Arriving someplace in a roundabout way

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Before the Beginning
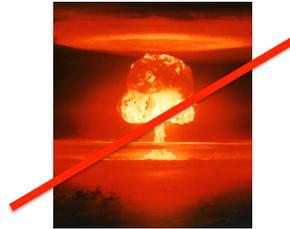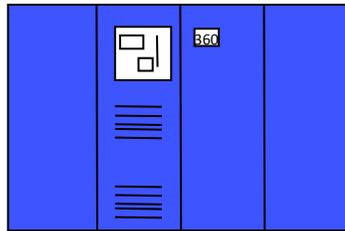
- **The** Phone Network from **T**he **P**hone **C**ompany
- circuit-based
- predictable interconnections between ends
- assumed absolute requirement for QoS
- assumption of being carrier-provided
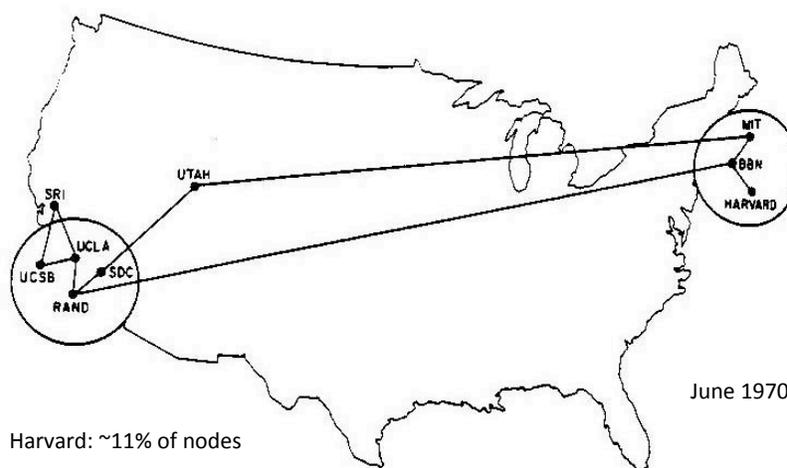- the (only) service was voice

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The Beginning, 1960s

- Len Kleinrock: packet-based networks work
- JC Licklider: global data networks imaginable
- Larry Roberts: need to share scarce computers
- Paul Baran: best effort networks can be reliable (and, by the way, survivable)

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First Contact

June 1970

Harvard: ~11% of nodes

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A Rider Not a Builder

- The ARPANET, and the follow on Internet, rode on the telephone network
  - But were not services offered by the telephone companies
  - Internet service providers (ISPs) bought "wires" from telephone companies
- ISP routers interconnected these wires
  - ISPs not limited to a single telephone carrier or to a single country
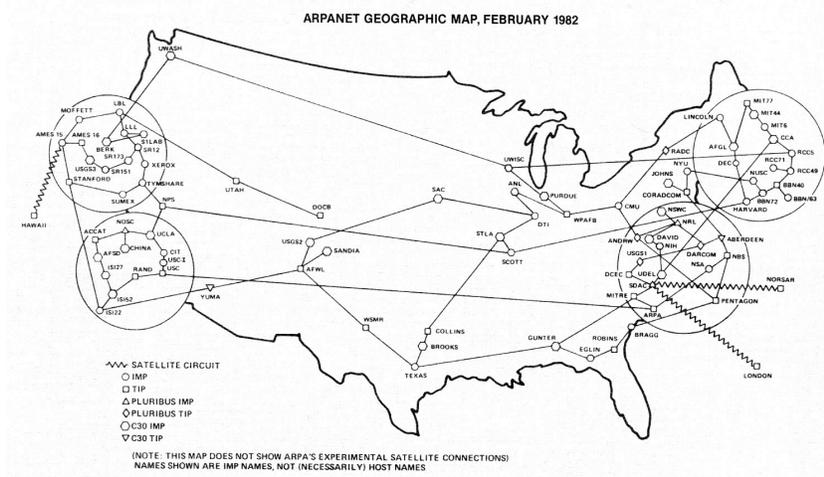
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The View From Most of Harvard

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Why Blank?

- No internal Harvard network

  But, so what – the ARPANET was between a computer at a site to a computer at another site

- No permission

  Only people getting federal funds were permitted to use the ARPANET

  And staff on the connected computer :-)

- Thus, very small percent of the Harvard community knew about, or used, the ARPANET

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The View Changed in 1983
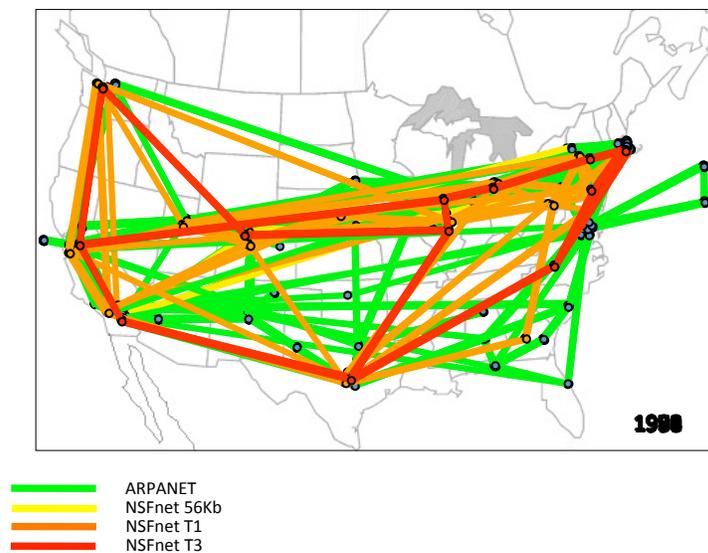

ARPANET view Enabled by CSNet

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Two Changes in 1983

- CSnet membership gave blanket access permission (for email)
    - Including all facility, students and staff
    - Exposing the first of many generations of students
- Deployment of TCP/IP
    - Change to interconnecting networks at sites
- Started & proven by the feds, who then fade

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Federal Net Topology

1988

▬	ARPANET
▬	NSFnet 56Kb
▬	NSFnet T1
▬	NSFnet T3

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What Did They Prove?

- That high-speed packet-based networks could be built and operated reliability
- That packet-based network were useful
- That packet-based networks could support many services

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Me @ Harvard

- ARPANET #1: sob at harv10
- NIC: SB28
- Usenet: {genrad|bbncca|panda|ihnp4| allegra|harvard}!wjh12!sob
- BITNET: sob at HARVUNXW
- ARPANET #2: sob@harvard.harvard.edu
- NSFNet: sob@harvard.edu

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History Feature: Bang Addressing

- Usenet (uucp) initially ran over dial-up connections between routers
  - Cost hidden in coms budget
- Uucp used source routing
- Sender defined store and forward path to reach destination
- Exclamation points (bangs) between node names

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How Not to Do it: Pathalias

- Pathalias discovered uucp paths to destinations
- Worked off of a map of uucp nodes and connections
- Uucp mapping project started in early 1984 to create a whole-world map of uucp nodes
  - *Unknown Mailer Error 101, or Why Its So Hard To See You* – USENIX summer 1984
- Project closed in 2000, OBE

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History Feature: BITNET

- Because Its There Network
  - Later changed to "Because its Time"
- Interconnected IBM mainframes
  - And machines that pretended to be IBM mainframes
- Store & forward, world-wide
- Like uucp, costs buried in telecom bill
  - Avoided having to get permission

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Harvard and Internet #1

- Initial IP external connectivity via ARPANET
  - To one or two computers in Aiken Comp lab
- Internal connectivity by point-to-point twisted pair cables
  - Up to 1.5 Mbps
  - Running SLIP

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Gateway

- Wjh12 (an 11/44) served as a gateway between BITNET, usenet & ARPANET

  And the Harvard campus

- The first time I heard "do not ask questions you do not want to know the answers to"

  When I asked if it was OK to take over the Usenet/ ARPANET gateway function from Larry Landweber

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Internet Moves to Be All

- Both uucp & BITNET evolved to run over TCP/IP

  Then died

- Chaosnet, XNS, IPX, DECNET, AppleTalk, SNA, APPN bloomed, then withered, then died – leaving only TCP/IP

- VoIP not new

  Danny Cohen: Network Voice Protocol (RFC 741 1977)

- Nor is video

  Van Jacobson et al, Whiteboard (1992)

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Harvard and Internet #2: 1986

- Internal fiber Ethernet – 13 buildings
    Passive optical
- External - John Von Neumann Computer Network (JvNCnet)
    NSF-funded network to connect to supercomputer
    T1 to MIT & then T1 to Princeton
- NSFNet v1 (56 Kbps) interconnected supercomputer centers

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Harvard and Internet #3: 1988

- We can do better: NEARnet
- MIT-, BU- & Harvard-founded regional network
    New England area
    10 Mbps microwave Ethernet
    BBN hired to manage
- Some DARPA funding, so they could end ARPANET – no NSF funding
- No rule against commercial traffic
- Connected to CIX (not just NSFnet)

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10 Decisions That Made a Difference

- support existing networks
- datagram-based
- creating the router function
- split ITCP into IP and TCP
- DARPA fund Berkeley to add TCP/IP to UNIX
- CSNET and CSNET/ARPANET deal
- NSF require TCP/IP on NSFnet
- ISO turn down TCP/IP standardization
- NSF Acceptable Use Policy (AUP)
- minimal regulation

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Enabler, Not Inventor

- High Performance Computing Act of 1991 (HPCA)
  Funded research centers and connectivity

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Commercial Internet

- Forced by ARPANET & NSFnet AUPs
- UUnet – 1987 (loan from Usenix)
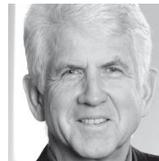- PSInet – 1989
- …

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Friends And Family (only)?

- 'I will not interconnect with him'

- Also Prodigy, AOL, CompuServe
- Isolation did not last

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But, Inconceivable Relevance

- Existing telecommunications world did not believe
  - E.g., IBM no-bid ARPANET router
    - no future in packet-based networks
  - Conventional wisdom: best effort useless
    - Guaranteed QoS required
  - Most connections low speed (dial-up)
  - No threat seen to telephone companies
- Thus, totally ignored by regulators
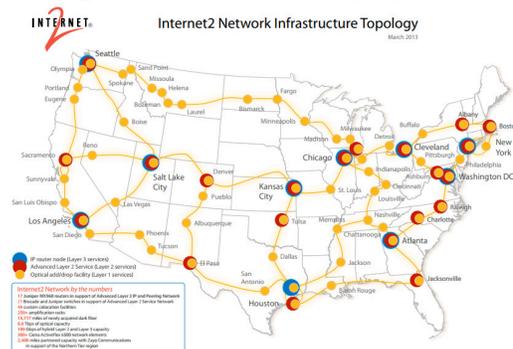 - including the ITU

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Many Non-Believers

- Harvard library: refused to put card catalog on-line
- Network World: discouraged me from writing about the Internet until the late 1990s
- ITU-T spent a decade working on NGN
- Regulators assumed uselessness so ignored the Internet until recently

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Internet2: A Non-Alternate Universe

- Born from MFUG in 1996
- 'High-speed, QoS & GigaPOPs'
- ISP for high-ed+, COTS equipment

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Side Trip (So Far)

- It is now 20 years since IPv6 was announced
  IETF 30, Toronto CA July 1994
  ALE WG: v4 addresses to run out 2008 ± 3
- Yes, we have no (v4) addresses: IANA (2011)
  Ditto APNIC (2011), ditto RIPE (2012)
  LACNIC: (projected 2014)
  ARIN: (projected 2015)
  AFRNIC: (projected 2019)
- Few choices but v6, but …
  Delaying by using a address market

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The Now Reality

- Its only IP for transport
  voice, video and other types of data
- Carriers, not ISPs, for residential market
- Little competition
- Much money made using the Internet, not so much providing the Internet
- Now the FCC wants to replace what got us here
- The net is too important to leave it to the people that know what they are doing

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Higher Ed and the Internet

- Without higher-ed the Internet would not have become **The Internet**
- Exposed students & others to the power of open communications – creating demand
- Implemented ideas when they were new (e.g. WWW)
- Supported ISPs (rather than carriers wanting a walled garden with a per-port fee)

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A Fun Ride

- From geek-bait to mom-surfing
- From aggressively ignored to can't take their hands off it
- From rot-13 for sensitive eyes to decimating the porn industry
- From pushing green cards to 70% spam
- From naïve libertarians to the Arab Spring
- From the Cuckoo's Egg to NSA world-Hoovering

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I hope we recognize what comes out of the next phase

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