CS 340 Introduction to Computer Networking

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To do …

- Class overview
- A broad view of the Internet
- A brief history of networking

Northwestern

This course

- Learning about
  - How to implement and manage networks
  - How to design apps that make efficient use of them
- In a hands-on manner
  - Experimenting with protocols
  - Working on projects

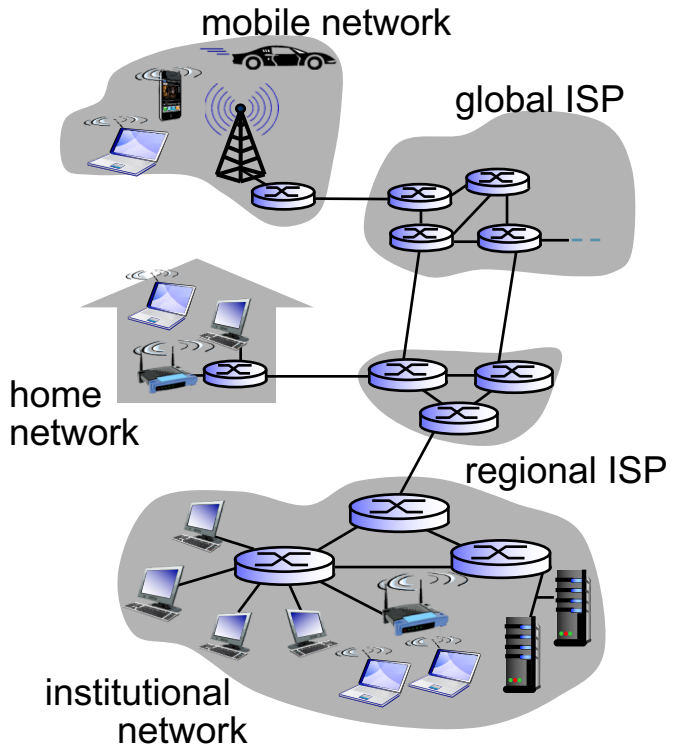
Communication networks in general

- The Inca relay system
  - Message encoded in a **quipu**, a communication medium with thousands of strings
  - An **encoding system** based on tying knots in the strings
  - Carried by **chasqui** runners between **tambos**; runners will use a **pututu** horn to warm the next runner

- The great wall of China
  - A set of beacon towers; the encoding was light/smoke on/off for danger/safe

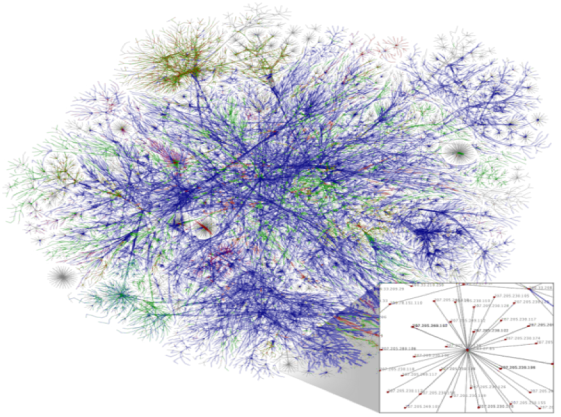
The network we study

- Billions devices, called hosts or end systems
  - From thermostats and lightbulbs to servers
- Many type of communication links
  - Copper wire, coaxial cable, fiber optic, radio
  - Each with different transmission rates
- Hosts communicate exchanging data packets
  - Packets are labeled with address of sender and receiver
- Routers and switches direct traffic using addresses on the packets



And have learned to depend on

- To 3.7 billion users
- 20 billion devices
- Trains, planes and automobiles
- …



- Society's increased dependency on connectivity
  - FB's 2.4 billion monthly users, on it 20% of online time

Why do you care about this class?

Would you rather have a supercomputer with no network connection or your phone connected to the Internet?

From Justin Sherry and Pete Steenkiste @ CMU

Course staff

- Instructor
  - Fabián Bustamante
- TAs
  - Yihan Zhang
  - Alex Liu
- Peer Mentors
  - Dillon Hall
  - Benjamin Warren
  - William Wang

Logistics/organization

- Course website
  - Slides, pointers to piazza, canvas, papers …
- Piazza
  - Main Q&A forum
- Canvas
  - Projects descriptions
  - Homework assignments
  - Grades

A brief summary, look at the website for details

Course components

- Lectures
  - Read and participate!
  - Slides available from the website (we'll try before class)
- Wireshark labs and homework assignments
  - Reading enforcers
- Projects
- Midterm and final exam

On projects – Code walkthrough

- For every project, code walkthrough by randomly selected groups with the staff

  To get full credit you must be able to carry the walkthrough, showing you understand your code

- A few points
  - Sampling with replacement, i.e., you may do it multiple times
  - To be done in first week after submission
  - All team member must be there, everyone drives at one point

Grading

- 3 Projects 50%
- Homework assignments and labs (5) 15%
  - Short written answers, based on reading, lectures, and Wireshark labs
- Midterm and final exam (cumulative) 25%
  - Homework assignments are good prep
  - Exam is open book and open notes
- Class participation 10%

On class participation

- A Wong-Baker's like scale

Contributes to the discussion (A)

Seem to follow the discussion (B)

I've seen her in class (C)

She's in class, but probably on FB (D)

Is he actually in this class? (F)

On that topic …

ELSEVIER

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Laptop multitasking hinders classroom learning for both users and nearby peers

Faria Sana[a], Tina Weston[b, c], Nicholas J. Cepeda[b, c].

The Pen Is Mightier Than the Keyboard
Advantages of Longhand Over Laptop Note Taking

Pam A. Mueller[1]

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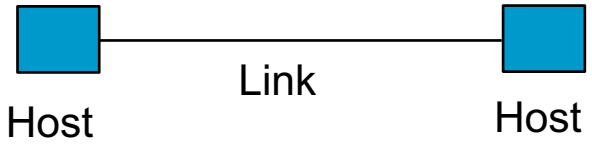
No cheating, please

- Collaboration is good, cheating is a very serious offense
- It's OK to
  - Meet with colleagues
  - Study for exams together
  - Discuss assignments with them
- But, *what you turn in must be your own work*
  - Do not copy code, solution sets, etc. from other people or any other sources (**Web included!**)
  - Do not make your code available for other (even future) students (**e.g., do not post in github, bitbucket, …**)

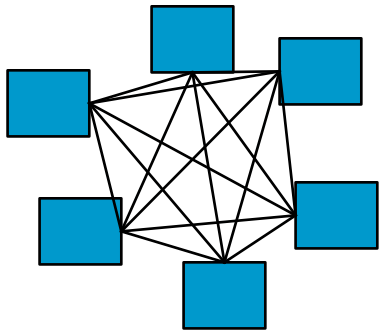

TAKE 5

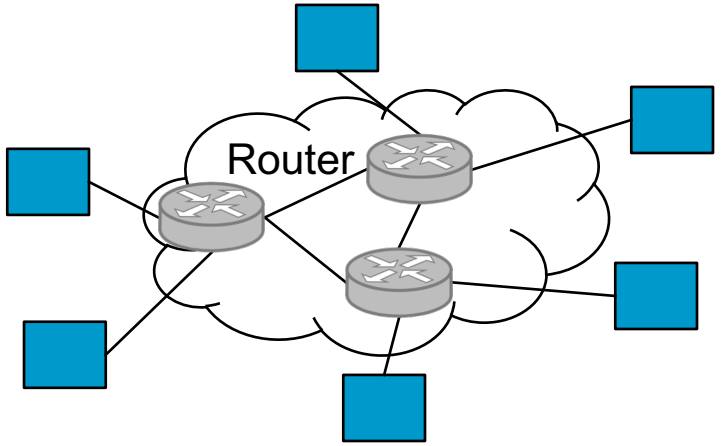
From basic building blocks

- End systems or **hosts** and **links**



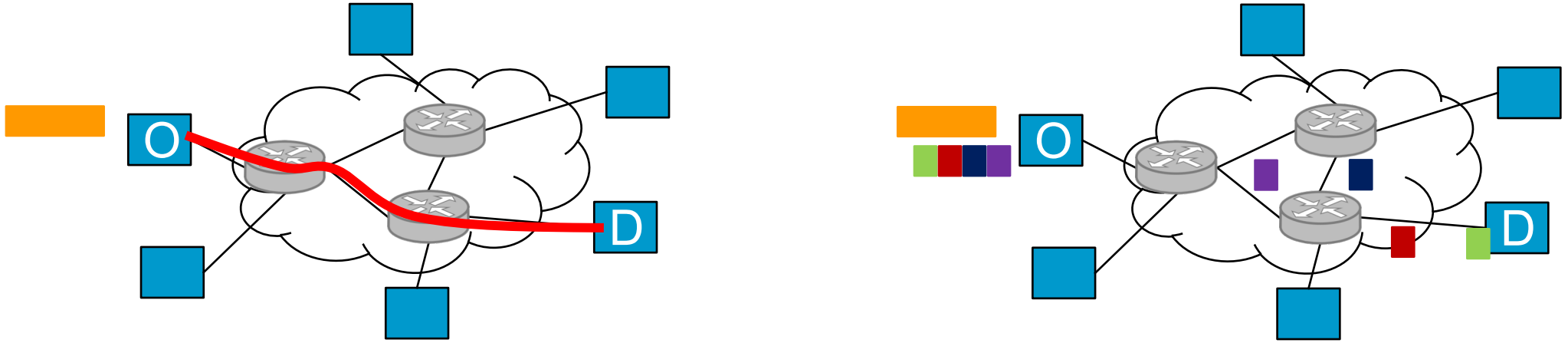
- More hosts?
  - Few host or tons of wires (for everyone out there)
  - Switched networks **routers** as switches





Circuit- and packet-switched Networks

- Circuit-switched networks – Typical of the old telephone system
  - A dedicated circuit established for two parties and lasting for the call



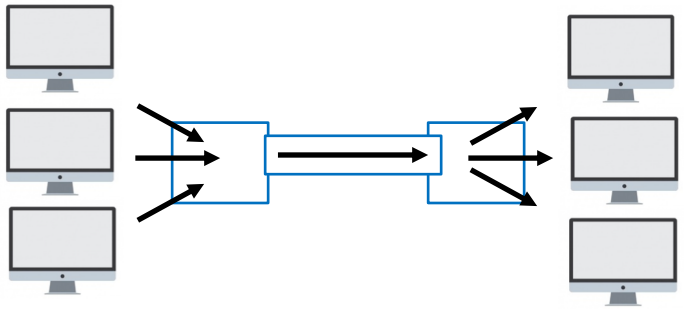
- Packet-switched networks – Majority of computer networks
  - Messages are sent as sets of self-contained packets, with an address
  - Each routed independently to its destination (may arrive out of order)

Circuit *or* packet-switched networks

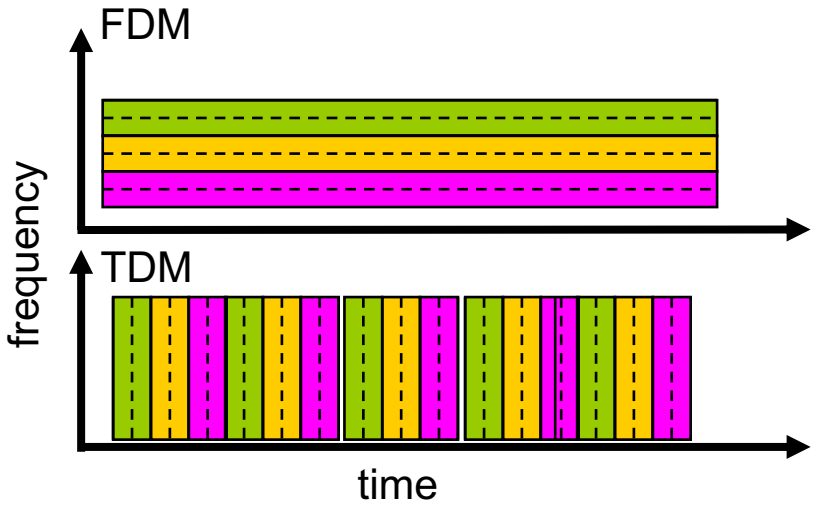
- Circuit-switched networks
  - A dedicated path/circuit …
  - Guaranteed performance but
  - You may have to wait to establish it and
  - Would waste resources while not talking
- Packet-switched networks
  - Simple – No connection setup is necessary, address packet and send it
  - Very efficient for sharing "bursty" customers

Cost effective resource sharing

- Supporting more than two communicating nodes over a shared infrastructure – how can they share at the same time?
  - Multiplexing

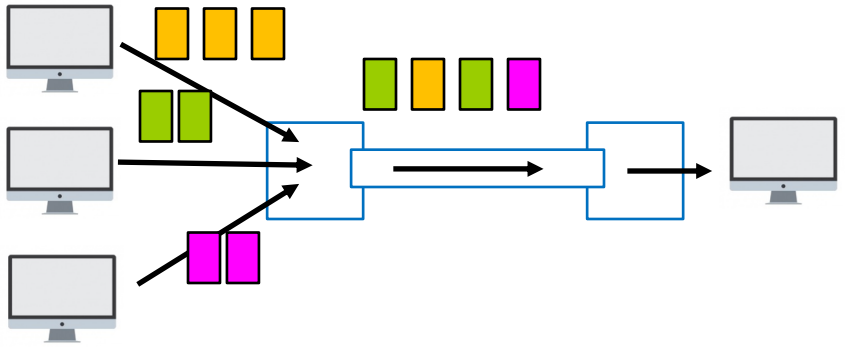


- Considering a single physical link
  - Synchronous time-division multiplexing
  - Frequency-division multiplexing
  - Packet switching relies on *Statistical multiplexing*



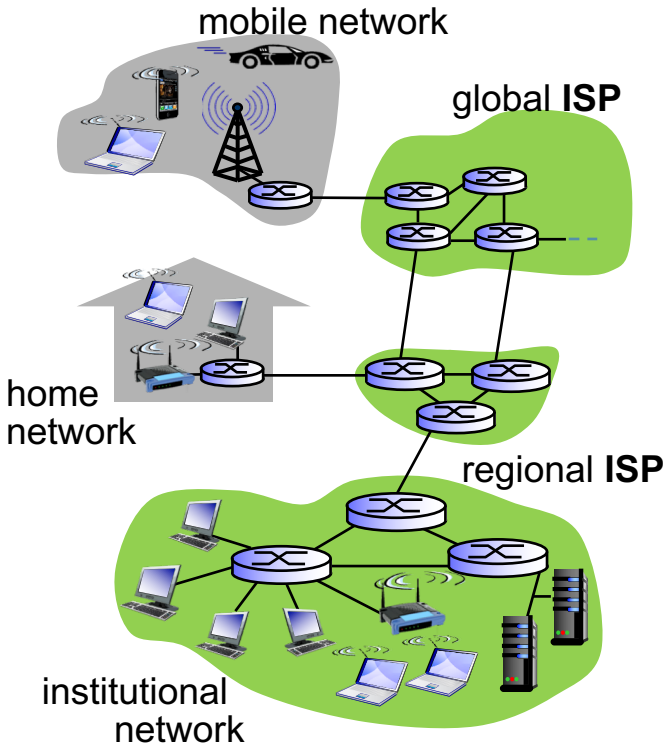
Statistical multiplexing

- Like STDM, the physical link is shared over time
- But unlike STDM, data is transmitted on demand
  - Instead of at a predetermined time slot
- How to ensure everyone gets a turn
  - Upper bound on size of block of data sent (packet)
  - Which packet to send? Each switch decides
  - Too many packets?
    - Buffer them
    - Run out of buffer? Drop them …



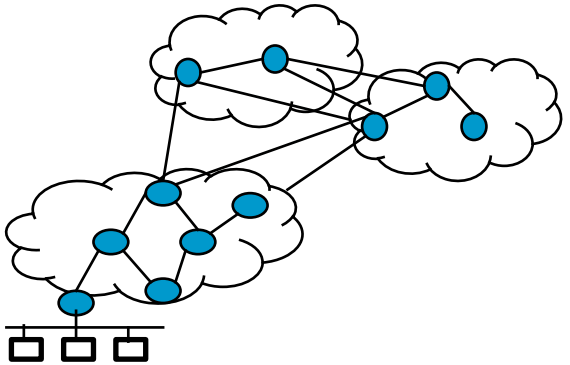
End systems, networks and protocols

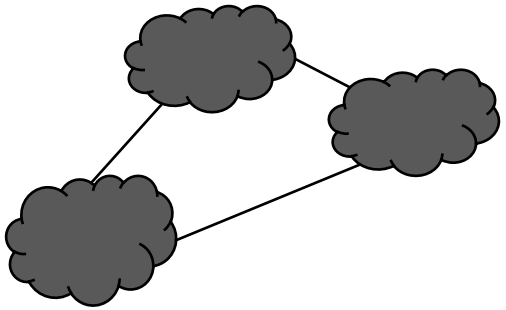
- End systems access the Internet through Internet Service Providers (ISP)
  - Each ISP is itself a network of packets switches and communication links
- ISPs connect to other ISPs in some form of hierarchy – the Internet

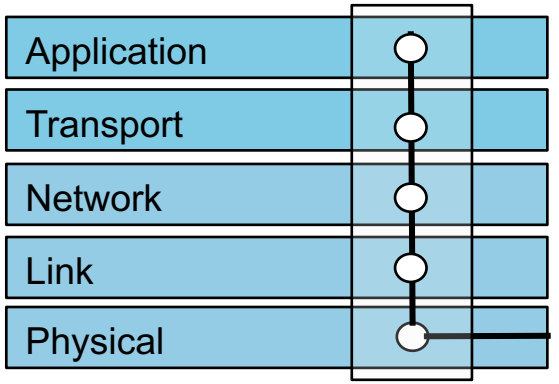


End systems, networks and protocols

- Internet– A set of separately, usually competing, networks aka Autonomous Systems
  - Autonomous System
    - Network elements under a single organization's control
    - to collaborate while retaining control
  - 1 ISP can manage *N* ASes; no AS managed by >1 ISP
  - ASes exchanged traffic at peering points
- End systems, packets switches and other entities in the network rely on protocols to communicate

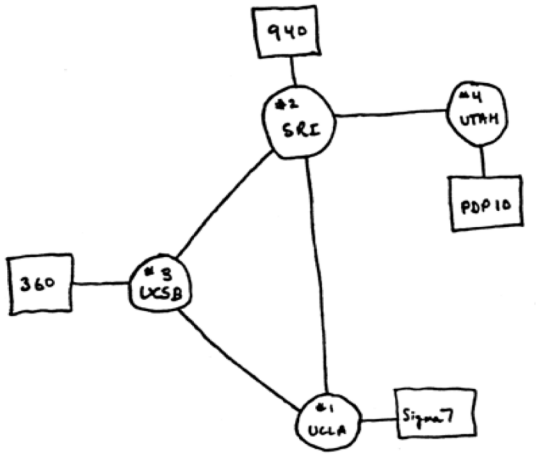




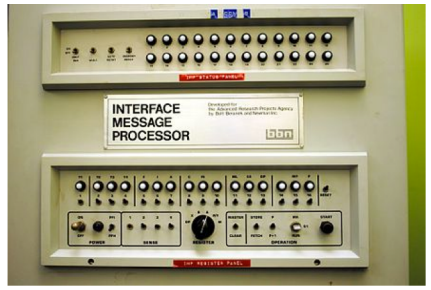


The Early days – 1960-1972

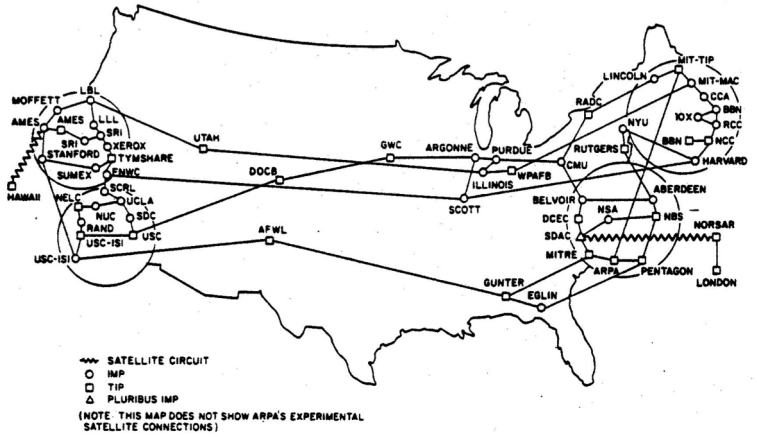
- Early 1960s ARPA sponsored research on networks to let researchers share (expensive) computers remotely
  - Early work on packet switching – Kleinrock (then at MIT), Baran at RAND, Davies and Scantlebury at National Physical Lab in England
  - J.C.R. Licklider and Larry Roberts at ARPA pushed ARPAnet based on this early work
- 1969 – First four ARPAnet nodes connected
  - UCLA (Kleinrock's lab), Stanford Research Institute, UCSB, U. Utah
- By 1972, 15 nodes, end-to-end protocol NCP and first email program (by Tomlinson)



Proprietary networks and Internetworking – 1972-1980



- Successful ARPANET ~100 nodes by 1975
  - A single, closed network; need to connect to an IMP to join
- Other networks being built
  - ALOHANet (microwave network in Hawaii), DARPA's packet-satellite network, BBN's Telenet, the French Cyclades, …
- Push to interconnect done by Vinton Cerf and Robert Kahn
  - Architectural principles embodied in TCP (early TCP+IP)

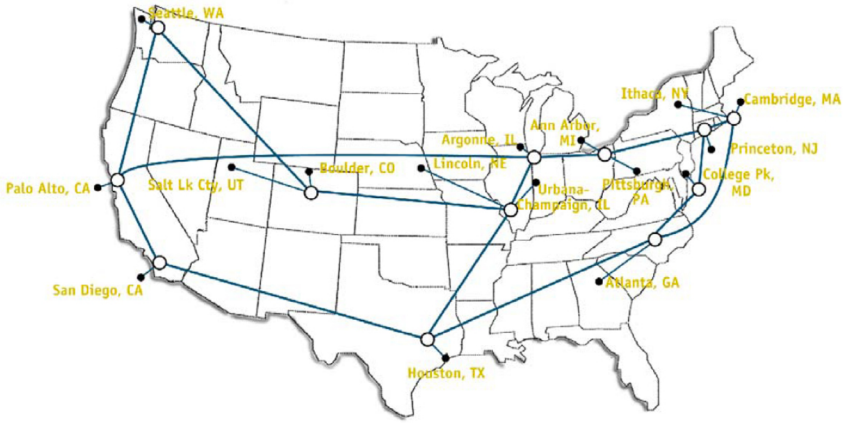


A Proliferation of Networks – 1980-1990

- In the early 1980s, Autonomous Systems
  - A network of networks – ARPANET as the backbone

- Late 1980s NSF takes over
  - Focus on expanding the backbone
  - Development of regional networks
  - 3 tiers: backbone, regional, enterprise

NSFNET T3 Network 1992

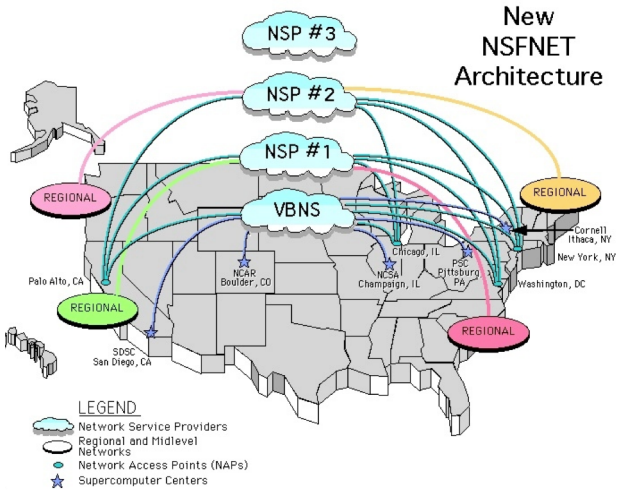


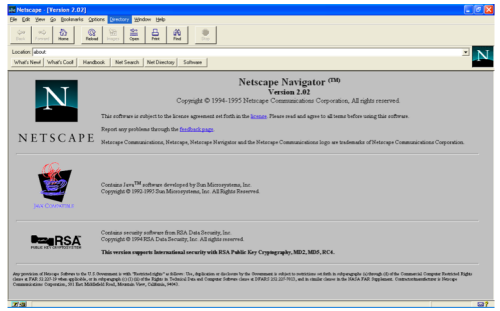
- Enterprises wanted to connect their networks
  - Had TCP/IP networks and wanted to connect
  - But NSF charter prohibited them from using NSFNET
  - 1987 first commercial ISP, others follow shortly

@THE WORLD

The Internet explosion – The 1990s

- By 1990 service providers where interconnected
  - By 1991 congress lets commercial networks link to NSFNET
  - By 1995, NSFNET was retired
    - Many backbones interconnected by Network Access Points
- Mid 1990s Web
  - Tim Berners-Lee based on Vannevar Bush's work from the 1940s
    - By 1993, 200 Web servers
  - Easier to use Internet; million of non-academic users
- Late 1990s
  - 100s of apps and some killer ones, e-mail, web, IM, P2P





The new millennium

- Innovation continues at rapid pace but some notable things
- Broadband coverage with high-enough bandwidth for video, on demand and even real-time
- Increasing ubiquity of high-speed WiFi and 4G/5G cell, enabling constant connectivity and location-specific apps
- Extensive private network by the Googles/FB/Amazon/MS/…
- Cloud-based deployments given access to providers' high-speed private networks (and leaving experimental researchers in the dark …)

Summary | TODO

- The Internet
  - The largest engineered system ever created
  - At once critical and transformational
- A complex system we'll try to get understand
  - Following a top-down approach
  - Focusing on the fundamental networking issues
- TODO
  - Go to Pizza
  - Find a partner for projects
  - Read first chapter of the book
  - First WS Lab is out!