History of the Internet

What are some pre-Internet communication technologies?

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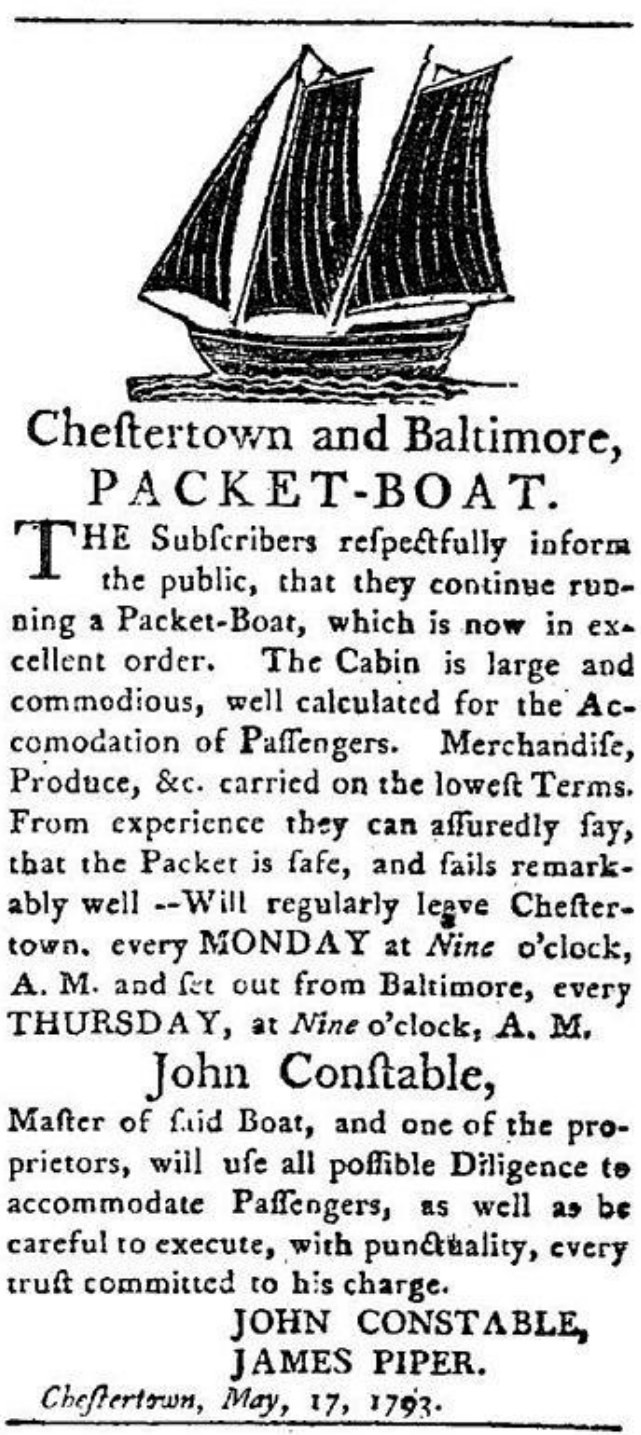
Pre-history

- Communication is a basic human *need*
  - I've never been in a place without some form of communications
- All require some form of *addressing, routing,* and *transport*
- Long history
  - Cyrus the Great credited with first mail service
  - Onto: Pony Express, Packet Boats, etc



Cheſtertown and Baltimore,
PACKET-BOAT.

THE Subſcribers reſpectfully inform the public, that they continue running a Packet-Boat, which is now in excellent order. The Cabin is large and commodious, well calculated for the Accomodation of Paſſengers. Merchandiſe, Produce, &c. carried on the loweſt Terms. From experience they can aſſuredly ſay, that the Packet is ſafe, and ſails remarkably well --Will regularly leave Cheſtertown, every MONDAY at *Nine* o'clock, A. M. and ſet out from Baltimore, every THURSDAY, at *Nine* o'clock, A. M.

John Conſtable,

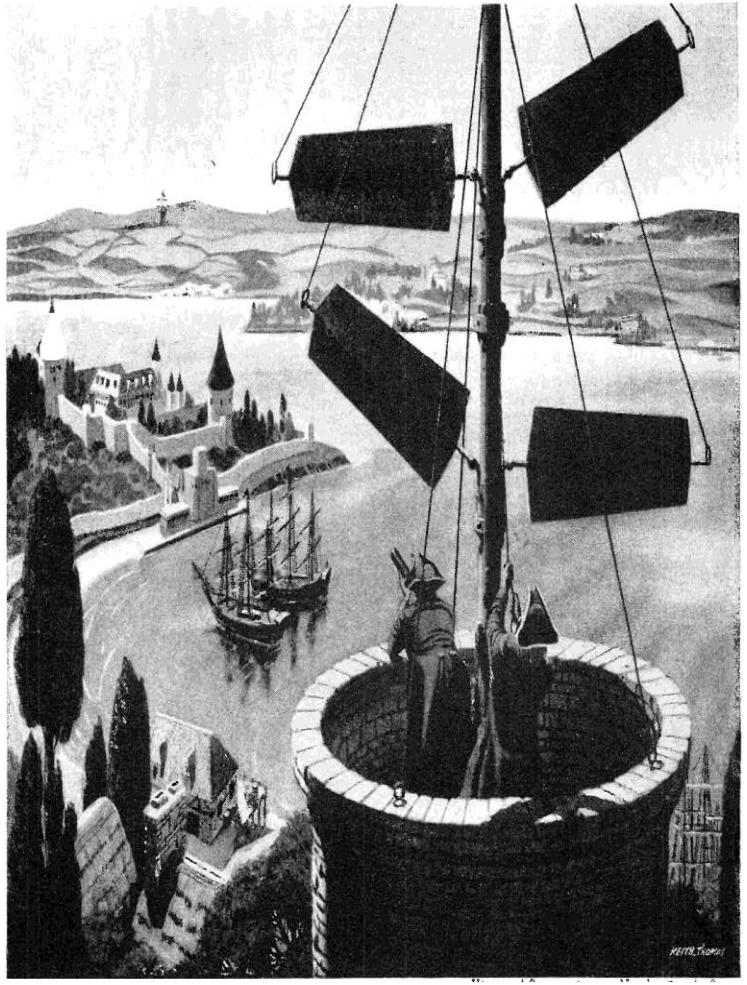
Maſter of ſaid Boat, and one of the proprietors, will uſe all poſſible Diligence to accommodate Paſſengers, as well as be careful to execute, with punctuality, every truſt committed to his charge.

JOHN CONSTABLE,
JAMES PIPER.

Cheſtertown, May, 17, 1793.

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”

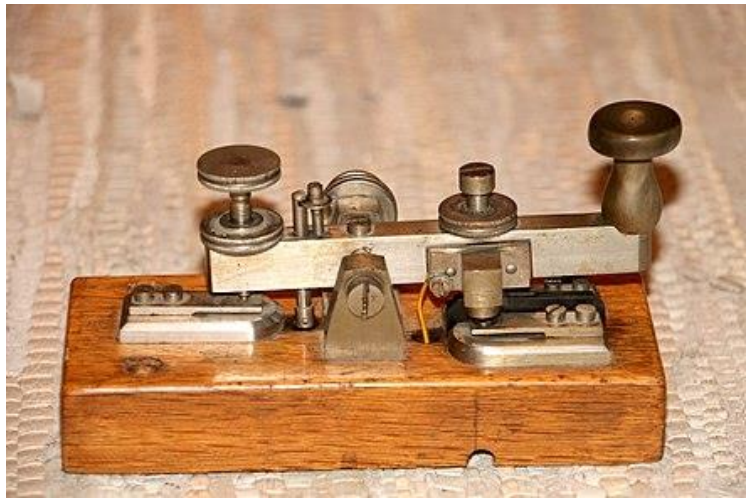


Telegraph

- 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.
  - Limited Range
- 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

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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?

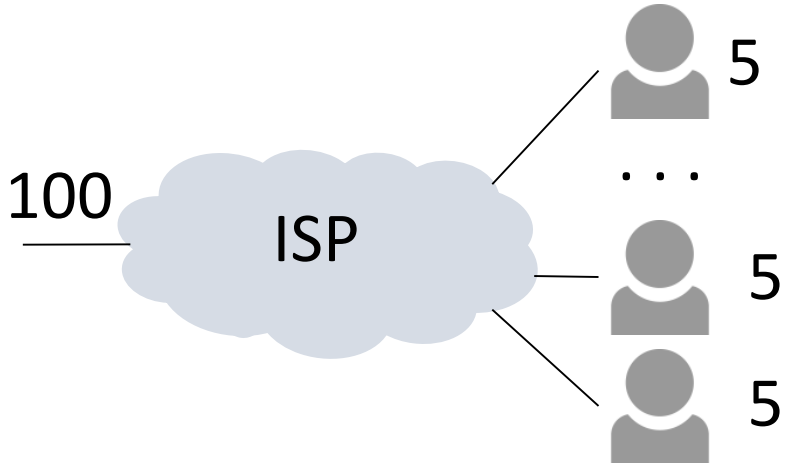
- Efficiency
  - Lines only used when trafficked
- Handles contention
  - Queue packets
- Robust
  - Routes can change
- Kleinrock (UCLA, 1969)
  - UCLA -> SRI
  - “Lo” – Was supposed to be “LOGIN” but crashed

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 …



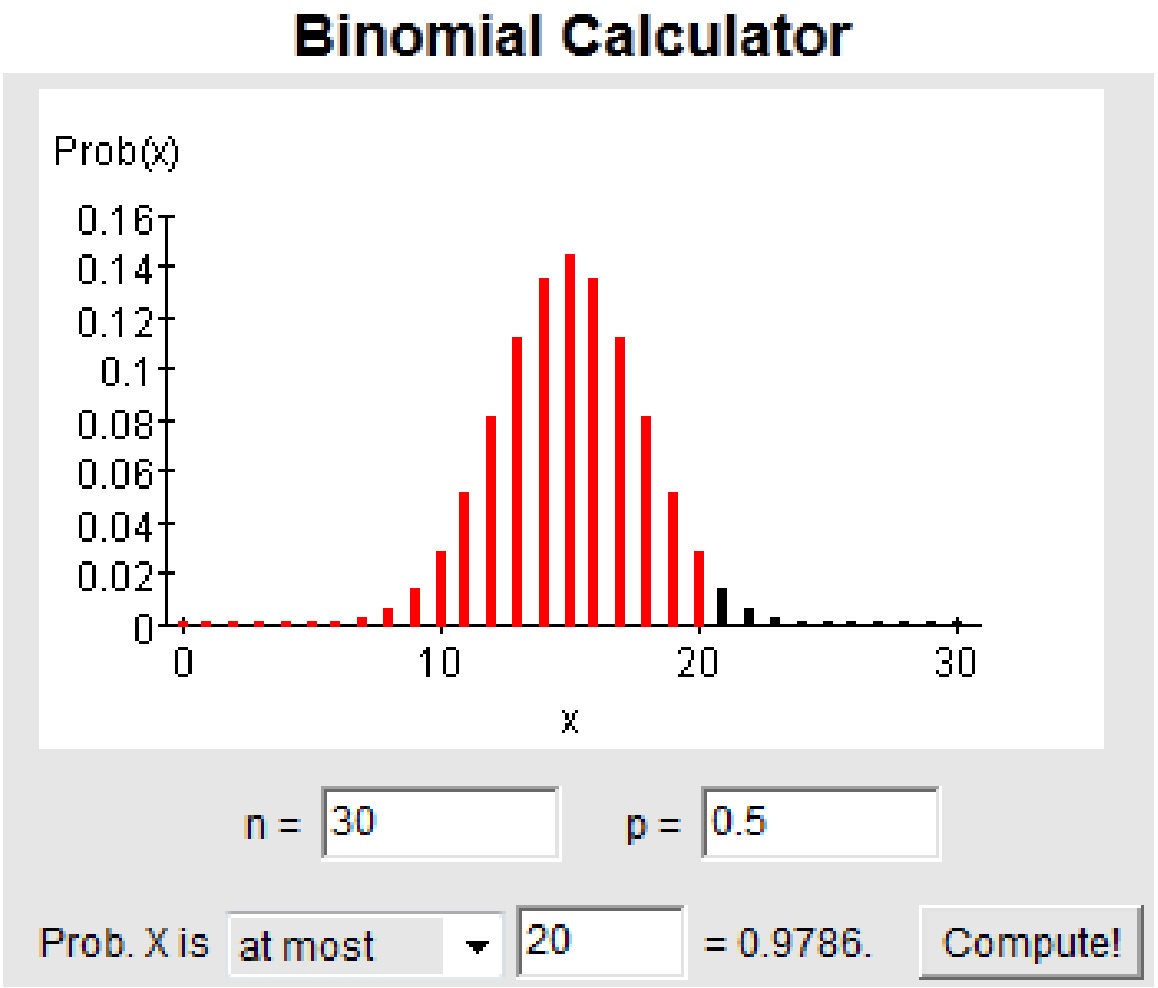
- How many users can the ISP support?
  - With dedicated bandwidth for each user:
  - Probability all bandwidth is used: (assuming independent users)

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

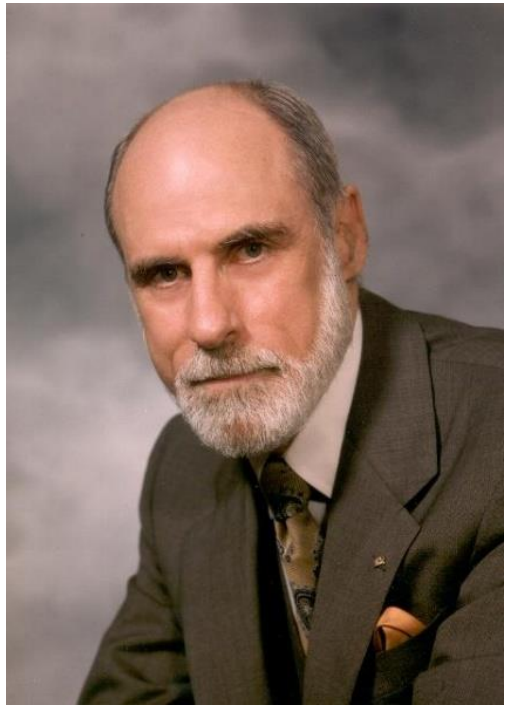
The Beginning – ARPANET

- 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

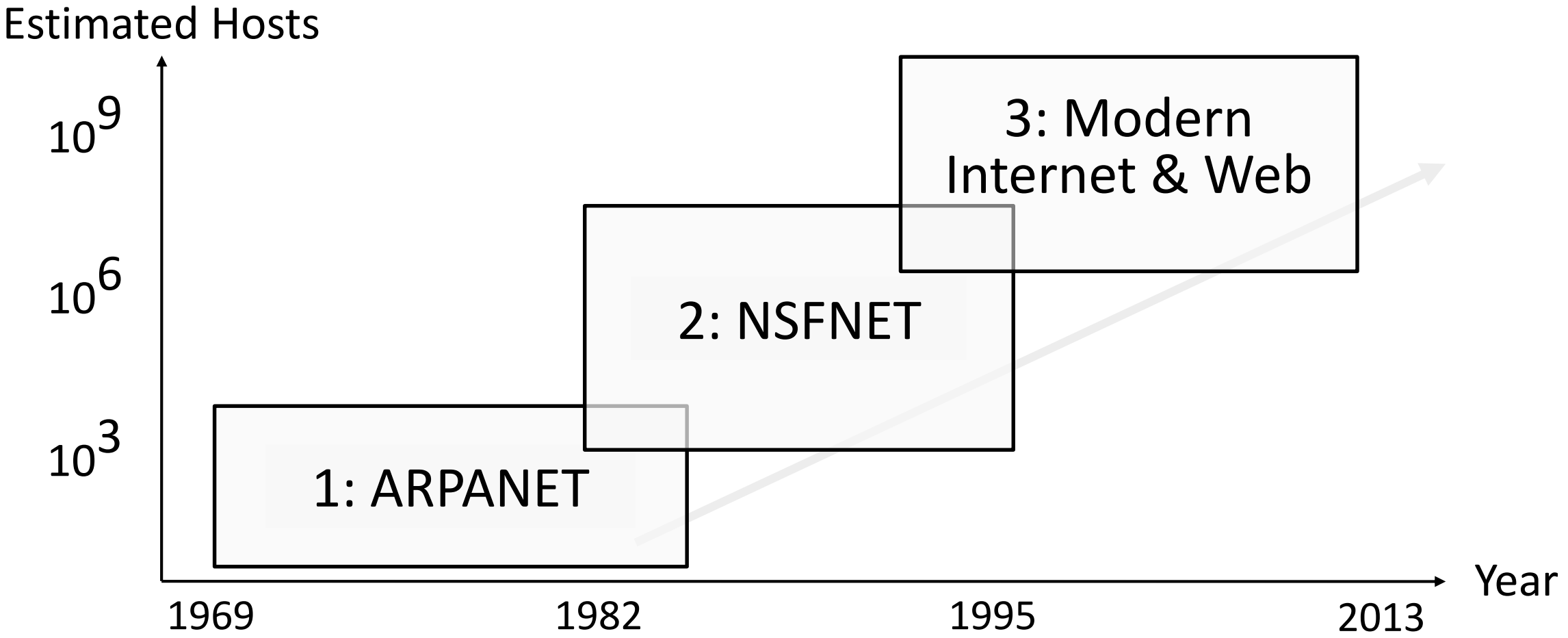
- In the early ARPANET
  - Internetworking became the basis for the Internet
  - Pioneered by Cerf & Kahn in 1974, later became TCP/IP
  - They are popularly known as the “fathers of the Internet”

Vint Cerf

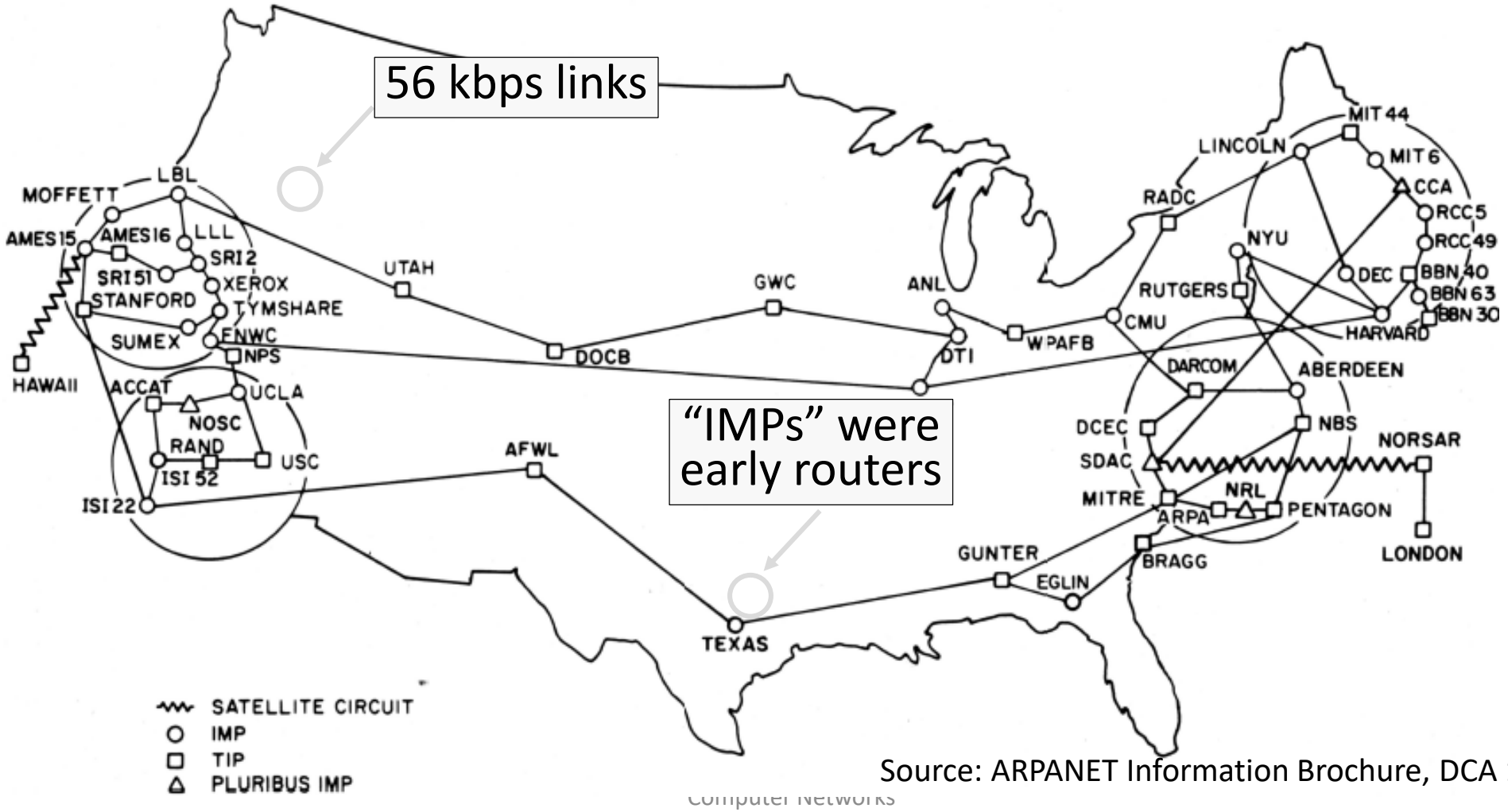


Bob Kahn

Rough Internet Timeline



ARPANET Geographical Map (Dec. 1978)

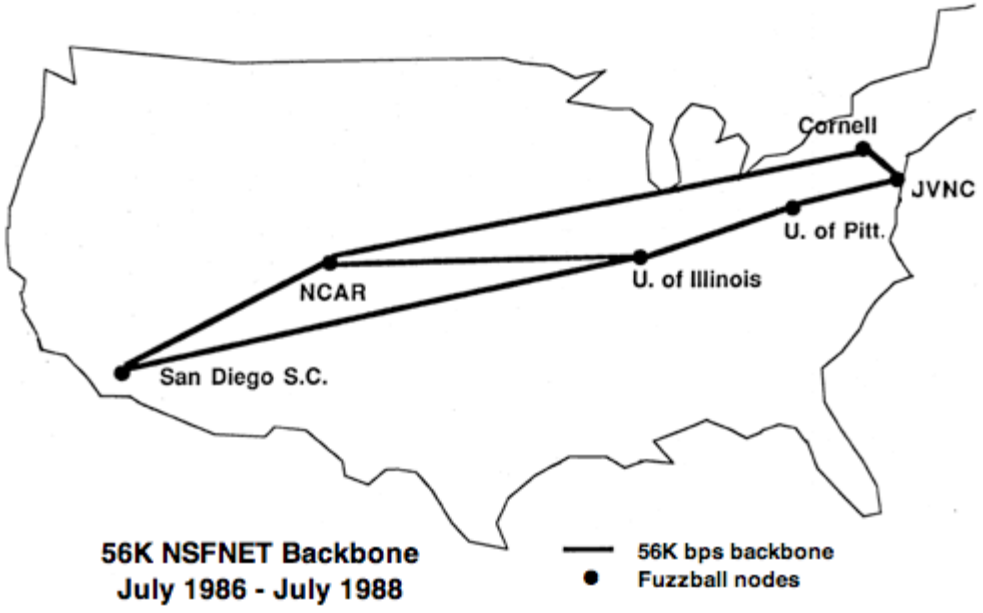


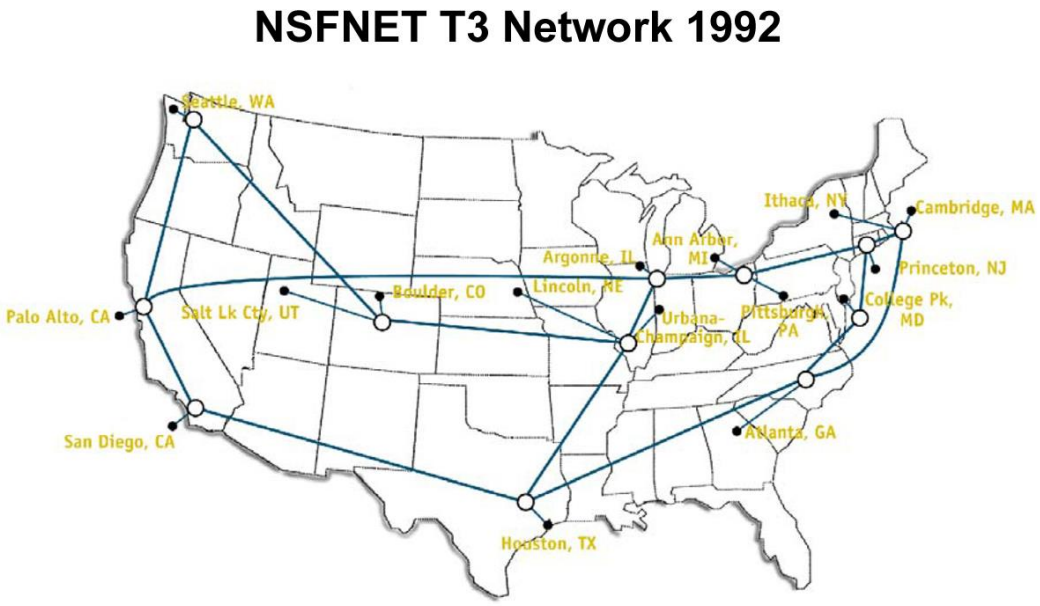
Source: ARPANET Information Brochure, DCA 1979

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 …

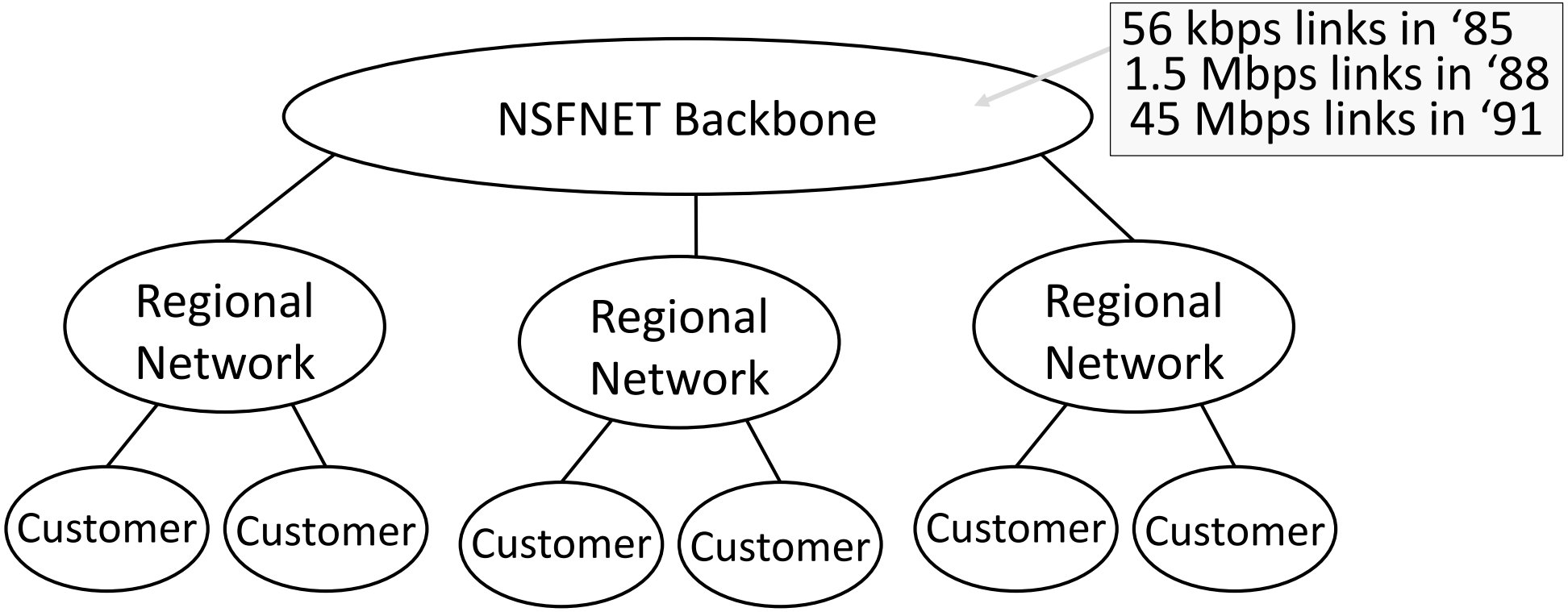
Growing Up- NSFNET





Early Internet Architecture

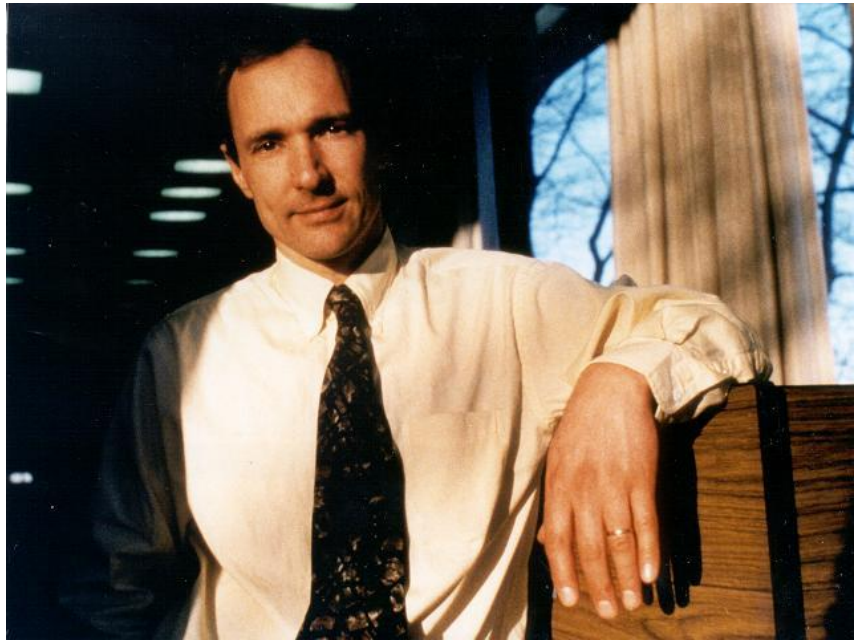
- Hierarchical, with NSFNET as the backbone



Modern Internet – Birth of the Web

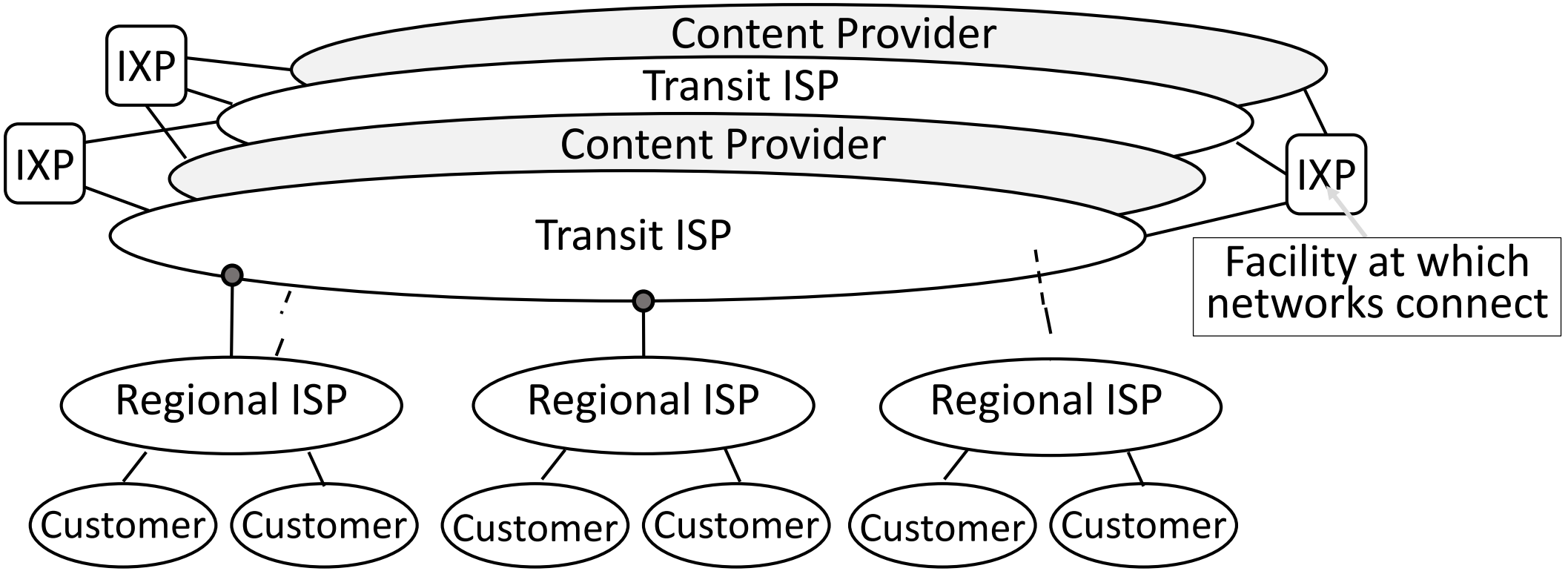
- After ’95, connectivity is provided by large ISPs who are competitors
  - They connect at Internet eXchange Point (IXP) facilities
  - Later, large content providers connect
- Web bursts on the scene in ’93
  - Key idea: Hyperlink
  - Growth leads to CDNs, ICANN in ‘98
  - Most bits are video (soon wireless)
  - Content is driving the Internet

Tim Berners-Lee



Modern Internet Architecture

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



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