History of the Internet
What are some pre-Internet communication technologies?

•?
Optical Semaphores

• Basic idea: Use visual indications of letters to signal next tower.

• Claude Chappe (France, 1792): Built 556 of these stations across France for communicating about war effort.

• First Message: “Si vous réussissez, vous serez bientôt couverts de gloire” (If you succeed, you will soon bask in glory) – 16km

• “Mechanical Internet”
Telegraph

• Robust work in trying to use electricity to transmit information instead.
• Many problems: Didn’t have consistent generators so coding was hard; some solutions used a wire for each letter.
• Eventually Gauss developed working system: Positive signal would move needle one way, negative another then alphabet
Telegraph

• Samuel Morse changes this to have the signal move a pen, creating a mark.
• Morse first message: was in 1838
  • 3 miles in New Jersey
• More famously sent "WHAT HATH GOD WROUGHT?“ 44 miles between DC and Baltimore
• Core innovation: Relays at frequent intervals that send a message through ten miles (16 km) of wire.
Telephone

• Basic problem: How to modulate voice onto electrical signals
• Reis (1861 Germany): "Das Pferd frisst keinen Gurkensalat" (The horse does not eat cucumber salad). Speech issues.
• Elisha Gray (1876) patents first method for encoding.
• Bell (1876) makes first call: "Mr. Watson, come here, I want to see you."

Circuit-Switching

- In January 1878, the first telephone switch went into operation in New Haven Connecticut
- Establish a complete circuit every time there’s a communication
- Still the case in cellular!
  - Circuit is established to “packet gateway”
Issues w/ Circuit Switching

• ?
Issues w/ Circuit Switching

• Large setup cost
  • Switching costs all along circuit

• Contention
  • Only X links, what if X+1 want to use?

• Inefficient
  • Circuit established even if not in use

• Fragile
  • Intermediary links go down circuit is broken

USAF wanted their networks to survive nuclear strikes... circuits would not.
Pre-internet: Packetization

The solution focused on three big ideas:

1. Use decentralized network with multiple paths between any two points
2. Divide user messages into message blocks, later called *packets*
3. Deliver these messages by store and forward switching.
Pre-Internet: Why Packetization?

- Efficiency
  - Lines only used when trafficked
- Handles contention
  - Queue packets
- Robust
  - Routes can change
- Kleinrock (UCLA, 1969)
  - UCLA -&gt; SRI
  - “Lo” – Was supposed to be “LOGIN” but crashed
Efficiency: Statistical Multiplexing

• Sharing of network bandwidth between users according to the statistics of their demand
  • (Multiplexing basically means sharing)
  • Useful if:
    • users are mostly idle and/or
    • traffic is bursty

• Key question:
  • How much does it help?
Efficiency: Statistical Multiplexing (2)

- Example: Users in an ISP network
  - Network has 100 Mbps (units of bandwidth)
  - Each user subscribes to 5 Mbps, for videos
  - But a user is active only 50% of the time ...

- How many users can the ISP support?
  - With dedicated bandwidth for each user:
  - Probability all bandwidth is used:  \( \text{(assuming independent users)} \)
Efficiency: Statistical Multiplexing (3)

• With 30 independent users, still unlikely (2% chance) to need more than 100 Mbps!
  • Binomial probabilities

→ Can serve more users with the same size network
  • Statistical multiplexing gain is 30/20 or 1.5X
  • But may get unlucky; users will have degraded service
Pre-Internet: Networks

Started building individual packet networks at different institutions:

• Octopus Network
  • 4 Machines at the Lawrence Livermore National Lab

• ALOHAnet
  • Wireless packets at University of Hawaii

• CYCLADES
  • French network exploring network responsibilities

• ARPANET
  • First packet network, a few universities online
The Beginning – ARPANET

• ARPANET by U.S. DoD was the precursor to the Internet
  • Motivated for resource sharing
  • Launched with 4 nodes in 1969, grew to hundreds
  • First “killer app” was email
ARPANET

• In the early ARPANET
  • Internetworking became the basis for the Internet
  • Pioneered by Cerf & Kahn in 1974, later became TCP/IP
  • They are popularly known as the “fathers of the Internet”
Rough Internet Timeline

Estimated Hosts

10⁹

10⁶

10³


Year

1: ARPANET

2: NSFNET

3: Modern Internet & Web
“IMPs” were early routers

56 kbps links

ARPANET Geographical Map (Dec. 1978)

Source: ARPANET Information Brochure, DCA 1979
Growing Up – NSFNET

• NSFNET ’85 supports educational networks
  • Initially connected supercomputers, but became the backbone for all networks
• Classic Internet protocols we use emerged
  • TCP/IP (transport), DNS (naming), Berkeley sockets (API) ’83, BGP (routing) ’93
• Much growth from PCs and Ethernet LANs
  • Campuses, businesses, then homes
  • 1 million hosts by 1993 …
Growing Up - NSFNET
Early Internet Architecture

• Hierarchical, with NSFNET as the backbone

- 56 kbps links in ‘85
- 1.5 Mbps links in ‘88
- 45 Mbps links in ‘91
Modern Internet – Birth of the Web

• After ’95, connectivity is provided by large ISPs who are competitors
  • They connect at Internet eXchange Point (IXP) facilities
  • Later, large content providers connect

• Web bursts on the scene in ’93
  • Key idea: Hyperlink
  • Growth leads to CDNs, ICANN in ‘98
  • Most bits are video (soon wireless)
  • Content is driving the Internet
Modern Internet Architecture

• Complex business arrangements affect connectivity
  • Still decentralized, other than registering identifiers

Facility at which networks connect
Modern Internet Architecture (2)

Major Transit ISPs:
• Level 3 (200,000mi of fiber)
• Century Link (550,000mi)
• ATT (410,000mi)
• Verizon (500,000mi)

Major Regional ISPs
• Dakotanet
• Dixienet
• Local telecoms (e.g., MTA)
• US West