

A history of the Internet (hint: It was not The Bomb.)

Scott Bradner

NANOG

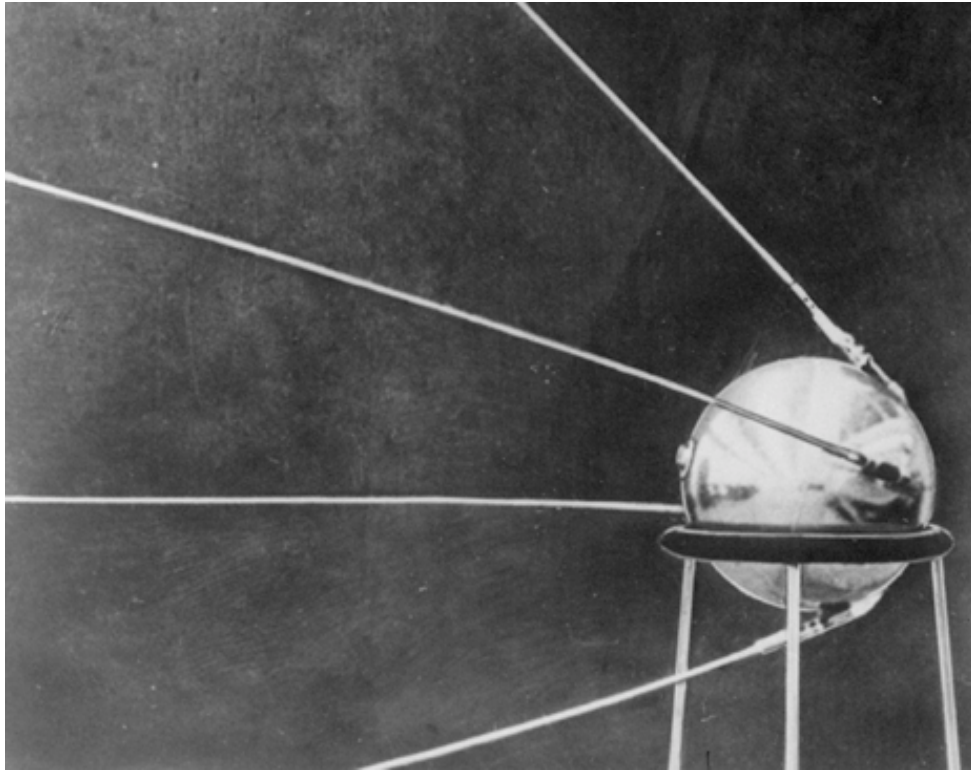
2018-02-19

Internet history

1957-present

- A series of people and events that got us to today's Internet
- Representative, not comprehensive

Internet history: Sputnik 1957



- 4 October 1957
- 1st man made satellite
- Launched by Soviet Union
- Caused *hysteria*

Roger Launius *Sputnik and the Origins of the Space Age*

- *The sky seemed almost alien*

Lyndon B. Johnson

Internet history: Dwight David Eisenhower

1958

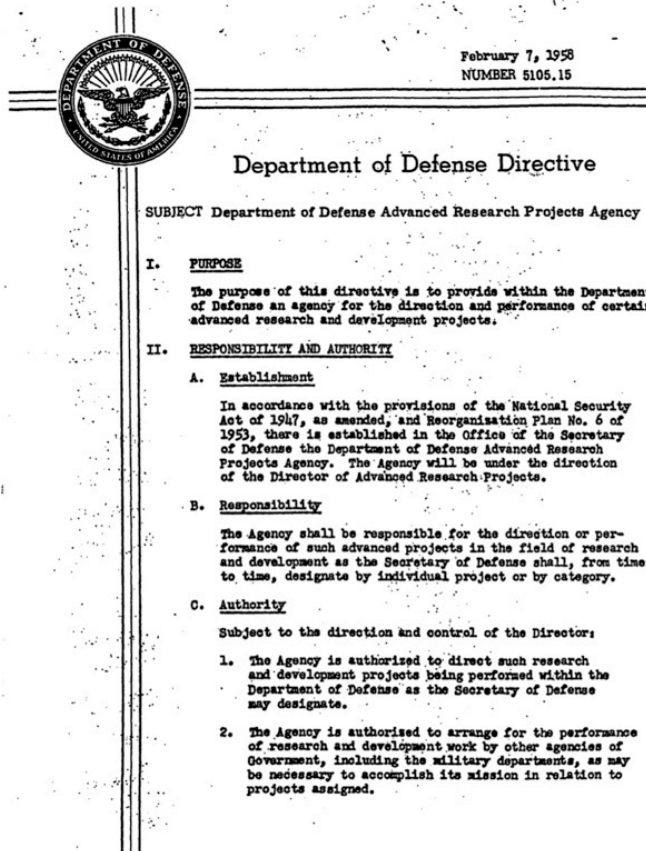


Dwight David Eisenhower

- U.S. President – 1953-1961
- January 1958: Eisenhower, following advice from his science advisor Jim Killian, reacted to Sputnik by establishing the *Advanced Research Projects Agency* (ARPA) within the U.S. Department of Defense



ARPA Mission



- Official:

The Agency shall be responsible for the direction or performance of such advanced projects in the field of research and development as the Secretary of Defense shall, from time to time, designate by individual project or by category.¹

- Actual?:

to prevent technological surprise like the launch of Sputnik²

1: http://semanticvoid.com/docs/darpa_directive.pdf

2: <http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&ADA433949> DoD Directive No. 5105.15 [http](http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&ADA433949)

Internet history: J.C.R Licklider

1960-68



J.C.R Licklider

- 1960: *Man-Computer Symbiosis*
How people could interact with computers
- 1962-3: *Intergalactic Computer Network* memos
Global data networks interconnecting computers
- 1962: argued for, created & initially led the ARPA Information Processing Techniques Office (IPTO)

Internet history: Paul Baran

1960-64

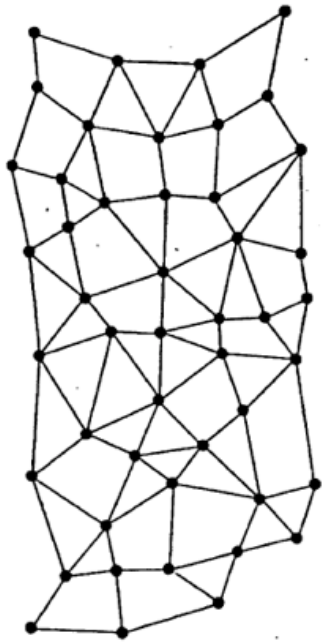
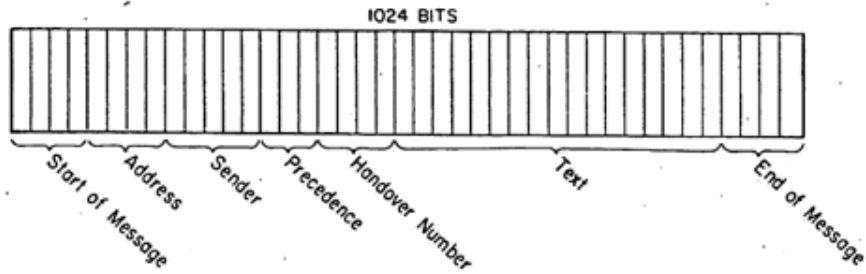


Paul Baran

- Hughes Aircraft & RAND Corp.
Funded by US Air Force
- 1960: *Reliable Digital Communications Systems Using Unreliable Network Nodes*
Reliability through redundancy
- 1962: *On Distributed Communications Networks*
Basic concepts of packet switched networks

Internet history: Paul Baran, contd.

1960-64



DISTRIBUTED
(C).

- “standardized message block”
 - Source & destination addresses
 - Precedence (QoS)
 - Payload
- Distributed network
 - Switching nodes (routers)
 - Store and forward
 - Redundant paths for reliability
 - Shortest-path hot-potato routing protocol

Internet history: why message blocks

1962-64

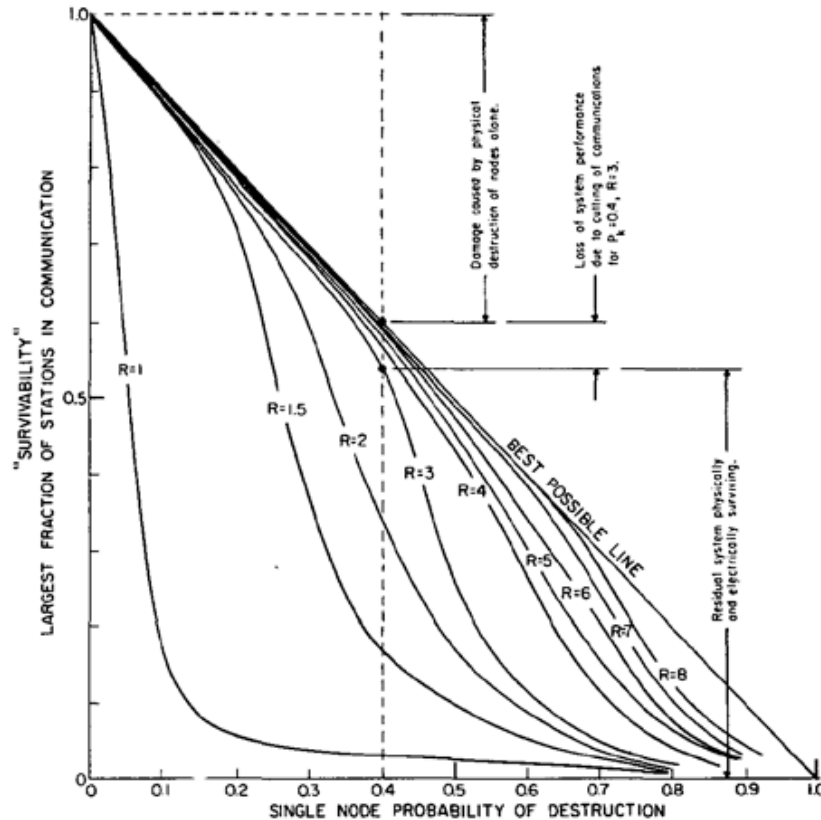


Fig. 4—Perfect switching in a distributed network: sensitivity to node destruction, 100 per cent of links operative.

- Communication at the time was circuit-based
- Circuit setup takes too much time relative to transmission length as links get faster
- Message-based networks also provide:
 - Multiplexing of different rate communications
 - Minimal message retransmission after failover to new routes
 - Resilience in the face of failure
 - Support for many applications (including speech)

Baran's Goal¹



- Develop a command and control network that could survive a first strike nuclear attack
- Make design public so Russia would have it
 - Almost all of Baran's documents were public
- AT&T: it will not work
- Did not get built
 - DCA would have had to do it

1: <https://conservancy.umn.edu/handle/11299/107101>

Internet history: Donald Davies

1966-70



Donald Davies

- U.K. National Physical Laboratory
- 1966: proposed “packet” based communication between computers
Later introduced to Baran’s work
- 1967: Roger Scantlebury (from Davies’s group) presented paper on packet switch networks

Larry Roberts in audience

Afterward Scantlebury reminded Roberts about Baran’s work

Internet history: Robert (Bob) Taylor

1965-66



Bob Taylor

- Took over ARPA IPTO in 1965
- 1966: requested & was authorized to spend \$1M to build a data network to enable remote access to ARPA-funded timeshare computers
- 1966: Appointed Lawrence (Larry) Roberts to manage network project, which became the ARPANET

ARPANET Mission



Resource Sharing Computer Networks

The objective of this program is twofold:

- (1) To develop techniques and obtain experience on interconnecting computers in such a way that a very broad class of interactions are possible, and*
- (2) To improve and increase computer research productivity through resource sharing.*

By establishing a network tying IPT's research centers together, both goals are achieved. ¹

1: <https://archive.org/stream/ResourceSharingComputersNetworks3/AAPA.txt>

Internet history: Lawrence (Larry) Roberts

1966-73



Larry Roberts

- Decided to offload network processing to separate computers
(Idea from Washington University physicist Wesley A. Clark)
Interface Message Processor (IMP)
- Decided did not want to use circuit switched networks
- Adopted packet switching for the ARPANET after 1967 meeting
- Took over ARPA IPTO in 1969

Internet history: Leonard (Len) Kleinrock

1968

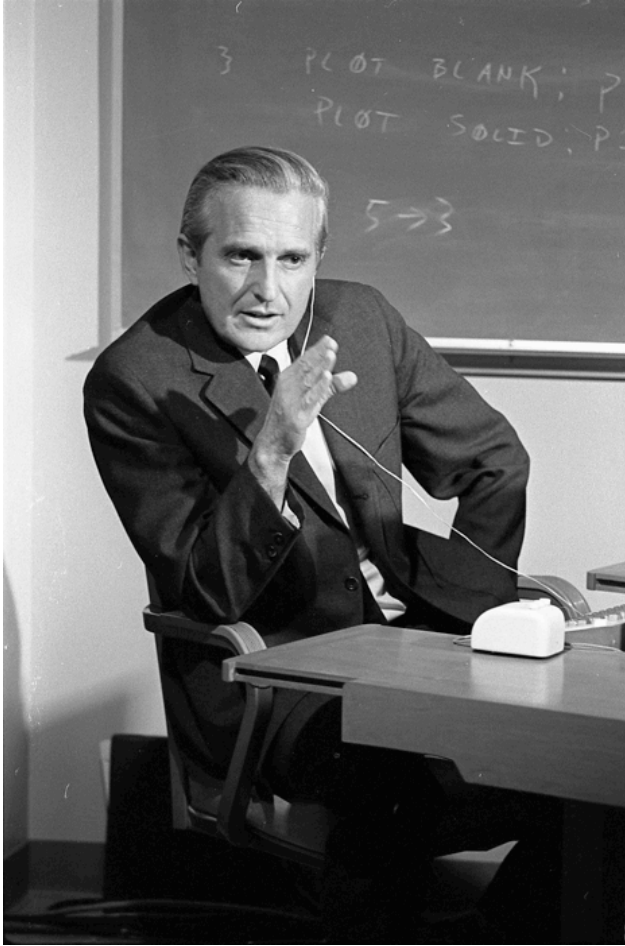


Len Kleinrock

- UCLA professor of computer science
- 1963: MIT thesis on queuing theory
Used in understanding operation of packet switches
- First ARPANET message sent from Kleinrock's UCLA lab

Internet history: Douglas Engelbart

1968



Douglas Engelbart

- Stanford Research Institute
- Founded ARPA funded Augmentation Research Center
- 1968: Mother of all Demos¹
 - computer mouse
 - windows
 - Real-time editing
 - bitmapped screens
 - hypertext

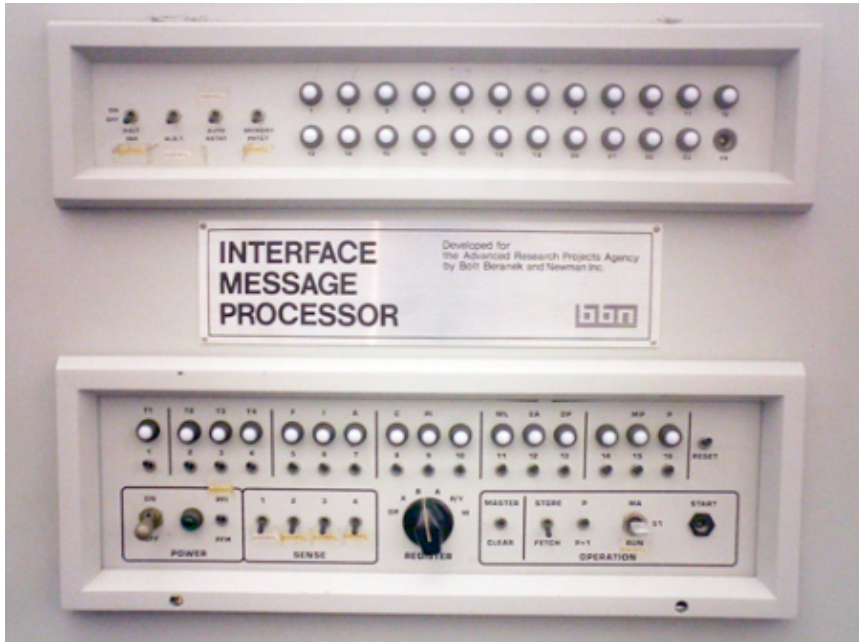
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1: <https://www.youtube.com/watch?v=yJDv-zdhzMY>

Internet history: ARPANET

1968-69



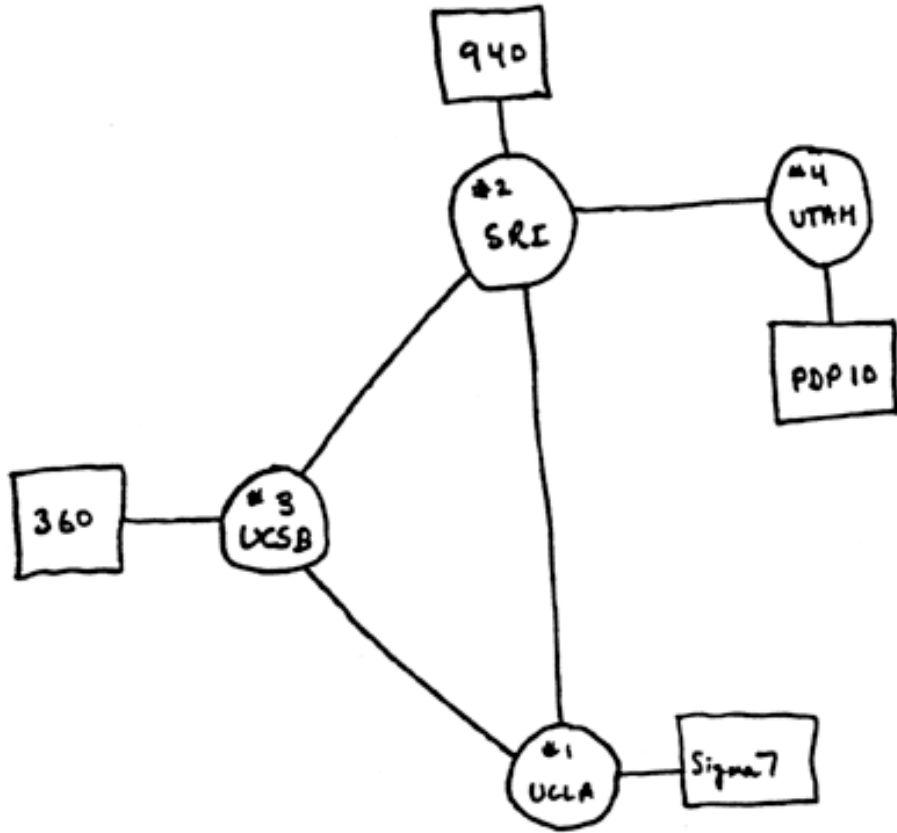
- 1968: RFQ for IMPs published
4-node initial network
- 12 of the 140 companies asked
submitted a bid

Neither IBM nor AT&T bid

- Bolt Beranek & Newman (BBN)
won the contract
- September 1969: First IMP
delivered to UCLA

Internet history: ARPANET, contd.

1969

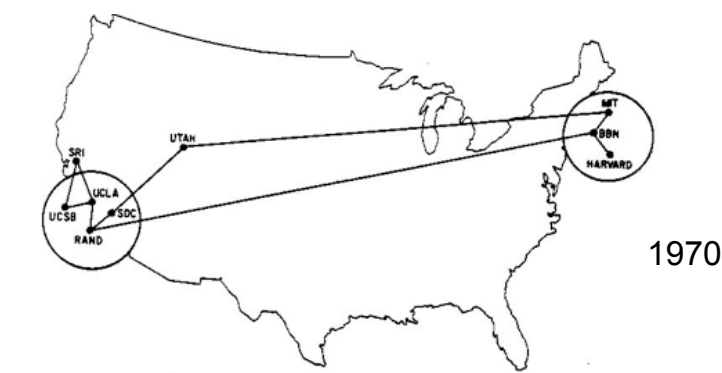


- First 4 nodes installed
 - UCLA – Len Kleinrock
 - Stanford Research Institute – Doug Engelbart
 - University of California, Santa Barbara – Glen Culler and Burton Fried
 - Early interactive on-line system
 - University of Utah – Ivan Sutherland

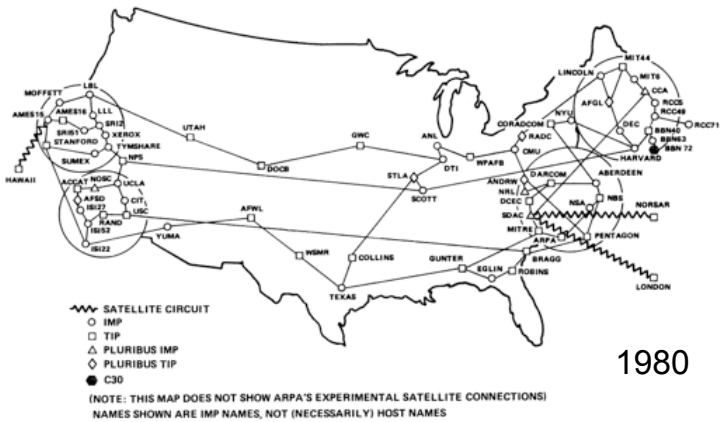
Internet history: ARPANET, contd.

1970-80

- 1970 – east coast
First MIT, then Harvard
9 hosts
- 1973 – International
Norway & London
22 hosts + 18 TIPs
TIPs supported terminals
- 1980 – 200 hosts
20,000 users



ARPANET GEOGRAPHIC MAP, OCTOBER 1980



Internet history: Robert (Bob) Kahn

1968-76

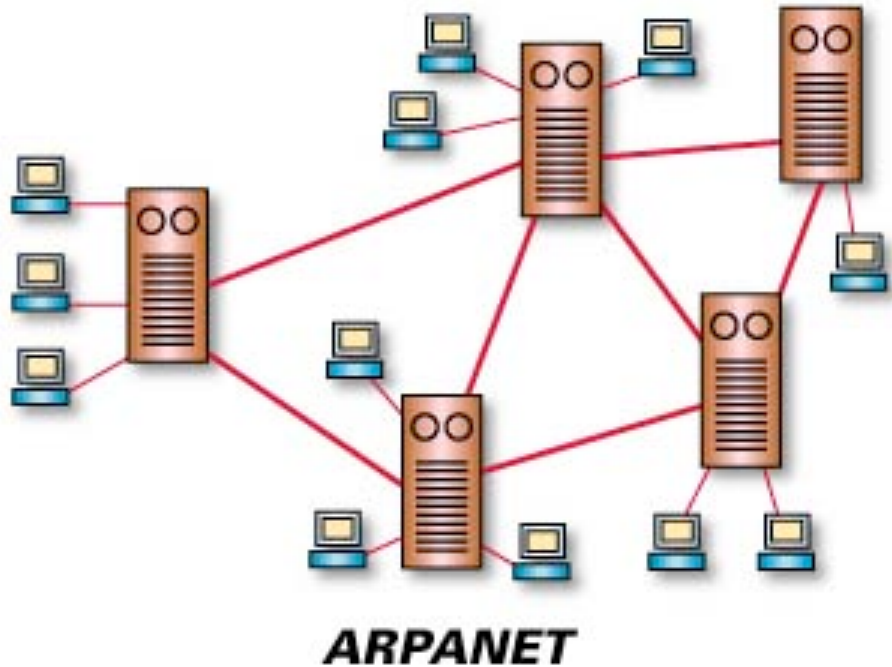


Bob Kahn

- 1964: PhD from Princeton explored sampling theory
- 1968: Joined BBN & worked on IMP
- 1972: moved to ARPA IPTO
- Late 1972: organized demonstration ARPANET communications (20-nodes)
- 1973: asked Vint Cerf to help design a new communications protocol for the ARPANET

Internet history: NCP

1969-83



- The original ARPANET communications protocol was the **N**etwork **C**ontrol **P**rogram
- IMPs communicated via NCP and communicated to directly attached hosts
- NCP allowed a host on the ARPANET to communicate with another host on the ARPANET
- NCP provided reliable communications between IMPs

Internet history: Danny Cohen

1976



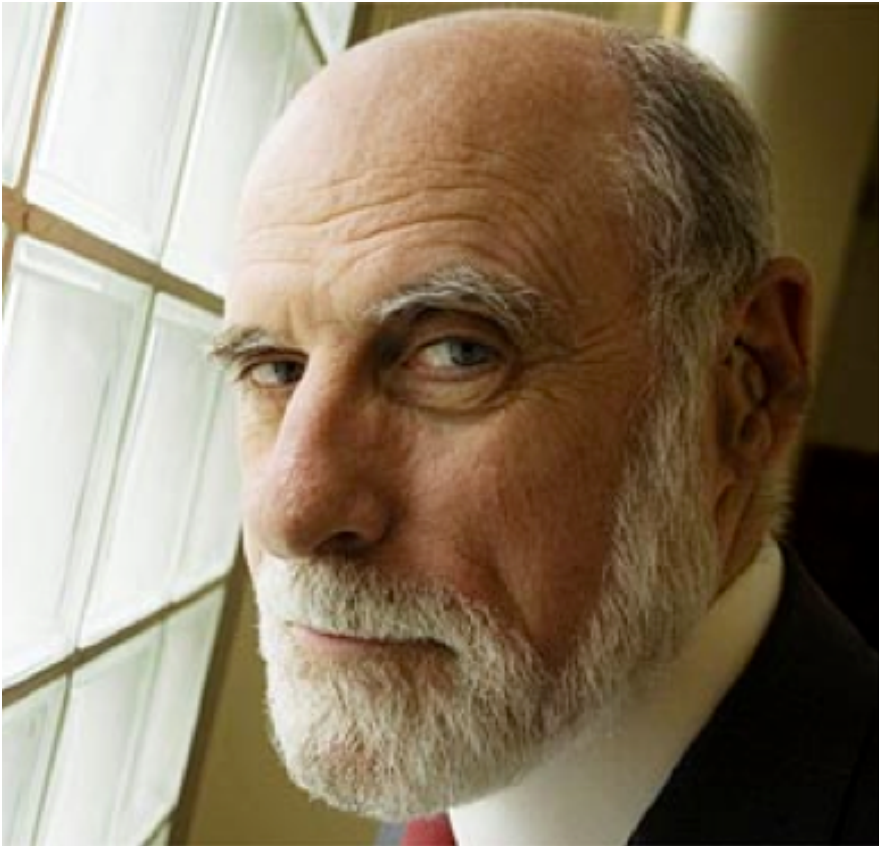
Danny Cohen

- Researched transporting speech over packet networks
- Realized that reliable transport protocols not good for speech
 - Delays introduced by reliability mechanism hurt understandability
- Used a reliability bypass option in NCP
- 1978: demo video of speech over the ARPANET¹

1: https://www.youtube.com/watch?v=MGat1jRQ_SM

Internet history: Vinton (Vint) Cerf

1973-81



Vint Cerf

- Kahn realized that just interconnecting hosts over a single network did not scale
Needed a way to interconnect hosts on different networks
- He asked Vint Cerf for help
- They took into account the design of the CYCLADES network

Internet history: Louis Pouzin

1971-76



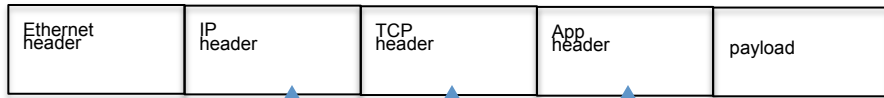
Louis Pouzin

- French computer scientist
 - Spent time at MIT in mid 1960s
- 1972: designed CYCLADES network – a “catenet”¹
- 1974: Deployed 7 nodes
- 1976: 20 nodes
- “Pure datagram network”
 - No delivery assumptions
 - Reliability, order, duplication
 - Ran over France Telecom lines
- Put reliability responsibility at end points “end-to-end”

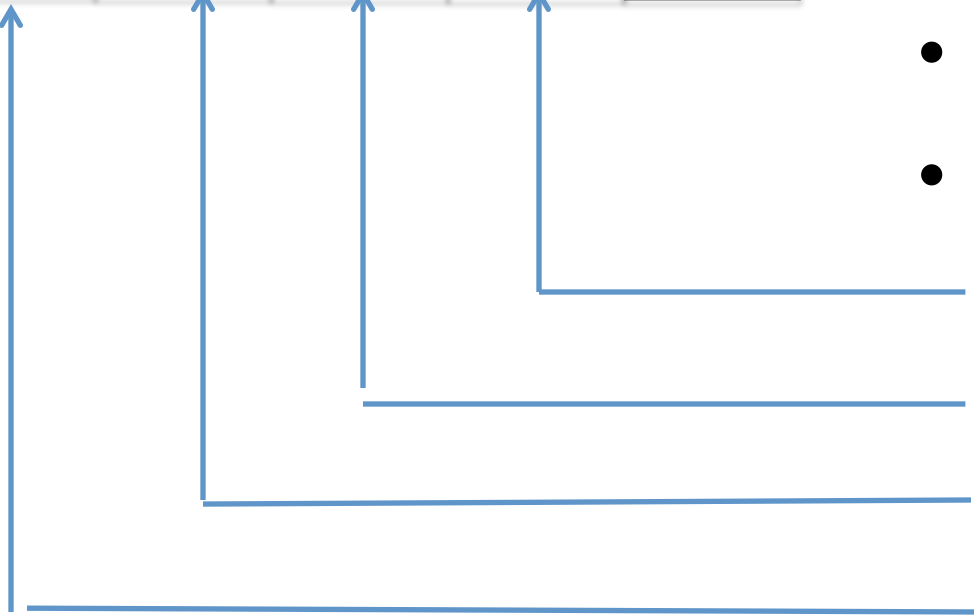
1: <https://www.rfc-editor.org/in-notes/ien/ien48.txt>

Internet history: Internet Protocol

1974-81

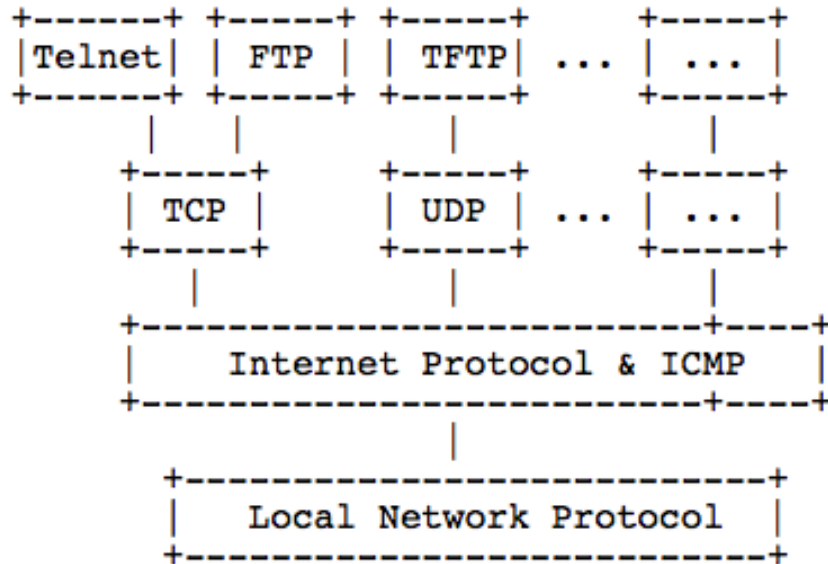


- Cerf & Kahn developed a datagram-based “Internet Protocol” suite
- Used Pouzin’s end-to-end concept
- Multiple layers
 - Application layer (e.g. telnet)
 - Transport layer (e.g. TCP)
 - Internet layer (IP)
 - Local network layer (e.g. Ethernet)



Internet history: TCP/IP

1974-81



Protocol Relationships

Figure 1.

TCP/IP

- 1974: Internet Transmission Control Program (ITCP)
 - Only provided a reliable service
 - Danny Cohen & others objected
- 1980 & 81: Internet Protocol, Transmission Control Protocol & User Datagram Protocol
 - Provided both reliable and unreliable services
 - Added UDP in parallel to TCP

End-to-End Principle

1981



Jerry Saltzer



David Reed



Dave Clark

- *End-to-End Arguments in System Design*
- Placing low level functions in the network is redundant and of little value compared to placing them in the end nodes

The ends know what they need, the network can't

What did *they* think the Internet was?



- Irrelevant
Only a “research network”
No guarantees, no security



- Result: no regulations
Key enabler

End-to-End Design

STEVE G. STEINBERG 10.01.96 12:00 PM

NETHEADS VS BELLHEADS

The most vicious battle on the Net today is a secret war between techies. At stake is nothing less than the organization of cyberspace.

It was a frequent observation among the laptop-toting 25-year-olds who crowded into the UC San Diego auditorium on an overcast morning last February that if a bomb were to go off right then, the entire Internet would collapse. It was the kind of braggadocio you hear among any large gathering of engineers, but, in this case, it was probably true.

The 250 engineers who filled the dark, wood-paneled auditorium during the two-day meeting of NANOG, the North American Network Operators' Group, were from America's largest Internet service providers - companies like UUNet, Netcom, and Sprint - and they possessed the self-confidence that comes from operating millions of dollars of bleeding-edge technology that the world increasingly depends on. They were the builders of a new age, and although lacking the brawn and defined cheekbones of the engineers in Soviet propaganda posters, they emanated the same heroic attitude of advancing civilization through Herculean struggles.

Rise of the Stupid Network

Why the Intelligent Network was once a good idea, but isn't anymore. One telephone company nerd's odd perspective on the changing value proposition

by

David Isenberg - isen@isen.com - www.isen.com

- “Stupid Network” just transports packets
 - Carrier does not own the customer
- Enables permissionless innovation
- The Internet is a Parent Revolution¹
 - Not the revolution itself

1: *Hunchback of Notre Dame* about the printing press

Internet history: commercialization

1990-



- Pre 1991: commercial use of ARPANET & NSFNET banned
- 1990: commercial ISPs formed
- 1991: Commercial Internet eXchange (CIx) formed
- 1991: limited commercial use of NSFNET permitted
- 1992: MAE-East formed
- 1995: NSFNET closed
U.S. government out of backbone business

Internet history: the web

1991-



Tim Berners-Lee

<http://www.internetlivestats.com/total-number-of-websites/>

- 1991: Tim Berners-Lee releases web browser and server
- 1991: first web sites
- 1993: NCSA Mosaic released
- 1994: Netscape browser
- 1995: 23 K web sites
- 2000: 17 M web sites
- 2005: 65 M web sites
- 2010: 200 M web sites
- 2015: 1 B web sites

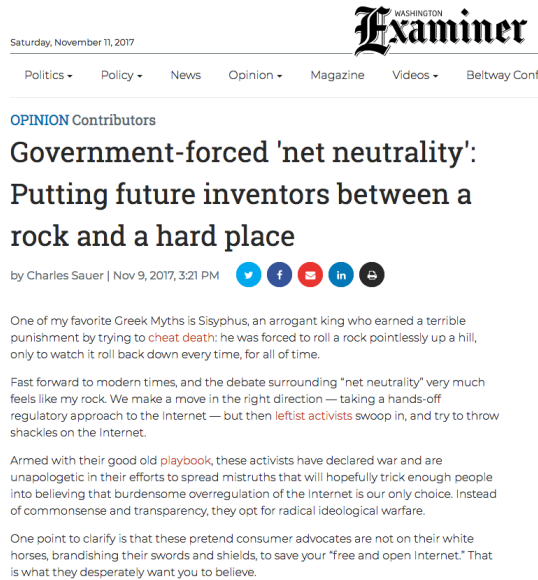
Decisions that Made a Difference



Can you imagine?

- Support existing networks
- Datagram-based
- Creating the router function
- Split TCP and IP
- DARPA fund Berkeley to add TCP/IP to UNIX
- USPS deciding that electronic messages were not “mail”
- CSNET and CSNET/ARPANET deal
- NSF require TCP/IP on NSFnet
- ISO turn down TCP/IP
- NSF Acceptable Use Policy (AUP)
- Minimal regulation

Today's Internet



- Too important to leave to the people that know how it works (and built it to what it is today)
E.g., fight over network neutrality
- Widespread (among governments, carriers and some in civil society) desire for Internet governance

The Internet in the Future, technology?



[Quinlan](#): Come on, read my future.

[Tanya](#): You haven't got any.

[Quinlan](#): Hmm? What do you mean?

[Tanya](#): Your future's all used up. ¹

- TCP/IP
- ATM
- MPLS
- Per-flow queuing
- Next Generation Internet
- 3/4/5G
- Information Centric Networking
- All-Intelligent Network
- . . .

1: <https://www.youtube.com/watch?v=UWtAZwxK5H0>

The Internet in the Future, Control?



Newt Gingrich

- The carriers have been trying to control the Internet ever since they figured out that it was not irrelevant
Same for governments & the ITU
- A “controlled” Internet would not be The Internet

Basic Questions



- 1996 I said there were two basic questions concerning the Internet:

“Who says who makes the rules?”

“Who pays for what?”

- These questions are still unanswered

<http://www.sobco.com/presentations/fdic.pdf>

Now, 20 years later



- *What achieved success was the very chaos that the Internet is. The strength of the Internet is that chaos. It's the ability to have the forum to innovate.*¹
- Will the forum continue?

1: Scott Bradner, March 22, 1996