Visions

Vannevar Bush, “As we may think” (1945): memex

J. C. R. Licklider (1962): “Galactic Network”

- Concept of a global network of computers connecting people
- First head of DARPA computer research, March, October 1962
Circuit switching

1920s

1967
1961-64: Packet switching

- Paul Baran (RAND)
- Donald Davies (National Physical Laboratories, UK)
Baran’s packet switching

Baran’s packet switching

There is an increasingly repeated statement made that one day we will require more capacity for data transmission than needed for voice. If this statement is correct, then it would appear prudent to broaden our planning consideration to include new concepts for future data network directions. ... New digital computer techniques using redundancy make cheap unreliable links potentially usable. ... Such a system should economically permit switching of very short blocks of data from a large number of users simultaneously with intermittent large volumes among a smaller set of points.

1965: First computer network

Lawrence Roberts and Thomas Merrill connect a TX-2 at MIT to a Q-32 in Santa Monica, CA

ARPA-funded project

Connected with telephone line

- works, but it’s inefficient and expensive
- confirmed one motivation for packet switching
The ARPANET begins

Roberts joins DARPA (1966), publishes plan for the ARPANET computer network (1967)

Dec. 1968: Bolt, Beranek, and Newman (BBN) wins bid to build packet switch, the Interface Message Processor

Sept. 1969: First IMP delivered to Kleinrock’s UCLA lab

An older Kleinrock with the first IMP
ARPANET comes alive
The first message is exchanged


Oct. 29 1969

Leonard Kleinrock @UCLA tries to log in a Stanford computer

UCLA

We typed the L... Do you see it?

Stanford

Yes! We see the L

We typed the O... Do you see it?

Yes! We see the O

We typed the G.

system crashes
ARPANET grows

ARPANET, April 1971
ARPANET grows

Dezember 1969

Juni 1970

März 1972

Juli 1977
ARPANET grows
Meanwhile, other networks such as PRnet, SATNET developed

May 1973: Vinton G. Cerf and Robert E. Kahn present first paper on interconnecting networks

Concept of connecting diverse networks, unreliable datagrams, global addressing, ...

Became TCP/IP
TCP/IP deployment

TCP/IP implemented on mainframes by groups at Stanford, BBN, UCL

David Clark guides architecture, implements it on Xerox Alto and IBM PC


January 1, 1983: “Flag Day” NCP to TCP/IP transition on ARPANET
Growth from Ethernet

Ethernet: R. Metcalfe and D. Boggs, July 1976

Spanning Tree protocol: Radia Perlman, 1985

Made local area networking easy
Growth spurs organic change

Early 1980s: Many new networks: CSNET, BITNET, MFENet, SPAN (NASA), ...

Nov 1983: DNS developed by Jon Postel, Paul Mockapetris (USC/ISI), Craig Partridge (BBN)

1984: Hierarchical routing: EGP and IGP (later to become eBGP and iBGP)
The Internet in 1986
NSFNET

1984: NSFNET for US higher education

- Serve many users, not just one field
- Encourage development of private infrastructure (e.g., backbone required to be used for Research and Education)
- Stimulated investment in commercial long-haul networks

1990: ARPANET ends
The Web and commercialization

1989  Birth of the Web
      Tim Berners Lee (CERN)

1993  Search engines invented (Excite)

1995  NSFNet is decommissioned

1998  Google reinvents search
Explosive growth!

In hosts

Hobbes' Internet Timeline
Copyright ©2006 Robert H Zakon
http://www.zakon.org/robert/internet/timeline/
Explosive growth!

In networks

Colors correspond to measurements from different vantage points

[Huston '12]
Explosive growth!

In complexity

Routing protocols
- eBGP, iBGP
- MPLS, CSPF, OSPF, RIP, OpenFlow, ...
- spanning tree + learning
- broadcast
Explosive growth!

In devices & technologies

- O(100 million) times as many devices
- Link speeds 200,000x faster
- NATs, firewalls, DPI, ...
- Wireless everywhere
- Mobile everywhere
- Tiny devices (smart phones)
- Giant devices (data centers)
- ...

In applications

- Morris Internet Worm (1988)
- World wide web (1989)
- MOSAIC browser (1992)
- Search engines
- Peer-to-peer
- Voice
- Radio
- Botnets
- Social networking
- Streaming video
- Cloud computing
- Mobile apps
- ...

Wireless everywhere
Mobile everywhere
Tiny devices (smart phones)
Giant devices (data centers)
...

Link speeds 200,000x faster
NATs, firewalls, DPI, ...
Wireless everywhere
Mobile everywhere
Tiny devices (smart phones)
Giant devices (data centers)
...

O(100 million) times as many devices
World wide web (1989)
MOSAIC browser (1992)
Search engines
Peer-to-peer
Voice
Radio
Botnets
Social networking
Streaming video
Cloud computing
Mobile apps
So we’re done! ... right?

Core protocols changed little, but the context has...

- Criminals and malicious parties
- Everyone trying to game the system
- Incredible growth
- Constant mobility
- Extreme complexity

...and fixing the net involves fundamental challenges

- It’s distributed
- Components fail
- Highly heterogeneous environments
- Highly complex systems components and interactions
- Must get competing parties to work together