CS4450

Computer Networks: Architecture and Protocols

Spring 2018
Rachit Agarwal
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)
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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 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 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**: 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 **evolution**!

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

We have no clue what 2020 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 (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 regular attention
  • 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?