CMSC 233: Computer Networking

Lecture 1: Introduction

Oct 1, 2018

Logistics

- Faculty
  - Heather Zheng (htzheng at cs.uchicago.edu)
  - Office hour: Monday 3pm or by appointment
    Location: 371 Crerar
  - http://people.cs.uchicago.edu/~htzheng/teach/cs23300/fall18/
- Teaching Assistants
  - Zhi Hong & Neng Huang
  - hongzhi@uchicago.edu, nenghuang@uchicago.edu
  - Office hours: TBD
- Lectures
  - M/W: 1:30-2:50 PM
  - Place: here (Rosenwald 011)

What is this class about?

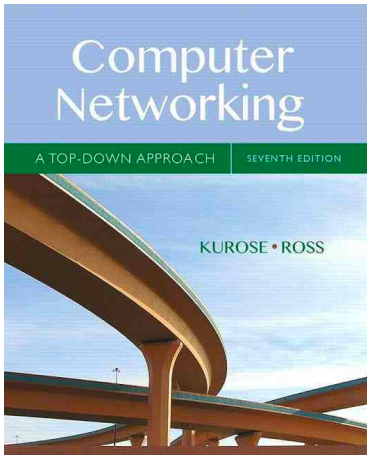
- Networks have changed our world
  - Email, web, BitTorrent, Facebook, Uber/Lyft, Drones, Self-driving cars …
  - Now integral infrastructure for every industry
  - Knowledge about how protocols work (and ability to build them) is critical for your future careers
- There's a lot to cover, and it's a moving target
  - Standard IP protocols and tools
  - Infrastructure services
  - Secure, private communication
  - Application level protocols
  - Future Internet, data centers, social networks, mobile networks

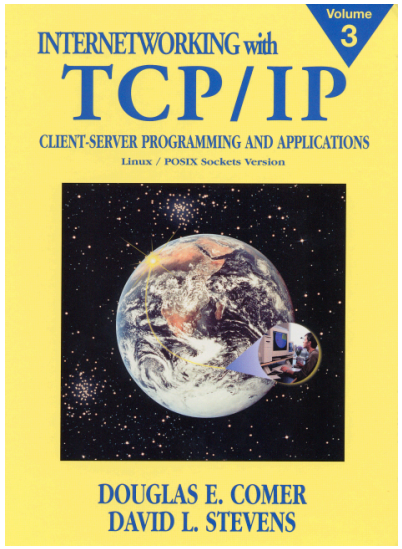
A Lot of Topics (Will Evolve)

- UNIX, C, TCP/IP, the real world
  - Autoconf, automake, libtools
  - Tcpdump, libpcap, libnet, netcat
- Client-server programming
  - Socket programming
  - RPC programming
- Data formats and data translation
  - XDR, MIME, HTML, CSS, XML, XSL…
- Secure communication
  - SSL, TLS, X-Mime, OpenPGP
- Infrastructure services
  - Naming: DNS and extensions
  - Routing protocols: RIP, OSPF, BGP
- Application protocols
  - HTTP, SMTP, SSH, FTP
- Web-based applications
  - Apache
  - Server-side scripting (PHP, Perl)
  - Client-side scripting (JavaScript)
  - Data access
- Advanced topics
  - Mobile/wireless networks
  - Peer-to-peer networks
  - Datacenters and cloud computing
  - Social Networks

Textbooks

- Two books, both "optional"
  - Computer Networking: A Top-Down Approach Featuring the Internet, by Kurose & Ross, "recent" edition
    - "Top-down" view of Internet, great for conceptual understanding
  - Internetworking with TCP/IP, Vol. III: Client-Server Programming and Applications (Linux/Posix Sockets Version), by Comer and Stevens, Prentice Hall, 2001.
    - "programmer" view of networking, great for coding references





One Aside on Teaching Style

- Ask questions in class
  - I may slip and assume things you don't know
  - I tend to talk fast if no one stops me
  - Solution: slow me down with questions
- See something that can be improved?
  - Tell me, and I'll consider it
  - This class is adaptable, (almost) nothing is set in stone

Administrivia

- Course webpage
  - http://people.cs.uchicago.edu/~htzheng/teach/cs23300/fall18/
- Piazza = Class discussion group / mailing list
  - Sign up today please
    - https://piazza.com/uchicago/fall2018/cmsc23300/home
    - Lectures will be posted after class
  - Do not forget, your responsibility to know lecture material!
- Deadlines
  - Unless otherwise specified, assignments due at 11:59PM
  - Special circumstances must be brought to me before deadlines, **not after**
  - Except for true emergencies™, late assignments will not be accepted
    - One extension available / quarter, 2 days (cannot be split)

About Grading

Projects	5/20/25%
Class quizzes	5%
Exam 1	20%
Exam 2	25%

- Focus on learning how to build network applications
  - Assignments will demand time and dedication
- Cheating / plagiarism not tolerated
  - Projects to be done individually
  - Discussion, idea sharing is OK, sharing code is **not**
  - Code will be run through similarity checkers
  - Cheaters will fail the course, and be reported

Three Projects

- Ultimate goal(s)
  - Prepare you for the "real world"
  - Get exposure to real network protocols and applications
- Three homework/projects
  - Simple network application
  - FTP
  - Fun project, more details TBD

Everyone still awake?

- Let's take a quiz…

- No stress, this is for my benefit only
  - Not one of the class quizzes
  - Will not count in any way towards your grade

Question #1

- What does AIMD stand for

a) Active Implantable Medical Devices
b) Accounting and Information Management Division
c) Additive Increase, Multiplicative Decrease
d) Aircraft Immediate Maintenance Department
e) Ab Initio Molecular Dynamics

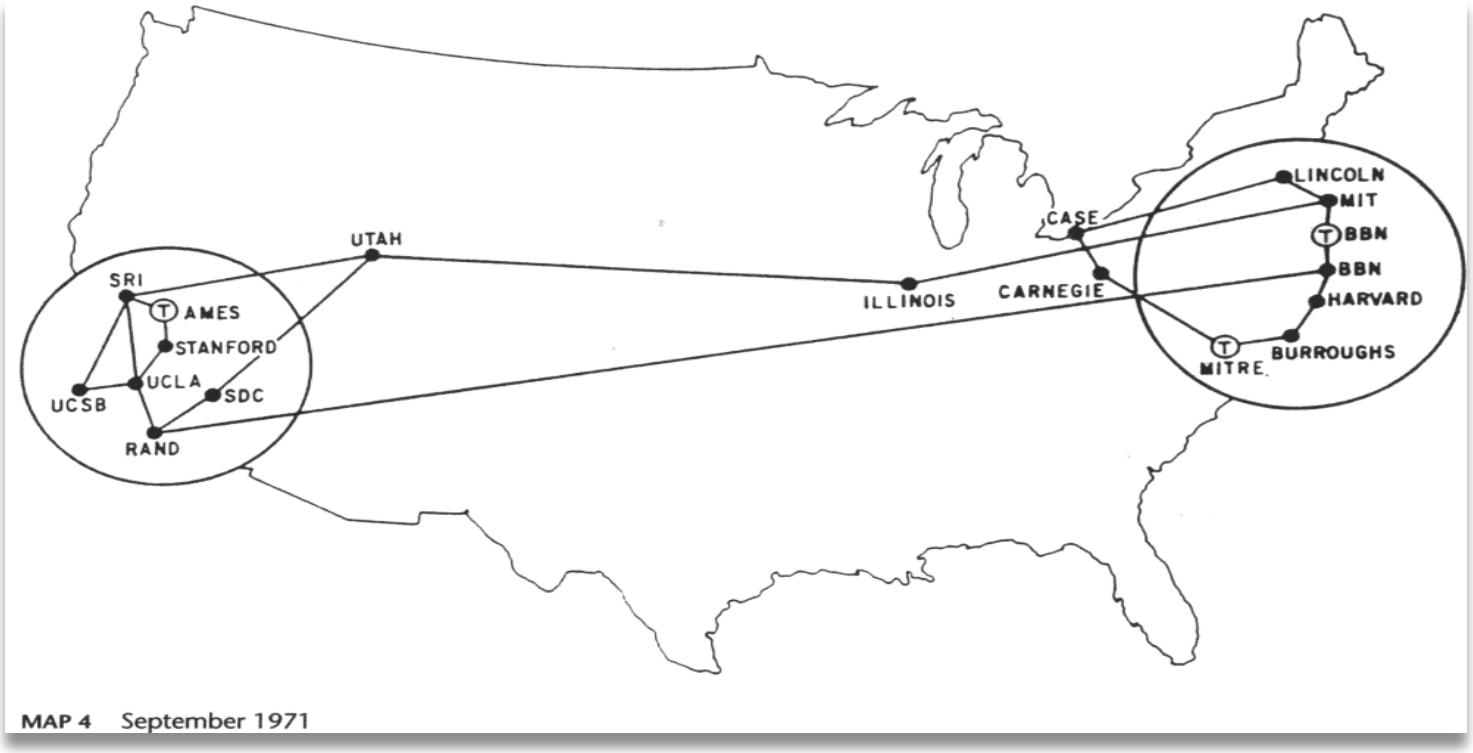
Question #2

- The first emoticon is commonly credited to Kevin Mackenzie in 1979, and it looked like:
  1. :)
  2. : -)
  3. -)
  4. ;)

Question #3

- Of the 247 BILLION email messages sent every day, X% are pure spam. X=?

1. 18%
2. 5%
3. 81%
4. 63%



Internet History

https://www.youtube.com/watch?v=9hIQjrMHTv4

https://www.youtube.com/watch?v=h8K49dD52WA

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

https://www.youtube.com/watch?v=XE_FPEFpHt4

Why study Networks?

Networks **have** transformed everything

- The way we do business
  - E-commerce, advertising, cloud-computing
- The way we have relationships
  - Facebook friends, E-mail, IM, virtual worlds
- The way we learn
  - Wikipedia, MOOCs, search engines
- The way we govern and view law
  - E-voting, censorship, copyright, cyber-attacks
- The way we cure disease
  - Digital health, remote diagnostics

Networks are big business

- Many large and influential networking companies
  - Cisco, Broadcom, AT&T, Verizon, Akamai, Huawei, …
  - $200B+ industry (carrier and enterprise alone)
- Networking central to most technology companies
  - Google, Facebook, Uber, Microsoft, HP, Dell, VMware, …

Networking research has impact

- The Internet started as a research experiment!
- 4 of 10 most cited authors work in networking
- *Many* successful companies have emerged from networking research(ers)

But why are networks *interesting*?

"What's your formal model for the Internet?" -- *theorists*

"Aren't you just writing software for networks" – *OS community*

"You don't have performance benchmarks???" – *hardware folks*

"It's just another communication network!" – *old timers at AT&T*

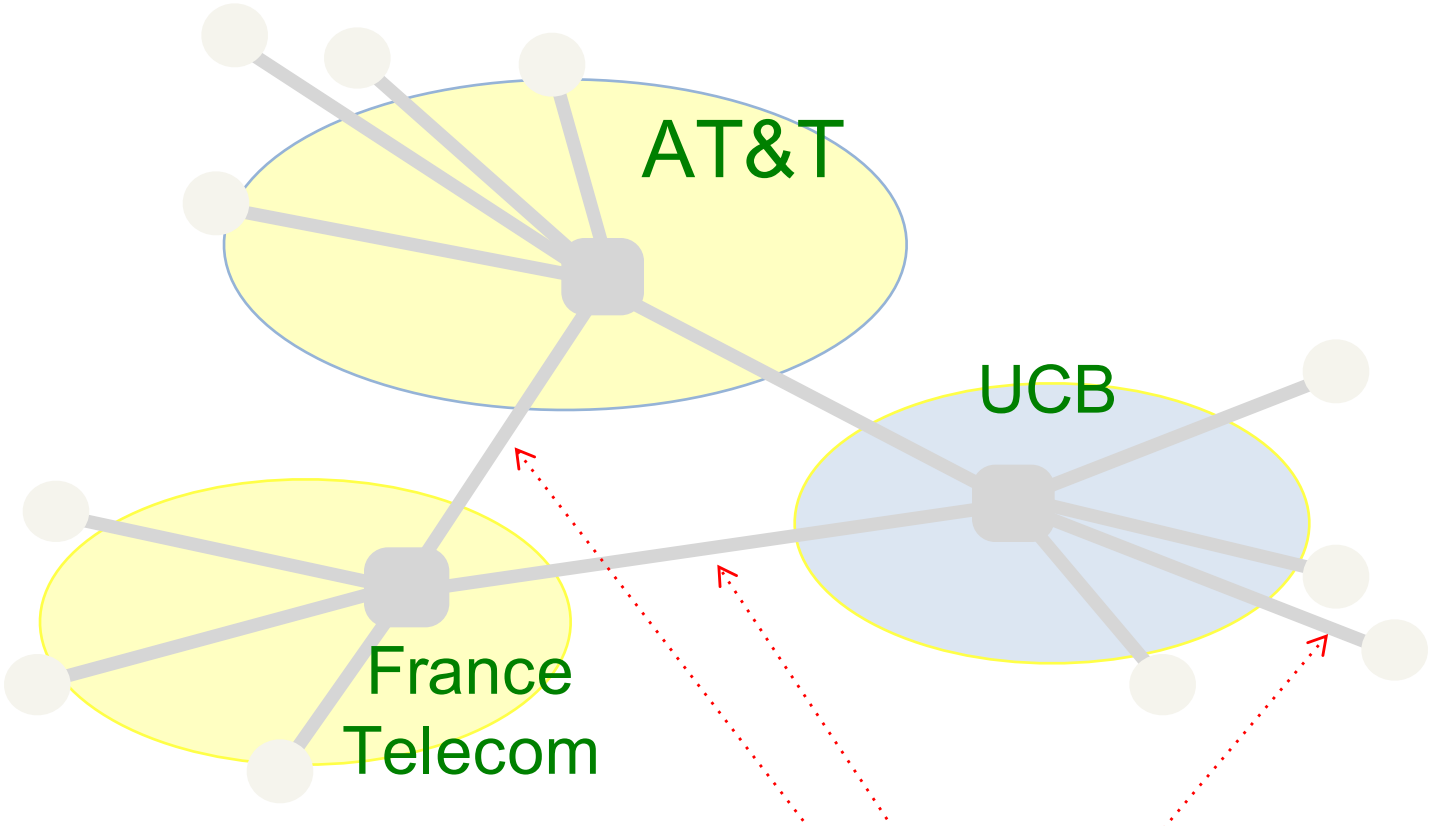
"What's with all these TLA protocols?" – *all*

"But the Internet seems to be working…" – *my parents*

A few defining characteristics of the Internet

A federated system

The Internet interconnects different networks (>18,000 ISPs)



One common protocol -- the "Internet Protocol (IP) -- between users and the network and between networks

A federated system

- Interoperability is the Internet's most important goal

- Leads to a constant tussle between business and technical factors
  - competing ISPs must cooperate to serve their customers
  - practical realities of incentives, economics and real-world trust determine physical topology and path selection
  - a common protocol is great for interoperability …
  - … but complicates innovation

Tremendous scale

- 3.2 Billion users (~half of world population)
- 1 Billion unique websites (since 2014)
- 205 Billion emails sent per day
- 2 Billion smartphones
- 2 Billion Facebook users *(monthly active users)*
- 300 hours of video uploaded to YouTube every minute
- Switches that move 300Terabits/second (10^{14})
- Links that carry 100Gigabits/second

1 minute in Internet

Enormous diversity and dynamic range

- Communication latency: microseconds to seconds (10^6)
- Bandwidth: 1Kbits/second to 100 Gigabits/second (10^7)
- Packet loss: 0 – 90%
- Technology: optical, wireless, satellite, copper
- Endpoint devices: sensors, cell phones, datacenters, bikes/cars
- Applications: skype, live video, gaming, remote medicine,
- Users: the governing, governed, operators, selfish, malicious, naïve, savvy, embarrassed, paranoid, …

Constant Evolution

1970s:

- 56kilobits/second "backbone" links
- <100 computers, a handful of sites in the US
- Telnet and file transfer are the "killer" applications

Today

- 100+Gigabits/second backbone links
- 5B+ devices, all over the globe
- 20M Facebook apps installed per day

Asynchronous Operation

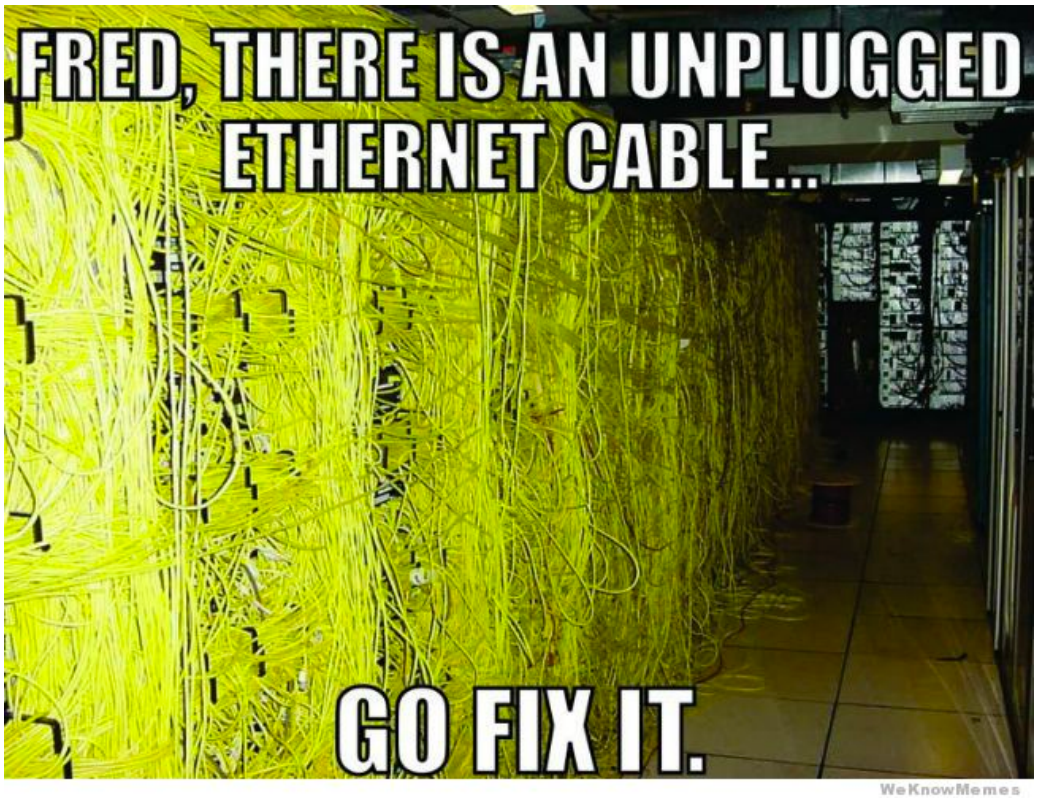
- Fundamental constraint: **speed of light**
- Consider: How many cycles does your 3GHz CPU in Chicago execute before it can possibly get a response from a message it sends to a server in Hawaii?
  - Chicago to Hawaii: 4,189 km
  - Traveling at 300,000 km/s: 13.96 milliseconds
  - Then back to Chicago: 2 x 13.96 = 28 milliseconds
  - 3,000,000,000 cycles/sec * 0.028 = 84,000,000 cycles!
- Thus, communication feedback is always *dated*

Prone to Failure

- To send a message, **all** components along a path must function correctly
  - software, modem, wireless access point, firewall, links, network interface cards, switches,…
  - Including human operators
- Consider: 50 components, that work correctly 99% of time → 39.5% chance communication will fail
- Plus, recall
  - scale → lots of components
  - asynchrony → takes a long time to hear (bad) news

An Engineered System

- Constrained by limits of available technology
  - Link bandwidths
  - Switch port counts
  - Bit error rates
  - Cost
  - …



Question #4

- According to legend, Amazon became the number one shopping site before Google was on, because?
  - **Yahoo would list the sites in their directory alphabetically!**

Recap: The Internet is…

- A federated system
- Of enormous scale
- Dynamic range
- Diversity
- Constantly evolving
- Asynchronous in operation
- Failure prone
- Constrained by what's practical to engineer
- Too complex for theoretical models
- "Working code" needn't mean much
- Performance benchmarks are too narrow

We will study networks in cs23300!

Before you go, remember to…

- Sign up for Piazza page
  - https://piazza.com/uchicago/fall2018/cmsc23300/home
  - Link also on class webpage

- Get to know your TAs (Zhi, Neng)
  - they will likely save your life at least once this quarter

- See you Wed …

BACKUP ON INTERNET HISTORY

Internet History

- 1961 Kleinrock @ MIT writes paper on packet-switched network
- 1962 Licklider's vision of Galactic Network
- 1965 Roberts connects two computers over phone line
- 1967 Roberts publishes vision of ARPANET
- 1969 BBN installs first InterfaceMsgProcessor at UCLA
  - 2nd node installed at SRI, then at UCSB and Utah
- 1970 Network Control Protocol
  - Assumed reliable transmission!
- 1972 Public demonstration of ARPANET
- 1972 Email invented by Tomlinson @ BBN
- 1972 Kahn @ DARPA advocates Open Architecture networking
  - Joined by Cerf @ Stanford to write TCP

Internet Evolution 1969

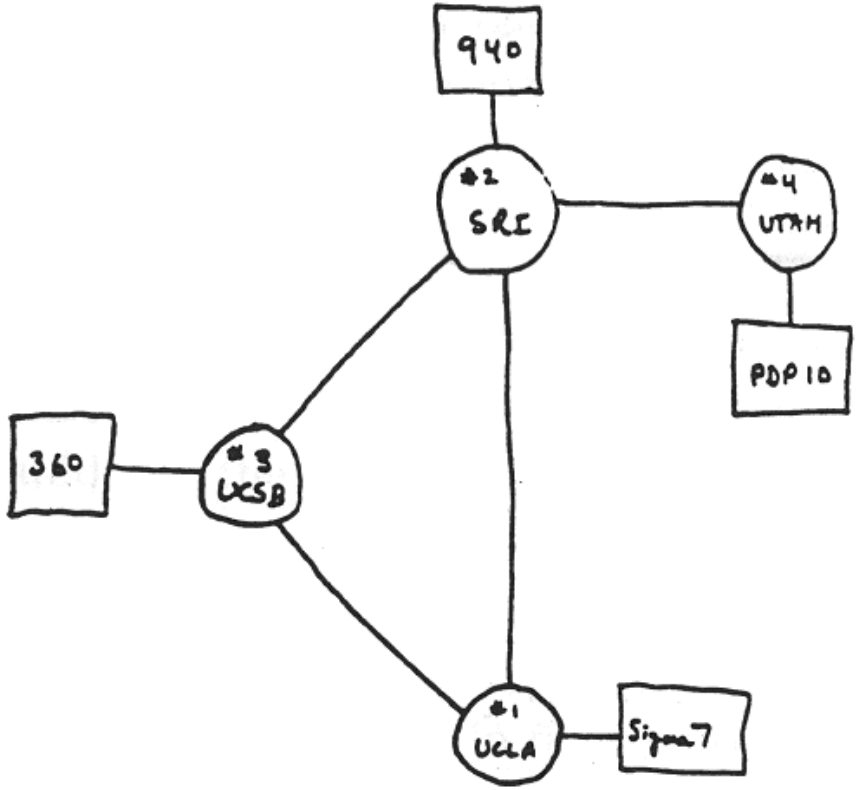
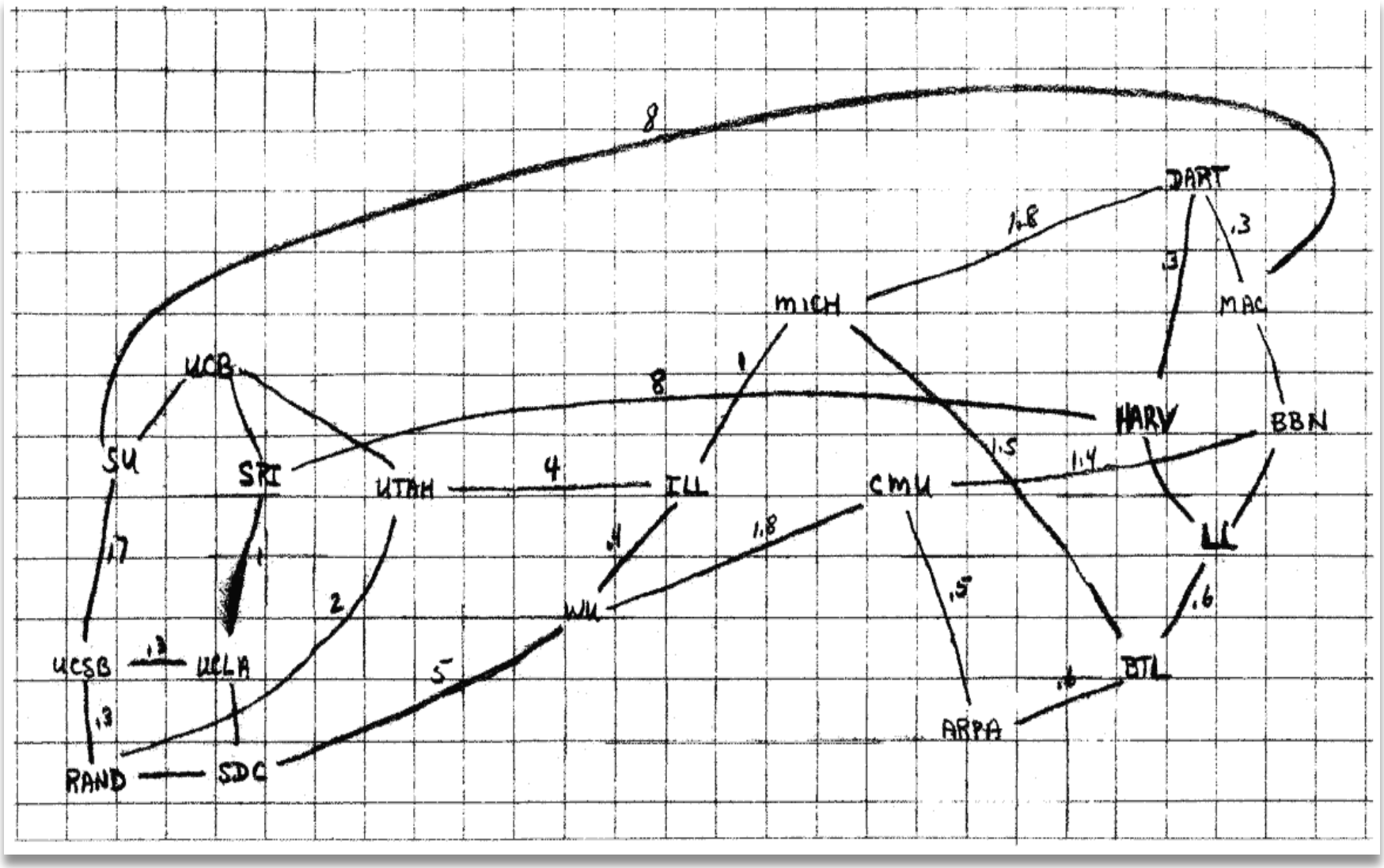
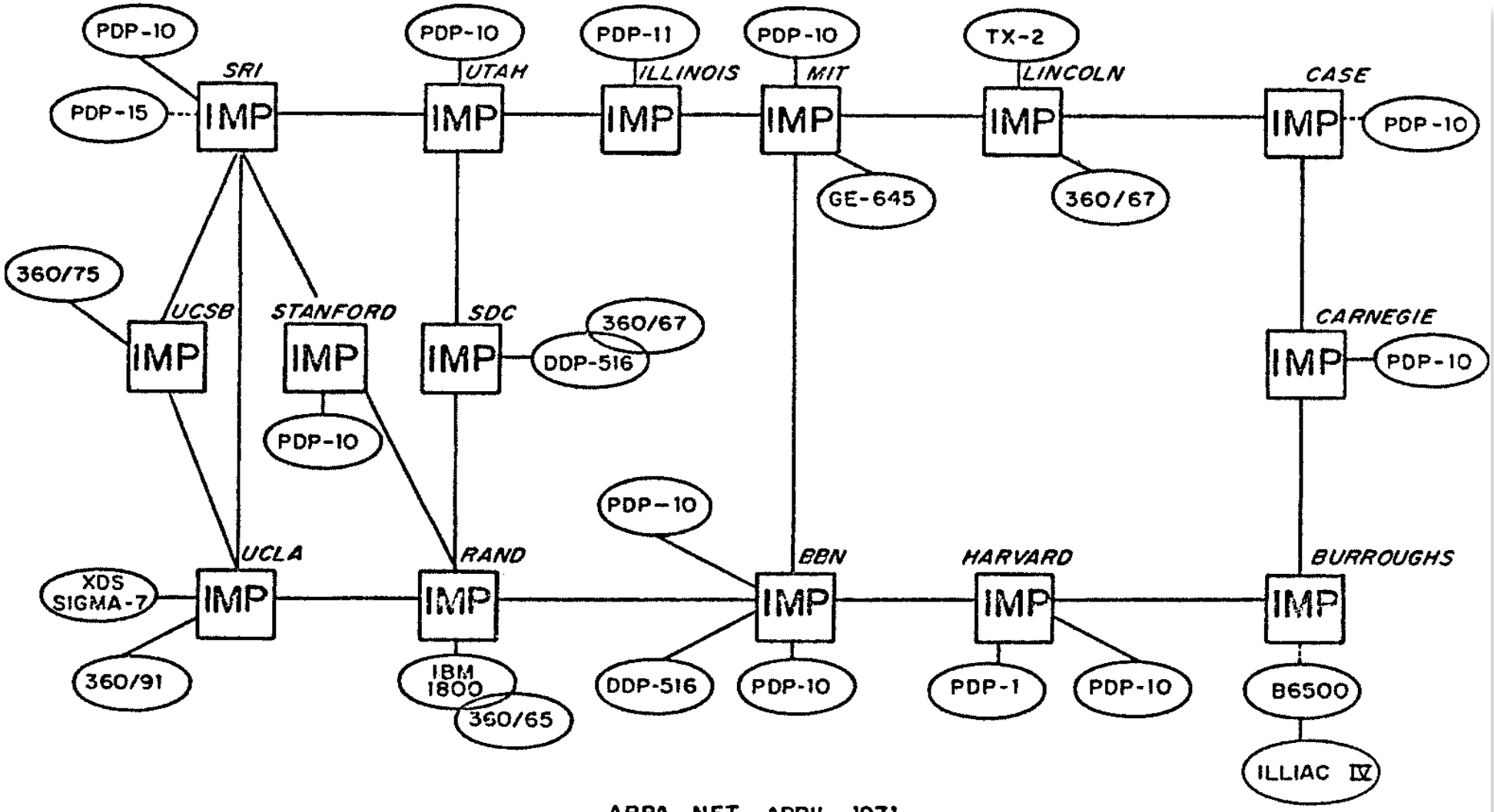


FIGURE 6.2 Drawing of 4 Node Network (Courtesy of Alex McKenzie)

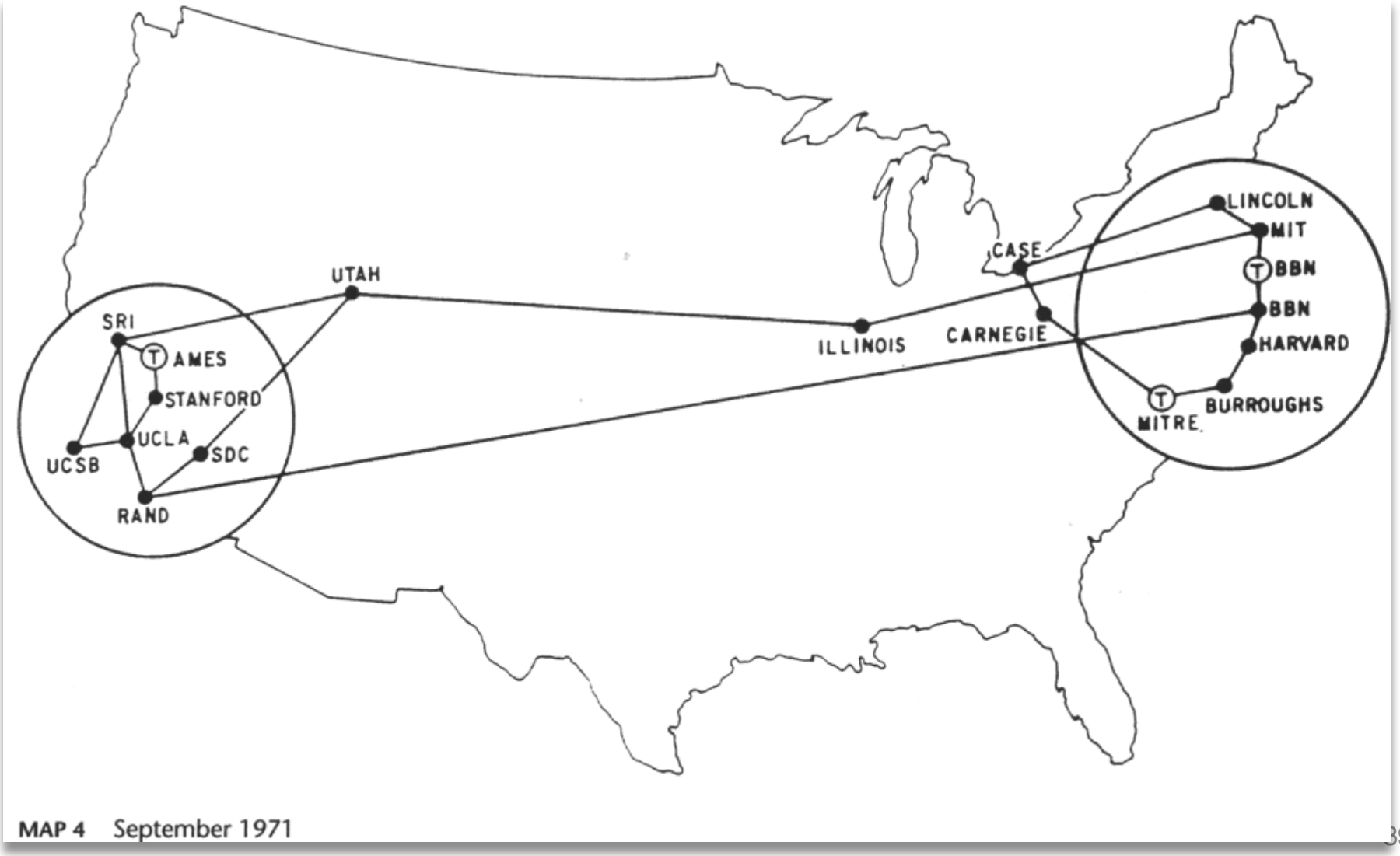
Internet Evolution (1960s plan)



Internet Evolution (April 1971)

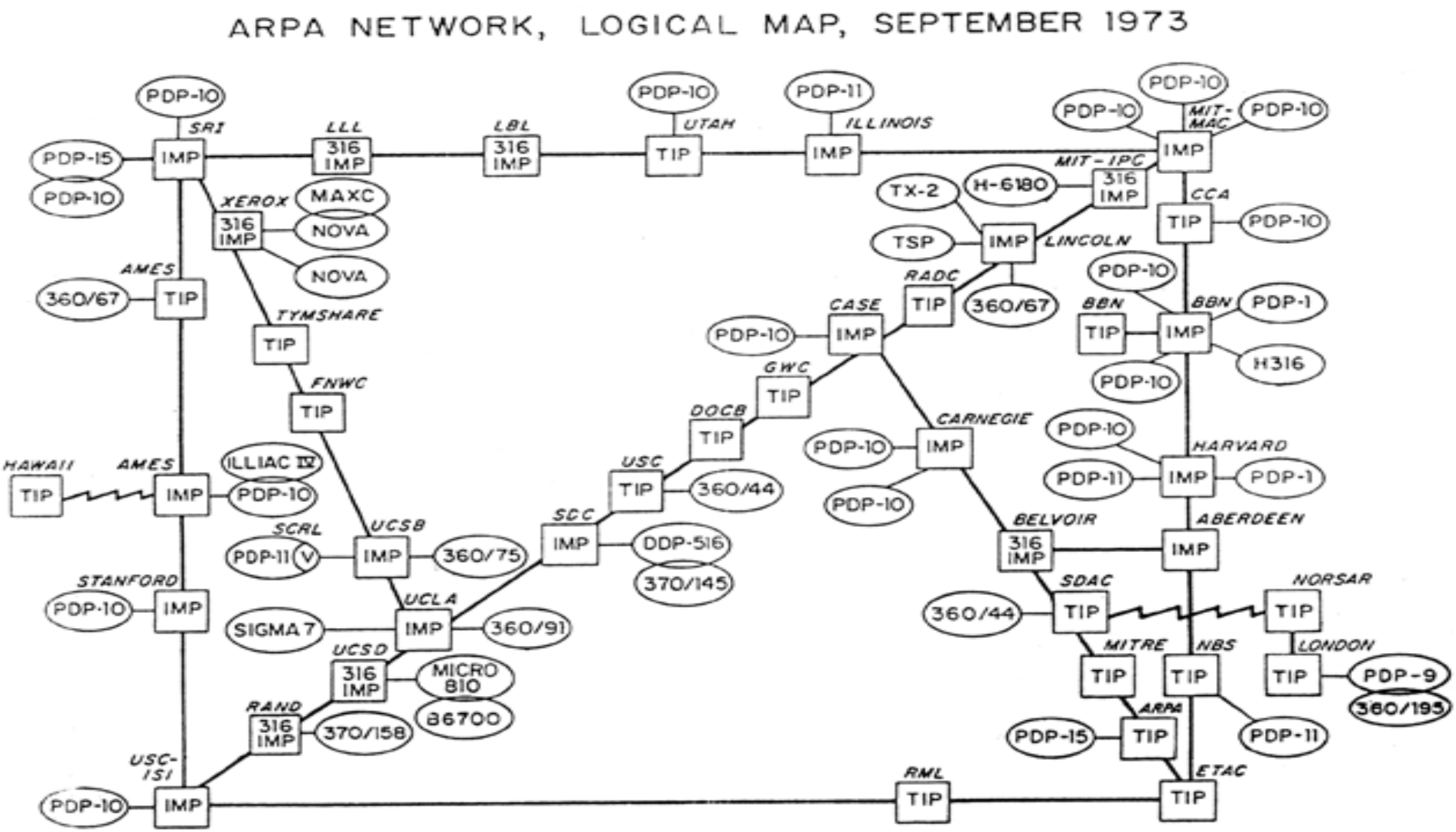


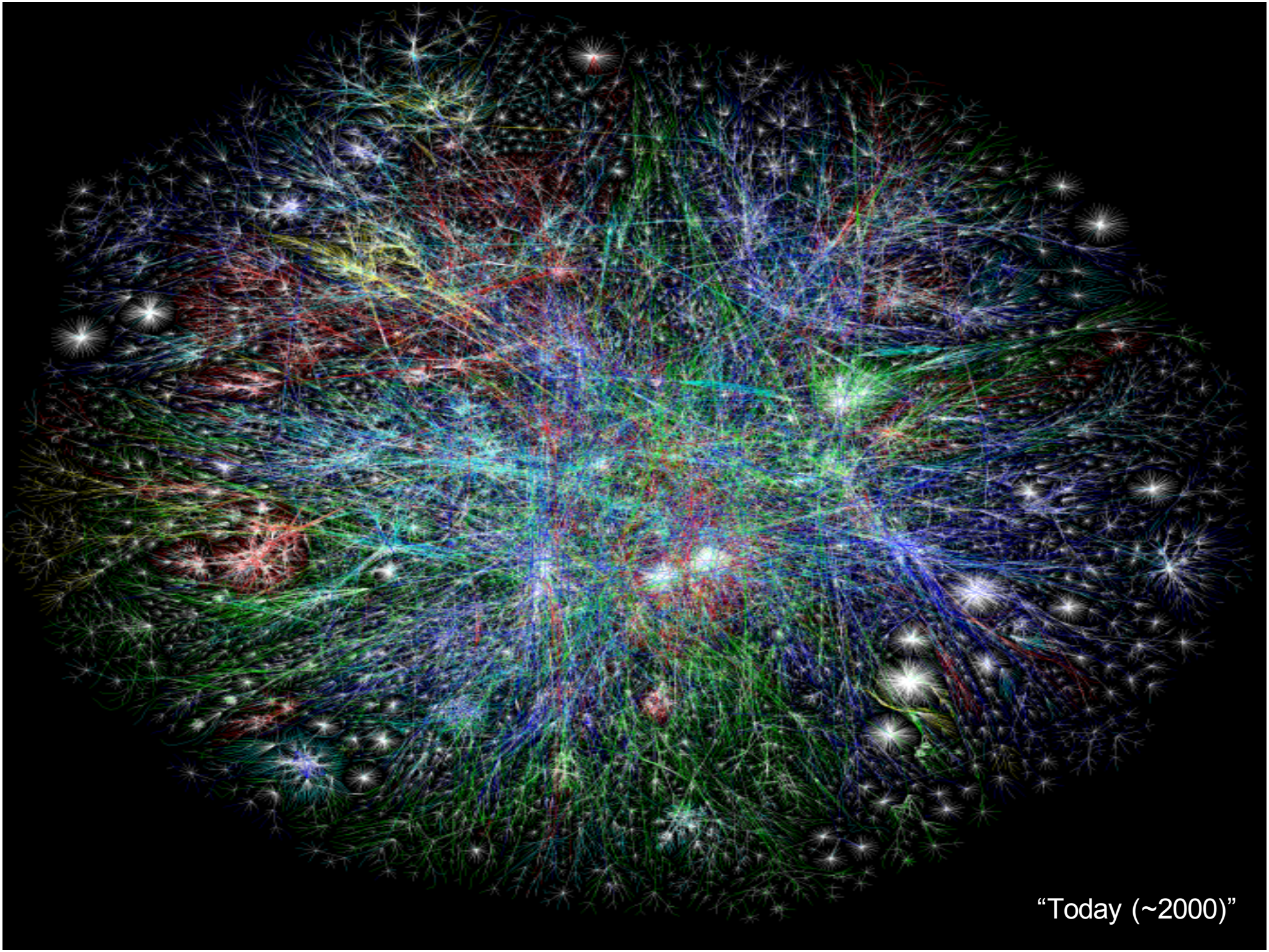
Internet Evolution (Sept. 1971)



MAP 4 September 1971

Internet Evolution (Sept. 1973)




“Today (~2000)”

History Continued

- 1974 Cerf and Kahn paper on TCP
  - Included basic flow control, parameters unclear
  - Experiments showed non-ideal for voice txns, thus separated out IP
- 1980 TCP/IP adopted as defense standard
- 1983 Global NCP to TCP/IP flag day
  - planned for several years
- 198x XNS, DECbit, and other protocols
- 1985 NSFnet (picks TCP/IP)
- 198x Internet meltdowns due to congestion
- 1986+ Van Jacobson saves the Internet (BSD TCP)
- 1988 Deering and Cheriton propose multicast
- 199x QoS rises and falls, ATM rises and falls
- 1994 Internet goes commercial
- 200x The Internet boom and bust
- 2006+

What's next?

- Internet of (Insecure) Things?
- Real-time Streaming Media everywhere?
- Autonomous Mobile Devices?