CS 4450, 5456

Computer Networks:
Architecture and Protocols

Rachit Agarwal
#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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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 Interprocess Communication (IPC)
  - 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?

• Let's see
Why study computer networks?

#1: Has transformed and more importantly, is transforming everything!

- **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 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 **diversity**!

- **Communication latency**: Microseconds to seconds
- **Bandwidth**: 1 Kilobits/second to 100 Gigabits/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 **evolution**!

<table>
<thead>
<tr>
<th></th>
<th>1970</th>
<th>Today</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bandwidth</strong></td>
<td>50 kbps</td>
<td>100+ Gbps</td>
</tr>
<tr>
<td><strong>#End hosts</strong></td>
<td>&lt; 100 computers</td>
<td>8 billion +</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Telnet and File transfer</td>
<td>!!</td>
</tr>
</tbody>
</table>

We have no clue what 2025 would be like!
Why study computer networks?

#6: To learn how to think “architecture rather than engineering”!

- 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 **not** 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
  - 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

- **New (5456):** some form of project/survey
Course workload

• My courses tend to be “heavy”: require regular attention
  • 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