CS 268: Computing Networking

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(Fall, 2010)

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- Sorry, no Teaching Assistant!
- Course Info: http://www.cs.berkeley.edu/~istoica/classes/cs268/10/
Goals of this Course

- Understand
  - How does the Internet work?
  - What are the Internet’s design principles?
  - Where is the Internet heading to?

- Get familiar with current Internet research efforts

- Understand solutions in context
  - Goals
  - Assumptions

Goals of this Course (cont’d)

- Appreciate what is good research
  - Problem selection
  - Solution & research methodology
  - Presentation

- Apply what you learned in a class project
What Do You Need To Do?

- A research-oriented class project
  - Groups of two
- Two quizzes
- Paper reading, presentation & discussion
  - Two to three 15min paper presentations

Research Project

- Investigate new ideas and solutions in a class research project
  - Define the problem
  - Execute the research
  - Work with your partner
  - Write up and present your research
- Ideally, best projects will become conference papers (e.g., SIGCOMM, INFOCOM, NSDI, MOBICOM)
Research Project: Steps

- We’ll distribute a list of projects
  - You can either choose one of these projects or come up with your own
- Pick your project, partner, and submit a one page proposal describing:
  - The problem you are solving
  - Your plan of attack with milestones and dates
  - Any special resources you may need
- A midterm presentation of your progress (8-10 minutes)
- Poster session
- Submit project papers

Materials on Course Syllabus Page

- Research papers
  - Links to pdfs on Web page
  - Two (sometimes three) papers per class meeting
  - Combination of classic and recent work
  - ~40 papers

- Class
  - Seminar/discussion style and participation will dominate!

- Recommended textbooks
  - For those who need to review their networking background
  - Peterson & Davie/4ed or Kurose & Ross/4ed
Paper Reviews

- Each of you will be responsible to write a short review for each paper
  - Length: about half page per paper

- Create a blog, if you do not have one already:
  - E.g., https://www.blogger.com/
  - Publish reviews on your blog 10 minutes before class

- Send us your blog address by Wednesday, September 1

Paper Selection for Presentations

- Each of you will be responsible to present around 2-3 papers

- Go through the reading list (http://www.cs.berkeley.edu/~istoica/classes/cs268/10/) and send the list of your 10 most preferred papers by Friday, September 3

- We’ll do the match and send you the assignment by Monday, September 6
  - Presentations will start on Monday, September 13
Questions to Answer in your Review/Presentation

- What is the problem? Is the problem real?
- What is the solution’s main idea (nugget)?
- Why is solution different from previous work?
  - Is technology different?
  - Is workload different?
  - Is problem different?

Questions to Answer in your Review/Presentation (cont’d)

- Does the paper (or do you) identify any fundamental/hard trade-offs?
- Do you think the work will be influential in 10 years?
  - Why or why not?
- Others
  - What was different then from now? (for old papers)
  - Any big flaws?
  - Any assumptions you disagree with?
  - ...
Paper Discussion Format

- 25-30min per paper
  - 15 min presentation (verbal, whiteboard, or slides)
  - 10-15min discussions

Grading

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term project</td>
<td>50%</td>
</tr>
<tr>
<td>Quiz I</td>
<td>10%</td>
</tr>
<tr>
<td>Quiz II</td>
<td>15%</td>
</tr>
<tr>
<td>Class participation and presentation</td>
<td>15%</td>
</tr>
<tr>
<td>Paper reviews</td>
<td>10%</td>
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</tbody>
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- This is a graduate networking class: more important is what you realize/learn than the grade
Enrollment Policy

- Graduate students get highest priority
- Among other students, priority is given to those who
  - Have backgrounds in networking, operating systems
  - Have relatively light course load
- Procedure of enrollment for undergraduate students
  - Be officially on the waiting list
  - Send me an email with URL that has pointers to
    - Your resume or cv
    - A short statement of relevant courses (textbook, university, grade) and experience
    - Other courses you are taking this semester

Send the Following Information

- Please send istoica@cs.berkeley.edu an e-mail with the subject "cs268 registration" and the following information:
  - Last and first name
  - Student ID
  - Your department
  - Preferred email address
  - URL of your home page
  - URL of your blog

- Send this e-mail by Wednesday, September 1
Class Topic Coverage

- Little on physical and data link layer
- Little on undergraduate material
  - Supposedly you already know this, though some revisiting/overlap is unavoidable
  - Focus on the why, not the what
- Focus on network to application layer
- We will deal with:
  - Protocol rules and algorithms
  - Investigate protocol trade-offs
  - Why this way and not another?

Lecture Topics

**Traditional**
- Layering
- Internet architecture
- Routing (IP)
- Transport (TCP)
- Queue management (FQ, RED)
- Naming (DNS)

**Recent Topics**
- Software Defined Networks
- Wireless and Sensor Networks
- Content-delivery Networks
- Flat Naming
- Datacenter networking
- P2P
  - ....
5 Minute Break

Questions Before We Proceed?

The ARPANet

- Paul Baran
  - RAND Corp, early 1960s
  - Communications networks that would survive a major enemy attack
- ARPANet: Research vehicle for “Resource Sharing Computer Networks”
  - 2 September 1969: UCLA first node on the ARPANet
  - December 1969: 4 nodes connected by phone lines
History of the Internet

- 70's: started as a research project, 56 kbps, < 100 computers
- 80-83: ARPANET and MILNET split
- 85-86: NSF builds NSFNET as backbone, links 6 Supercomputer centers, 1.5 Mbps, 10,000 computers
- 87-90: link regional networks, NSI (NASA), ESNet (DOE), DARTnet, TWBNet (DARPA), 100,000 computers
- 90-92: NSFNET moves to 45 Mbps, 16 mid-level networks
- 94: NSF backbone dismantled, multiple private backbones
- Today: backbones run at >100 Gbps, >700 millions computers in >200 countries
Why Networking Is Challenging

- Fundamental challenge: the speed of light
- Question: how long does it take light to travel from Berkeley to New York?
- Answer:
  - Distance Berkeley → New York: 4,125 km
  - Traveling 300,000 km/s: 13.75 msec

Fundamental Challenge: Speed of Light

- Question: how long does it take an Internet “packet” to travel from Berkeley to New York?
- Answer:
  - For sure ≥ 13.75 msec
  - Depends on:
    - The route the packet takes (could be circuitous!)
    - The propagation speed of the links the packet traverses
      - E.g., in optical fiber light propagates at about 2/3 C
    - The transmission rate (bandwidth) of the links (bits/sec)
      - and thus the size of the packet
    - Number of hops traversed (store-and-forward delay)
    - The “competition” for bandwidth the packet encounters (congestion). It may have to sit & wait in router queues.
  - In practice this boils down to: ≥ 40 msec
Fundamental Challenge: Speed of Light

- Question: how many cycles does your PC execute before it can possibly get a reply to a message it sent to a New York web server?
- Answer:
  - **Round trip** takes ≥ 80 msec
  - PC runs at (say) 3 GHz
  - \( 3,000,000,000 \text{ cycles/sec} \times 0.08 \text{ sec} = 240,000,000 \text{ cycles} \)
- Thus,
  - Communication **feedback** is always *dated*
  - Communication fundamentally asynchronous

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Fundamental Challenge: Speed of Light

- Question: what about between machines directly connected (via a *local area network* or LAN)?
- Answer:
  ```
  % ping www.icir.org
  PING www.icir.org (192.150.187.11): 56 data bytes
  64 bytes from 192.150.187.11: icmp_seq=0 ttl=64 time=0.214 ms
  64 bytes from 192.150.187.11: icmp_seq=1 ttl=64 time=0.226 ms
  64 bytes from 192.150.187.11: icmp_seq=2 ttl=64 time=0.209 ms
  64 bytes from 192.150.187.11: icmp_seq=3 ttl=64 time=0.212 ms
  ``
  - 200 µsec = 600,000 cycles
  - Still a looong time …
  - … and asynchronous
Why Networking Is Challenging (con’t)

- Fundamental challenge: components fail
  - Network communication involves a chain of interfaces, links, routers and switches …
  - … all of which must function correctly.
- Question: suppose a communication involves 50 components which work correctly (independently) 99% of the time. What’s the likelihood the communication fails at a given point of time?
  - Answer: success requires that they all function, so failure probability = 1 - 0.99^{50} = 39.5%.
- So we have a lot of components, which tend to fail …
  - … and we may not find out for a looong time
Why Networking Is Challenging (con’t)

- **Challenge: enormous dynamic range**
  - Round-trip times (latency) vary 10 μsec’s to sec’s ($10^5$)
  - Data rates (bandwidth) vary from kbps to 10 Gbps ($10^7$)
  - Queuing delays inside the network vary from 0 to sec’s
  - Packet loss varies from 0 to 90+%.
  - End system (host) capabilities vary from cell phones to supercomputer clusters.
  - Application needs vary enormously: size of transfers, bidirectionality, need for reliability, tolerance of jitter.

- Related challenge: very often, there is no such thing as “typical”. Beware of your “mental models”!
  - Must think in terms of design ranges, not points.
  - Mechanisms need to be adaptive.

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Why Networking Is Challenging (con’t)

- **Challenge: different parties must work together**
  - Multiple parties with different agendas must agree how to divide the task between them.

- Working together requires:
  - **Protocols** (defining who does what)
    - These generally need to be standardized.
  - Agreements regarding how different types of activity are treated (policy).
  - Different parties very well might try to “game” the network’s mechanisms to their advantage.
Why Networking Is Challenging (con’t)

- Challenge: incessant rapid growth
  - Utility of the network scales with its size
    ⇒ Fuels exponential growth (for more than 2 decades!)
- Adds another dimension of dynamic range …
  - … and quite a number of ad hoc artifacts

What drives Internet’s Evolution?

- Scale

- Technology

- Demands of most successful services
  - At each point in time there was a “killer” service (application)
Services Provided by Internet

- Shared access to computing resources
  - Telnet (1970’s)

- Shared access to data/files
  - FTP, NFS, AFS (1980’s)

- Communication medium over which people interact
  - Email (1980’s), on-line chat rooms (1990’s)
  - Instant messaging, IP Telephony (2000’s)

Services Provided by Internet

- A medium for information dissemination
  - USENET (1980’s)
  - WWW (1990’s)
    - Replacing newspaper, magazine
  - Audio, video (2000’s): peer-to-peer systems
    - Replacing radio, telephony, TV, …

- Shared access to computing resource, storage (coming full circle)
  - Cloud computing
Your Action Items

- By this Wednesday (September 1)
  - Send registration info
    - Last and first name
    - Student ID
    - Your department
    - Preferred email address
    - URL of your home page
    - URL of your blog
  - Submit first two reviews

- By this Friday (September 3) send you preference of top 10 papers