What computers talk about and how.
(Networking & the Internet.)

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Brief history

- Local area networks & university networks
- Military communication networks
  - ARPANET ['68] (a.k.a. DARPANET), etc.
- Early 1980s: US government decides on new way to connect various networks: the “Internet”
- 1989: World Wide Web; html, browsers
- 1998: Internet naming system handed over to private non-profit corporation ICANN.
Modern Internet

- Collection of computers (including devices, servers, etc.) connected by wires, optical cables, wireless, etc.

- To join, need:
  - Device capable of “speaking the right protocol” (TCP/IP)
  - IP “address” given by an Internet provider
  - Connection to provider's servers (via modem, DSL, wireless, etc.)

Your PC
IP Address: 128.156.16.201
Today: A Peek Underneath the 'Net

Why?

- Dominant technological artifact of second half of 20th century
- Interesting example of design of a large, heterogeneous system (decentralized, yet fairly robust).
Caveat: Internet ≠ WWW

- Internet: network connecting computers, devices, etc.
- WWW: hyperlinked content (webpages) stored on servers; requested and served using http protocol
- Built on top of the internet
Theme 1:

Building reliability on top of unreliable protocols
The (shaky) foundation of the Internet: TCP/IP Protocol

- All transmissions broken up into packets

A Packet:

<table>
<thead>
<tr>
<th>Destination address</th>
<th>Book-keeping info</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 bits</td>
<td></td>
<td>Often about 1500 bytes (but can vary)</td>
</tr>
</tbody>
</table>
Hopping along

- Internet is actually a bunch of connected computers called *routers*.
- Packets hop from router to router until they reach destination.

See, for example:  http://network-tools.com
“Best effort transmission”

- Packet not guaranteed to arrive quickly (or ever!)
- If many packets sent, may arrive out of order
Discussion

- Is there some unreliable communications device you use everyday?

- How do you cope with the cellphone's unreliability?
Some mechanisms

- Retransmission ("Could you say that again?")

- Timeout ("Let me hang up and try redialing?")

- Acknowledgements ("Finally understood you. Go on.")

(In TCP/IP: if sequence of packets, number them and sort at receiver end.)
Theme 2:

Decentralized control
Political and Military Setup in Medieval Europe (?)

- What is a suitable postal system for this “army”?
How should a peasant in one town send mail to a peasant in another town?

- What happens if a knight leaves the army?
First example of decentralization: Physical network

- 12 major providers
- Many local providers

Princeton homes & businesses

Princeton Schools

McCarter

Sprint

USLEC

Patriot Media
The Second Decentralization: Domain Name System

.com
.edu
.net
.uk
.in
.princeton.edu
.cs.princeton.edu
.econ.princeton.edu
What happens when you type URL?

- Address translated by asking appropriate DNS server up/down the DNS hierarchy
  - www.nytimes.com → query to .com server → 199.239.136.200

- Physical routing of packets up/down the physical network hierarchy based upon address

- Other stuff
Theme 3.

Dependence upon the kindness of strangers
Congestion

- Queue full $\rightarrow$ packets are dropped
How does a good netizen respond to congestion?

- Packets getting dropped? → Halve the transmission rate

- All packets getting through? → Increase transmission rate a little.

- Done in all TCP/IP software
  But, no enforcement mechanism!
  (Allows “cheating”, as well as VoIP Telephony, Streaming media, etc.)
What's in the future?

- 128-bit instead of 32-bit addresses.
  - Can send email to your toaster.
    (Especially if it lives in Asia)

- Mechanisms for pricing, security, quality of service, etc.
  - NSF's GENI initiative