EE 122: Introduction To Communication Networks

Fall 2008 (MW 4-5:30 in **106 Stanley**)
Ion Stoica (and Brighten Godfrey)
TAs: Lucian Popa and David Zats
http://inst.eecs.berkeley.edu/~ee122/
Materials with thanks to Vern Paxson, Jennifer Rexford, and colleagues at UC Berkeley

Goals for Today's Class

- EE 122 overview
  - Goals of the course
  - Structure of the course
  - Instructor & TAs
  - Prereqs & assignments
  - Course grading
  - Academic policies
- What makes networking challenging
  - The fundamental issues we must grapple with to build a global Internet

What You Learn in This Course

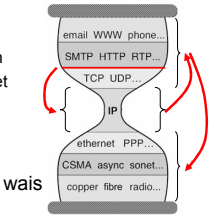
- Insight: key concepts in networking
  - Protocols
  - Layering
  - Resource allocation
  - Security
  - Naming
- Knowledge: how the Internet works
  - Internet architecture
  - IP protocol suite
  - Applications (Web, e-mail, P2P, …)
- Skill: network programming
  - Socket programming
  - Designing and implementing protocols

What This Course Is and Isn't

- EE122 comes in two flavors:
  - Spring offering: taught by EE faculty
    - More emphasis on diverse link technologies, wireless & mobility, communication theory & simulation
  - Fall offering: taught by CS faculty
    - More emphasis on Internet technology, applications, practice & empiricism / hands-on
  - Differences aren't huge, though
- My particular emphasis:
  - Network architecture, naming, resource allocation
  - Overlays, peer-to-peer applications

Structure of the Course (1st Half)

- Start at the top
  - Protocols: how to structure communication
  - Sockets: how applications view the Internet
- Then study the "narrow waist" of IP
  - IP best-effort packet-delivery service
  - IP addressing and packet forwarding
- And how to build on top of the narrow wais
  - Transport protocols (TCP, UDP)
  - Domain Name System (DNS)
  - Applications (Web, email, file transfer)
- Looking underneath IP
  - Link technologies (Ethernet, bridges, switches)



Internet Hourglass

Structure of the Course (2nd Half)

- How to get the traffic from here to there …
  - Routing (intradomain, interdomain)
  - Glue (ARP, DHCP, ICMP)
- … in a way that's both efficient and stable
  - How much data to send without clogging the sender (*flow control*) or the network (*congestion control*)
  - With some assurance (*quality of service*) … or not
- How to control network traffic …
  - Enforcing policy
  - Defending against attacks
- … and scale it to potentially huge structures
  - Peer-to-peer & overlays

Instructor

- Ion Stoica (istoica@cs.berkeley.edu)
  - Research focus
    - Network architectures
    - Tracing & debugging distributed systems
    - Overlay & p2p networks
  - http://www.cs.berkeley.edu/~istoica/
  - Office hours M 1-2PM & W 2-3PM in 413 Soda
  - Phone: 643-4007
    - Email preferred!

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TAs

- Lucian Popa (popa@eecs.berkeley.edu)
  - Office hours: W 1:30-2:30, F 11:30-12:30pm in 413 Soda
    - And by appointment
  - Section: W 12-1pm (299 Cory) & F 10-11am (293 Cory)
- David Zats (dzats@eecs.berkeley.edu)
  - Office hours: TT, 2:30-3:30 (location TBA)
    - And by appointment
  - Section: M 2-3pm (237 Cory), T 10-11am (299 Cory)
- Another TA will join next week

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Brighten Godfrey

- pbg@cs.berkeley.edu
- 2008 graduate
- Will join UIUC in Fall 2009 as Assistant Professor
- Will help with teaching several lectures

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Interact!

- Inevitably, you won't understand something(s) … that's my fault, but you need to help
- Come to office hours, request an appointment, communicate by e-mail
  - We are here to help, including general advice!
  - TAs first line for help with programming problems
- Give us suggestions/complaints/feedback as early as you can
- What's your background? Tell us at
  - http://tinyurl.com/5rsdx5

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Course Materials

- Textbooks
  - J. Kurose and K. Ross, *Computer Networking: A Top-Down Approach,* 4th Edition, Addison Wesley, 2007.
    - Note, we jump around in it a lot
  - Recommended & on reserve:
    - W. R. Stevens, *TCP/IP Illustrated, Volume 1: The Protocols, Addison-Wesley, 1993.*
- Web site: *http://inst.eecs.berkeley.edu/~ee122/*
  - Updated frequently, including lecture slides
  - Note: if you are following the slides during lecture, please don't use them to answer questions I ask
- Mailing list: ee122@lists.berkeley.edu
  - Sign up: https://calmail.berkeley.edu/manage/list/listinfo/ee122@lists.berkeley.edu

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Class Workload

- Four homeworks spread over the semester
  - Strict due dates (no slip days!)
  - Unless otherwise specified, deadlines are **before** lecture starts
- Two projects
  - Chat application (teams of two)
    - Includes socket programming, client/server
  - Dynamic DNS (teams of two)
    - You design and implement a DNS server
  - C (or C++) required
  - Deadlines 11:50PM
  - These are **extensive** undertakings, particularly the second
- Exams
  - Midterm: Monday, October 13 in class, 4-5:30PM
  - Final: Thursday, December 18 location 277 Cory, 8-11AM
  - Closed book, open crib sheet

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Prerequisites

- CS 61A, 61B
  - Programming, data structures, software engineering
  - Knowledge of C or C++
- Math 53 or 54
  - In fact, we'll be relatively light on math, though your algebra should be very solid, you should know basic probability, and you'll need to be comfortable with thinking abstractly
- Background material will ***not*** be covered in lecture. TAs will spend very little time reviewing material not specific to networking

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5 Minute Break

Questions Before We Proceed?

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Grading

Homeworks	20% (5% each)
Projects	40% (20+20)
Midterm exam	15%
Final exam	25%

- Course graded to mean of B
  - Relatively easy to get a B, harder to get an A or a C
  - ≈ 10% A, 15% A-, 15% B+, 20% B, 15% B-, 15% C+, 10% C
  - A+ reserved for superstars (1 or 2 per class)
  - Mean can shift up for an excellent class
    - For which the TAs have significant input

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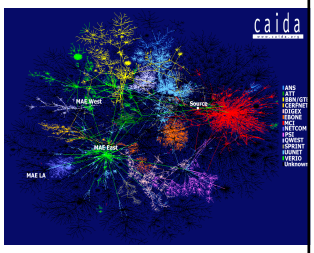
What do this two have in Common?

Johann Gutenberg (1398-1468)



The Internet

- First printing press
- Key idea: splitting up text in individual components
  - E.g., lower, upper case letters
- Both lower the cost of distributing information

book

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No Cheating

- Cheating means not doing the homework by yourself
- Fine to *talk* with other students about homeworks outside of class
  - Concepts, not specifics
- No copying, no Google, etc
- If you're unsure, then ask
- We will do *automated similarity detection* on assignments.

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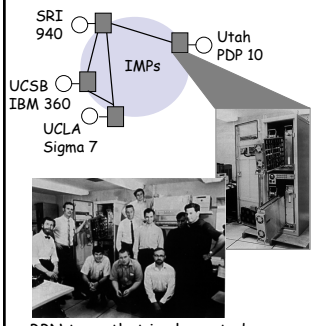
The ARPANet



BBN team that implemented the interface message processor

- 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

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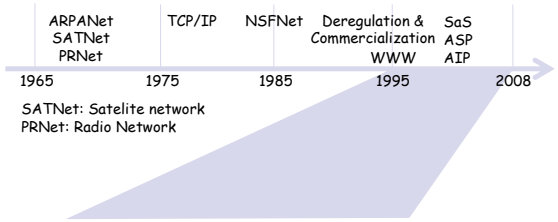
ARPANet Evolves into Internet



SATNet: Satelite network
PRNet: Radio Network

Web Hosting
Multiple ISPs
Internet2 Backbone
Internet Exchanges

Application Hosting
ASP: Application Service Provider
SaS: Software as a Service
Provider (e-commerce tookit, etc.)

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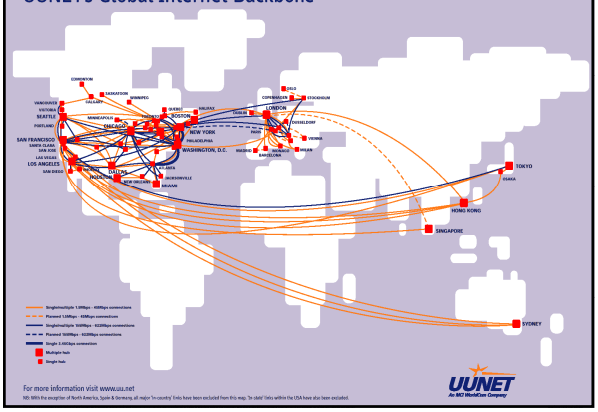
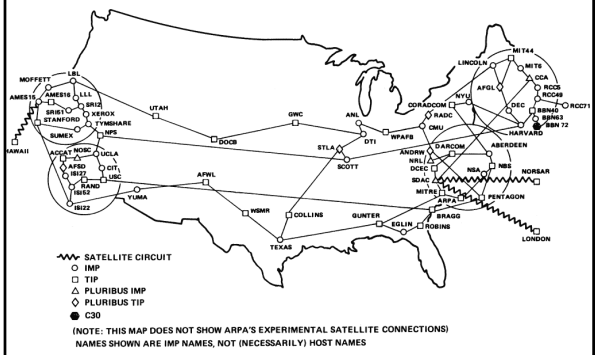
UUNET's Global Internet Backbone



ARPANET GEOGRAPHIC MAP, OCTOBER 1980



Networking: Actually Not Boring

- How hard can it be?
- You just string a wire (or other signaling path) between two computers …
- … first one pushes bits down the link …
- … and the second one gets them up. Right?
- Where does it get tricky?
  What are the challenges?

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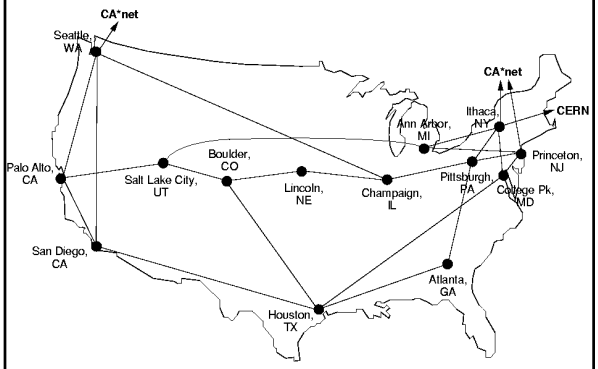
NSFNET T1 Network 1991



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

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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

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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 cyles/sec * 0.08 sec = 240,000,000 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

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Why Networking Is Challenging (con't)

- Fundamental challenge: components **fail**
  - Network communication involves a chain of interfaces, links, routers and switches …

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Examples of Network Components

Links


Fibers


Coaxial Cable

Interfaces

Ethernet card

Wireless card

Switches/routers

Large router


Telephone switch

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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

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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

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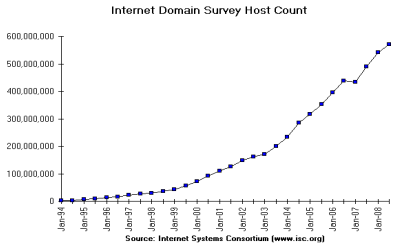
Why Networking Is Challenging (con't)



- 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

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Why Networking Is Challenging (con't)

- Challenge: **there are Bad Guys out there**
- As the network population grows in size, so does the number of
  - Vandals
  - Crazies
- What really matters, though: as network population grows, it becomes more and more attractive to
  - **Crooks**
  - (and also spies and militaries)

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7 71. ANCHETA would develop a worm which would cause infected
8 computers, unbeknownst to the users of the infected computers, to:
9 a. report to the IRC channel he controlled;
10 b. scan for other computers vulnerable to similar
11 infection; and
12 c. succumb to future unauthorized accesses, including
13 for use as proxies for spamming.

20 his worm caused 1,000 to 10,000 new bots to join his botnet over
21 the course of only three days.

18 73. ANCHETA would then advertise the sale of bots for the
19 purpose of launching DDOS attacks or using the bots as proxies to
20 send spam.
21 74. ANCHETA would sell up to 10,000 bots or proxies at a
22 time.
23 75. ANCHETA would discuss with purchasers the nature and
24 extent of the DDOS or proxy spamming they were interested in

35

9 79. ANCHETA would accept payments through Paypal.

15 103. In or about August 2004, ANCHETA updated his
16 advertisement to increase the price of bots and proxies, to limit
17 the purchase of bots to 2,000 "due to massive orders," and to warn,

14 adware on those computers without notice to or consent from the
15 users of those computers, and by means of such conduct, obtained
16 the following approximate monies from the following advertising
17 service companies:

COUNT	APPROXIMATE DATES	APPROXIMATE NUMBER OF PROTECTED COMPUTERS ACCESSED WITHOUT AUTHORIZATION	APPROXIMATE PAYMENT
SEVEN	November 1, 2004 through November 19, 2004	26,975	$4,044.26 from Gammacash
EIGHT	November 16,2004 through December 7,2004	8,744	$1,306.52 from LOUDcash
NINE	January 15, 2005	19,934	[illegible]

Summary

- Networking is about design in the presence of challenges/constraints:
  - Not akin to e.g. programming languages / compilers
    - Which have well-developed theories to draw upon
  - Much more akin to operating systems
    - Abstractions
    - Tradeoffs
    - Design principles / "taste"
- Next lecture: types of networks, protocols
  - Read through 1.3 of the Kurose/Ross book
  - Subscribe to the mailing list: ee122@lists.berkeley.edu
  - Take survey at: http://tinyurl.com/5rsdx5

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Why Crooks Matter for Networking

- They (and other attackers) seek ways to misuse the network towards their gain
  - Carefully crafted "bogus" traffic to manipulate the network's operation
  - Torrents of traffic to overwhelm a service (denial-of-service) for purposes of extortion / competition
  - Passively recording network traffic in transit (sniffing)
  - Exploit flaws in clients and servers using the network to trick into executing the attacker's code (compromise)
- They do all this **energetically** because there is significant $$$ to be made

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Why Networking Is Challenging (con't)

- Challenge: **you cannot reboot the Internet!**
  - Everyone depends on the Internet
    - Businesses
    - Hospitals
    - Education institutions
    - …
  - Cannot stop, fix, and restart it…
  - … akin to "changing the engine when you are in-flight"!

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