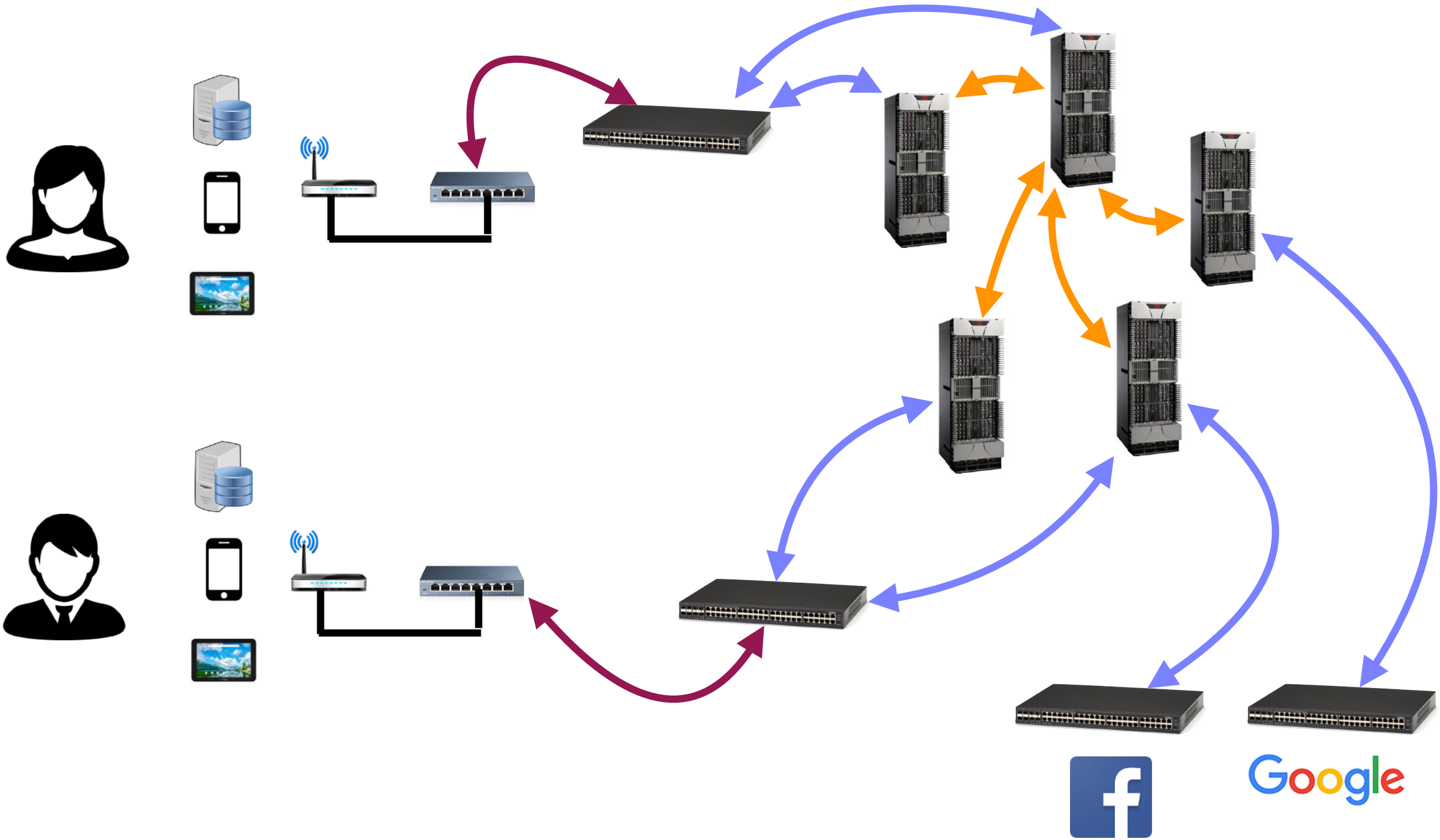
What do computer networks look like?

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, 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 <u>design for tussle</u>!

- **Federated System**
  - The <u>Inter</u>net 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 <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 2025 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

- **<u>What</u> tasks get done?**
  - What is delivered (packets, files, …)?
  - What are the semantics (reliability, ordering, …)?
- **<u>Where</u> 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?
- **<u>How</u> 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
- **Four projects**
    - To gain hands-on experience for people who are interested
- **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**
- **<u>New (5456):</u> some form of project/survey**

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**
    - 5th 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 via Cornell library

- **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

- **Ed Discussions**
    - Not a substitute for classes

- **Office hours**
    - We want to choose timings that suit you; **fill the poll (check email)**
    - We will announce office hours (time/location) on Ed Discussions
        - 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: cs4450-prof@cornell.edu