Computer Networks and Network Security

Qiao Xiang, **Congming Gao**

https://sngroup.org.cn/courses/cnns-xmuf23/index.shtml

9/12/2023

This deck of slides are heavily based on CPSC 433/533 at Yale University, by courtesy of Dr. Y. Richard Yang.

Outline

- *Administrative trivia's*
- What is a network protocol?
- A brief introduction to the Internet: past and present
- Summary

Personnel

- Instructor
  - Qiao Xiang, qiaoxiang@xmu.edu.cn
    - office hours: by appointment
  - Congming Gao, email
- Teaching assistant
  - Haohao Song, songhaohao2021@stu.xmu.edu.cn

Instructor: Qiao Xiang

- Joined XMU as a professor in January 2021
- Research: Computer Networks and Systems
- Previously,
  - Research assistant professor, Yale University, US., 2019-2020
  - Postdoctoral fellow, Yale University, US. 2016-2018
  - Postdoctoral fellow, McGill University, Canada, 2014-2015
  - Ph.D. in Computer Science, Wayne State University, US, 2014
  - B.E. in Information Security and B.Econ., NKU, 2007

Instructor: Congming Gao

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  - Research assistant professor, Yale University, US., 2019-2020
  - Postdoctoral fellow, Yale University, US. 2016-2018
  - Postdoctoral fellow, McGill University, Canada, 2014-2015
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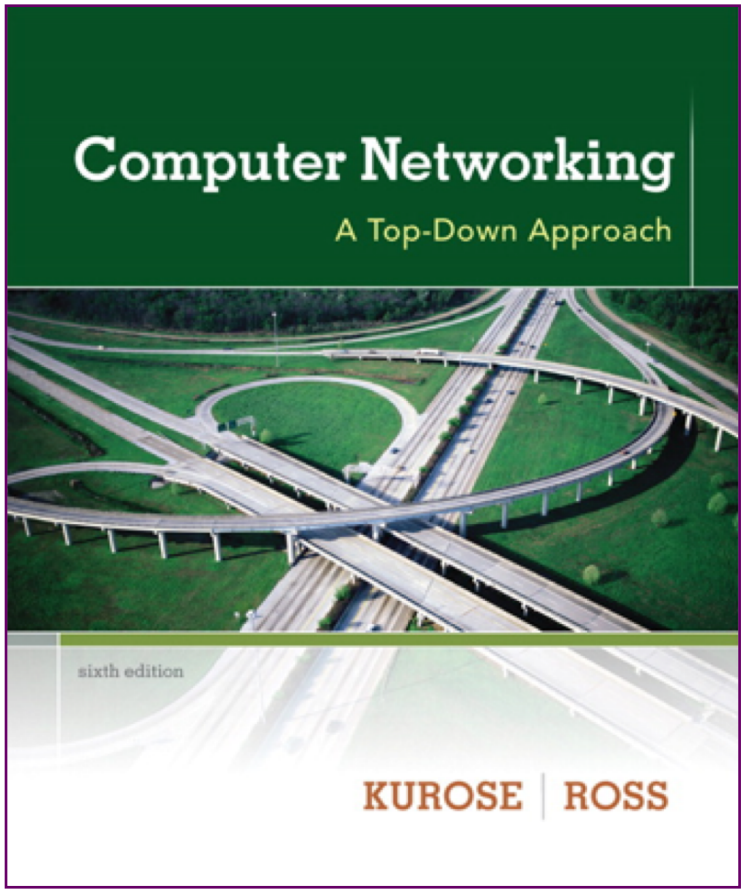
  - B.E. in Information Security and B.Econ., NKU, 2007

Textbook

- Textbook
  - *Computer Networking: A Top-Down Approach, 7/e*
    by Jim Kurose and Keith Ross
- Reference books
  - *Computer Networks*
    by Tanenbaum and Wetherall
  - *Computer Networks, A Systems Approach*
    by Larry Peterson and Bruce Davie
  - *TCP/IP Illustrated, Volume 1: The Protocols*
    by W. Richard Stevens
  - Java Network Programming,
    by Elliotte Harold
- Resources
  - https://sngroup.org.cn/courses/cnns-xmuf21/index.shtml



What are the Goals of this Course?

- Learn design principles and techniques of:
  - the Internet infrastructure (Internet service provider, data center, cloud)
  - large-scale Internet applications
- Focus on how the principles and techniques apply and adapt in real world:
  - real examples from the Internet

Computer Networks and Network Security vs. Computer Networks and Communication

CNNS:

- Bilingual:
  - English in slides / homework / exams
  - Chinese in lecture / lab classes / discussions
- More emphasis on design principles, theories and programming
- More emphasis on security issues
- Less emphasis on communication (e.g., physical layer and wireless networks)
- A top-down roadmap

Why Study Computer Networks?

- Looking for a job

Domestic	International
Huawei	Amazon
Alibaba	Google
Tencent	Microsoft
Xiaomi	Facebook
JD	Uber
…	…

Why Study Computer Networks?

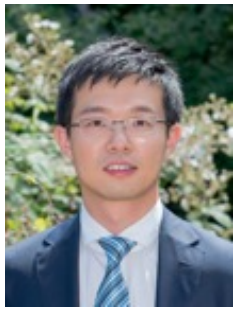
- Be an entrepreneur

Why Study Computer Networks?

- Pursue graduate degrees overseas

Why Study Computer Networks?

- Pursue graduate degrees domestically

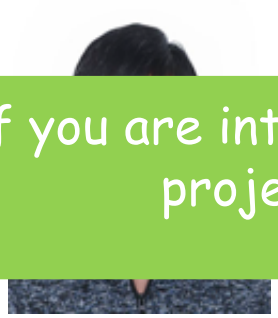


Xin Jin
PKU

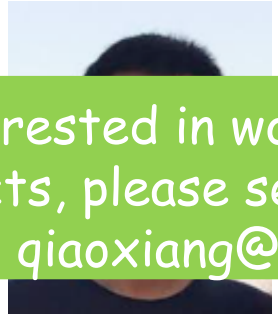
Tong Yang
PKU

Chenren Xu
PKU

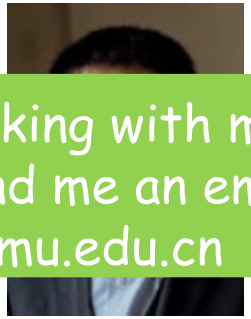
Linghe Kong
SJTU



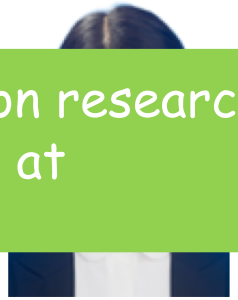
Chen Tian
NJU



Peng Zhang
XJTU



Qiao Xiang
XMU



Lu Tang
XMU

If you are interested in working with me on research projects, please send me an email at qiaoxiang@xmu.edu.cn

What Do You Need To Do?

- Please go to the class website to fill out the class background survey
  - help us determine your background
  - help us determine the depth, topics, and the details of assignments
  - suggest topics that you want to be covered (if you think of a topic later, please send me email)

What Do You Need To Do?

- Your workload
  - 6 lab assignments
    - 2-3 written assignments
    - 3-4 programming assignments
      - one HTTP 1.0 server, one TCP, one routing protocol
  - 1 class project (2-3 persons a team)
    - List of potential topics to be posted before midterm
  - 2 exams

- Different from previous years, you will have the opportunity to use ChatGPT in 1-2 designated programming assignments

How to Succeed in this Class?

- Engage in lectures
  - Questions are highly encouraged
- Read textbooks / references / online materials
- Apply the principles / techniques you learned in lectures to assignments and the project
- Do not procrastinate assignments and the project
  - For programming assignments and projects, follow the timeline of checkpoints to avoid the deadline panic

Class Project

- Research or engineering project related to computer networks and network security
- Grading criteria:
  - Innovation 25%, Practicality 25%, Completeness 25%, Presentation 25%
- Suggestions
  - Identify teams and talk to the instructor to decide on the topic as early as possible
  - Read latest papers/technical documents to get inspiration
  - If possible, target research papers / patents

Grading

Class Participation	10%
Lab Assignments	40%
Class Project	15%
Exams	15%+20%

- Grades are important, but you do not need worry too much about them
- More important is what you realize/learn than the grades !!

Questions?

Outline

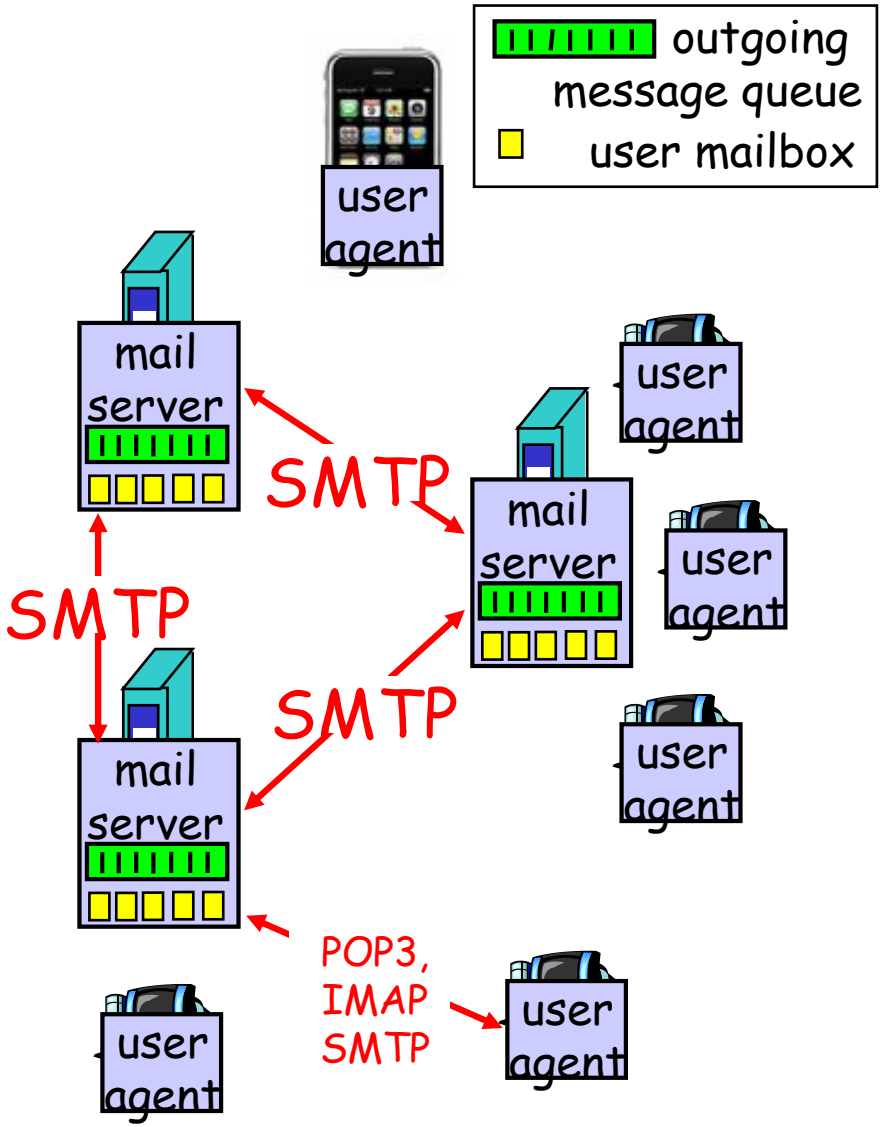
- Administrative trivia's
- *What is a network protocol?*

What is a Network Protocol?

- A **network protocol** defines the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other events.

Example Protocol: Simple Mail Transfer Protocol (SMTP)

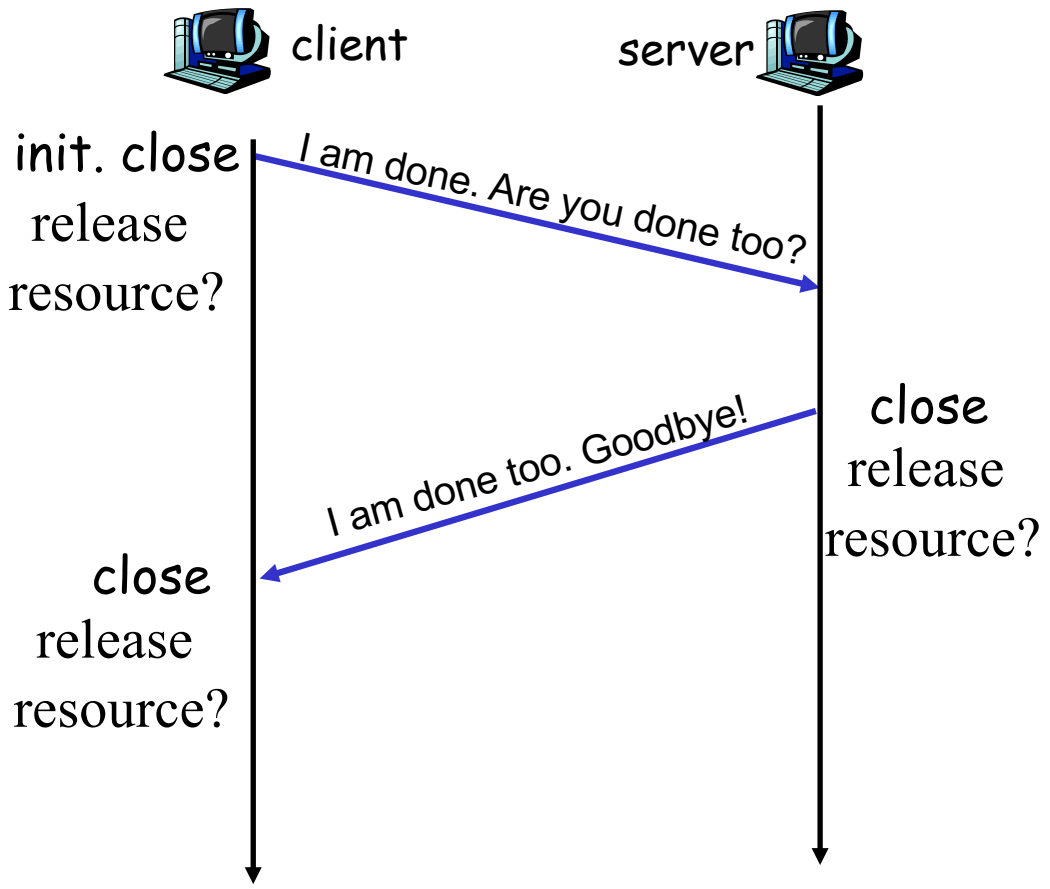
- Messages from a client to a mail server
  - HELO
  - MAIL FROM: <address>
  - RCPT TO: <address>
  - DATA
    <This is the text end with a line with a single .>
  - QUIT
- Messages from a mail server to a client
  - status code
    - The first digit of the response broadly indicates the success, failure, or progress of the previous command.
      - 1xx - Informative message
      - 2xx - Command ok
      - 3xx - Command ok so far, send the rest of it.
      - 4xx - Command was correct, but couldn't be performed for some reason.
      - 5xx - Command unimplemented, or incorrect, or a serious program error occurred.
  - content



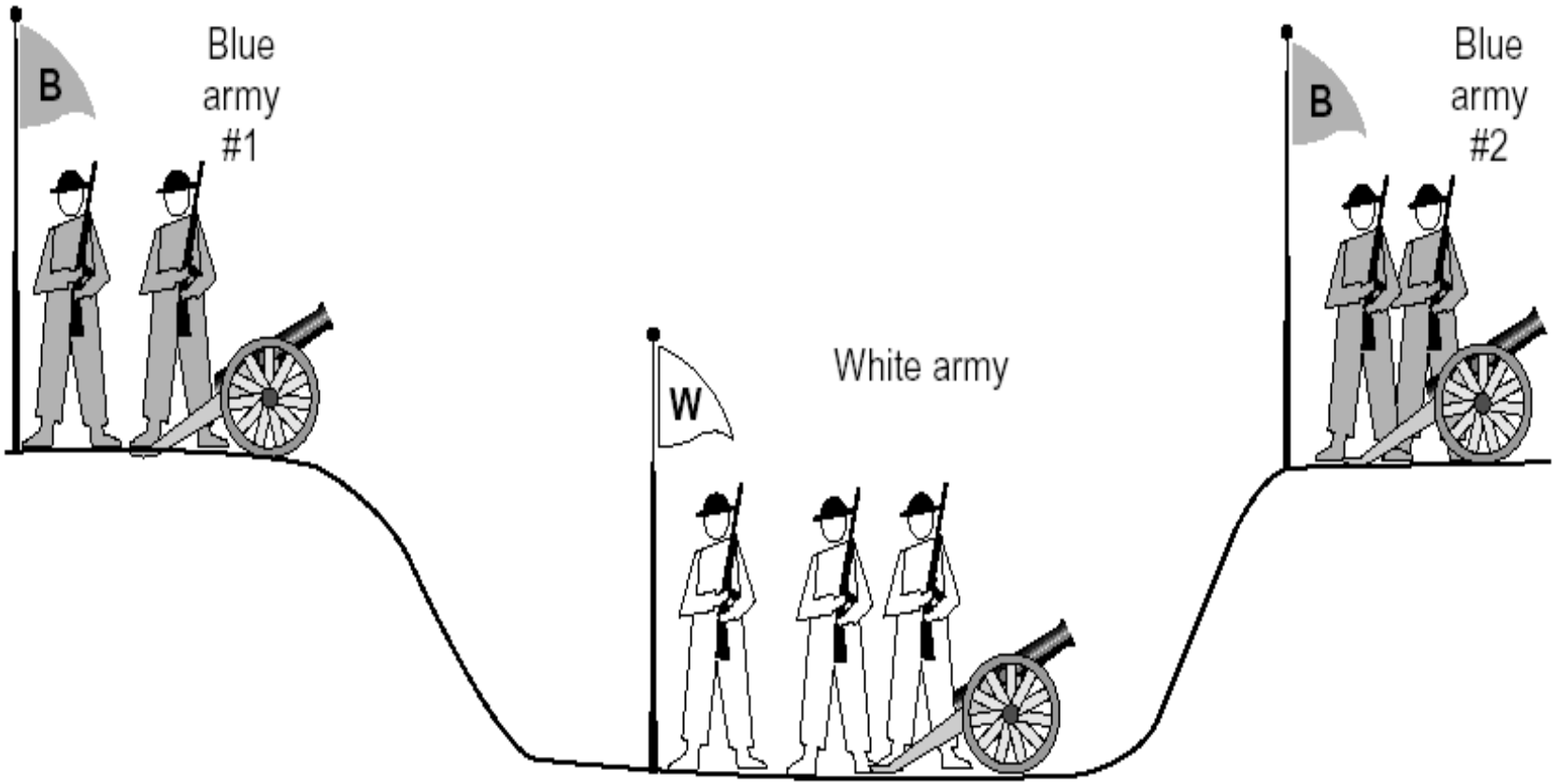
Command: %telnet smtp.xmu.edu.cn 25

Example Protocol: TCP Connection Close Protocol

- Why connection close?
  - so that each side can release resource and remove state about the communication

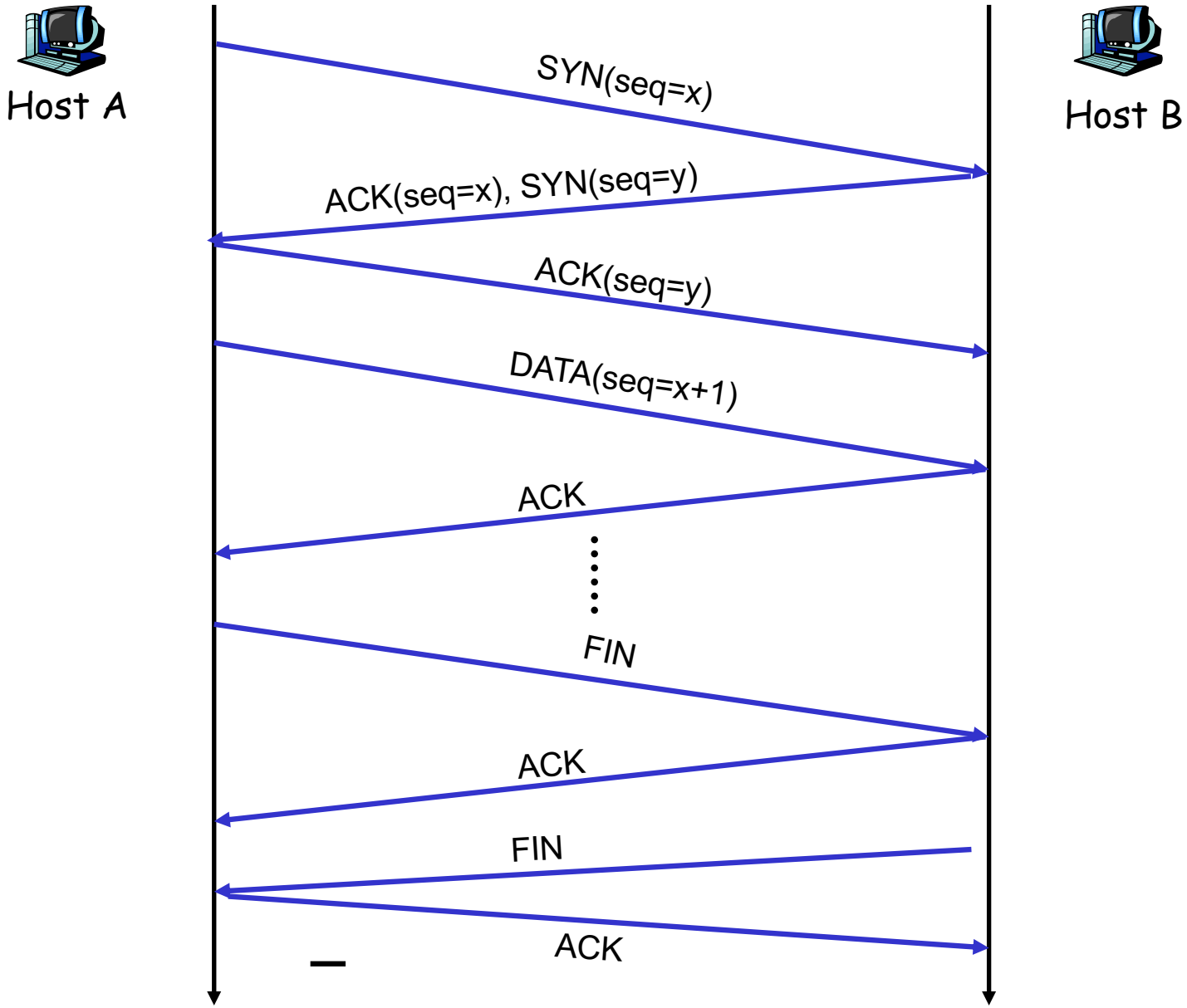


General Case: The Two-Army Problem



The gray (blue) armies need to agree on whether or not they will attack the white army. They achieve agreement by sending messengers to the other side. If they both agree, attack; otherwise, no. Note that a messenger can be captured!

Example: TCP Protocol Handshakes



Example: Google' new QUIC

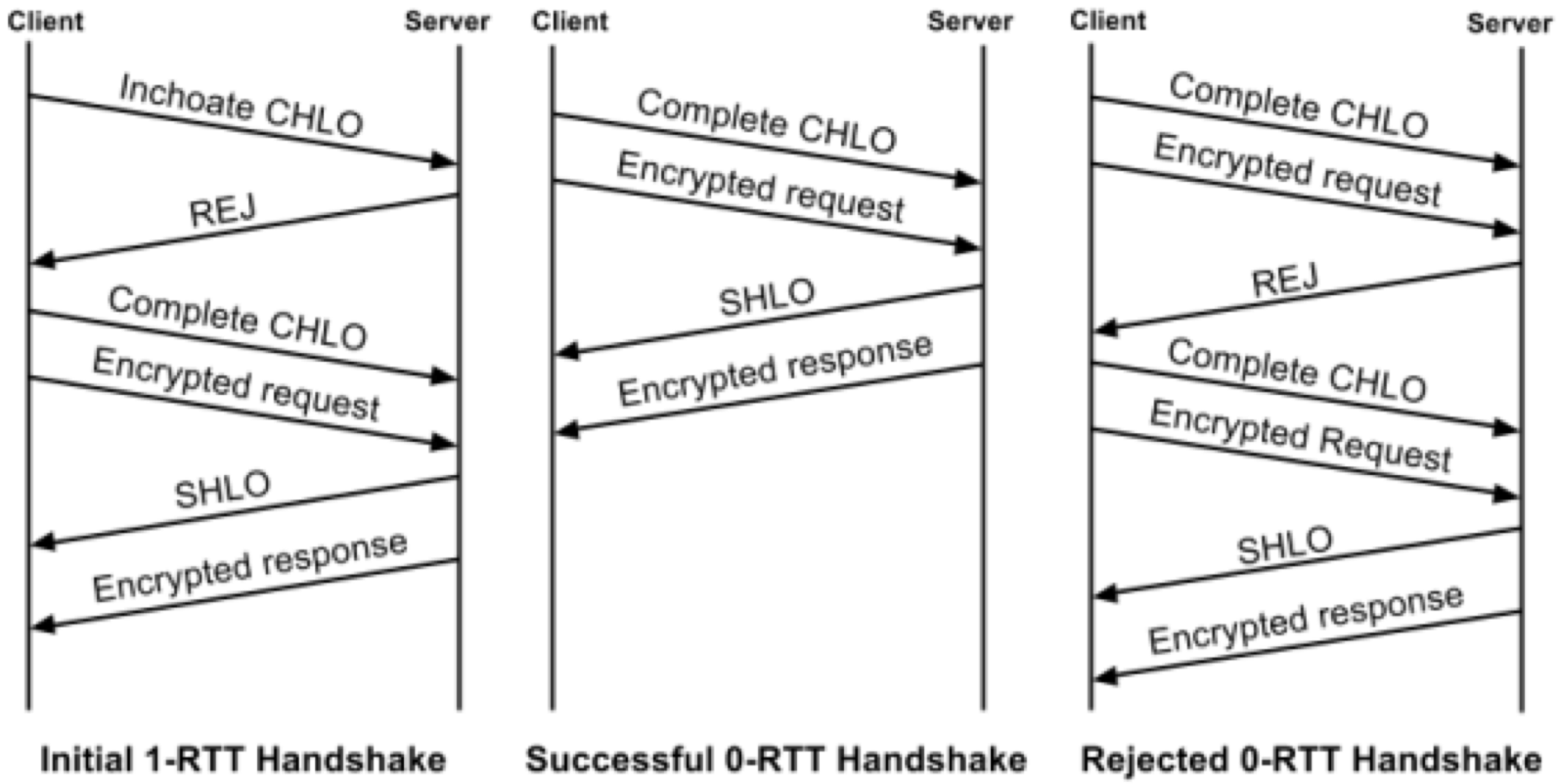


Figure 4: Timeline of QUIC's initial 1-RTT handshake, a subsequent successful 0-RTT handshake, and a failed 0-RTT handshake.

http://conferences.sigcomm.org/sigcomm/2017/files/program/ts-5-1-QUIC.pdf

Protocol Standardization

- Most widely used protocols are defined in standards
- **Why standard?**

Internet Standardization Process

- All standards of the Internet are published as RFC (Request for Comments)
  - e.g., the SMTP protocol is specified in RFC821
  - but not all RFCs are Internet Standards:
    http://qiaoxiang.me/courses/cnns-xmuf21/readings/interestingrfcs.html

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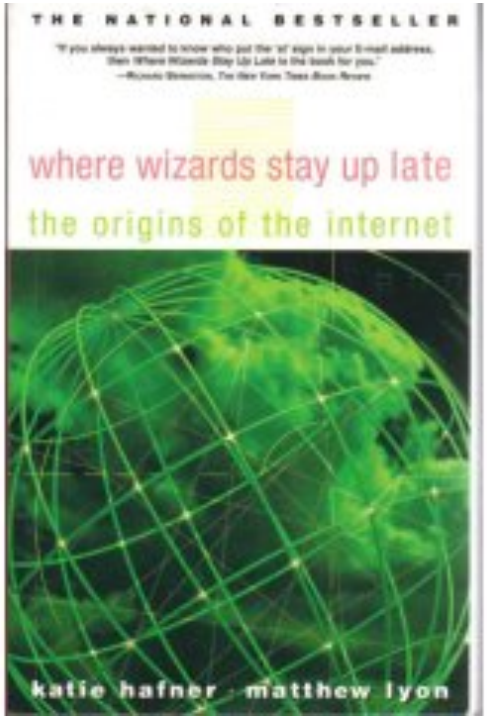
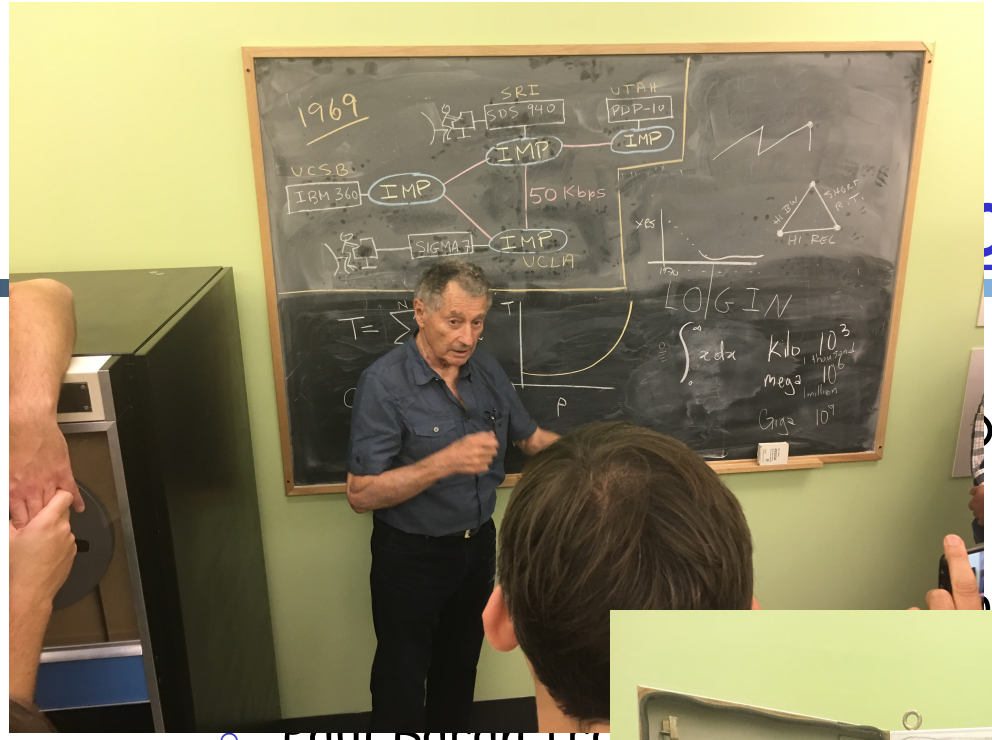
  - but not all RFCs are Internet Standards: https://sngroup.org.cn/courses/cnns-xmuf23/readings/interestingrfcs.html
- A typical (but not the only) way of standardization:
  - Internet draft
  - RFC
  - proposed standard
  - draft standard (requires 2 working implementations)
  - Internet standard (declared by Internet Architecture Board)
- David Clark, 1992:

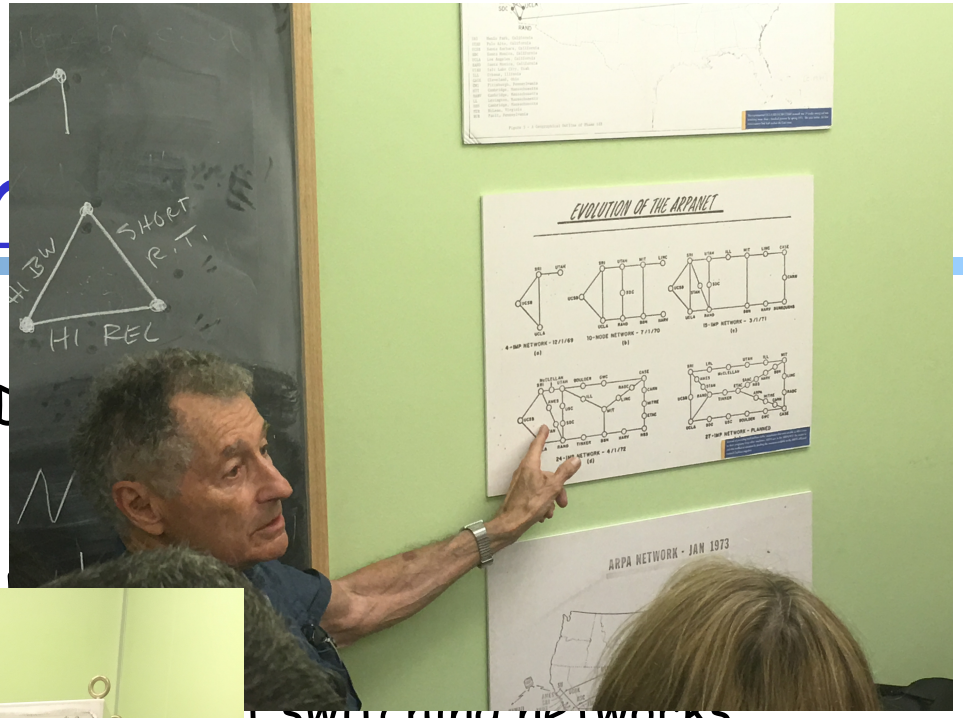
  We reject: kings, presidents, and voting. We believe in: rough consensus and running code.

Outline

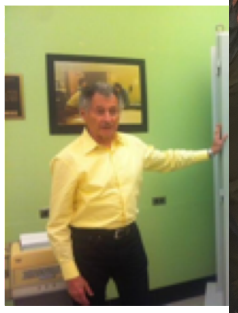
- Administrative trivia's
- What is a network protocol?
- *A brief introduction to the Internet*
  - *past (a brief history)*
  - present

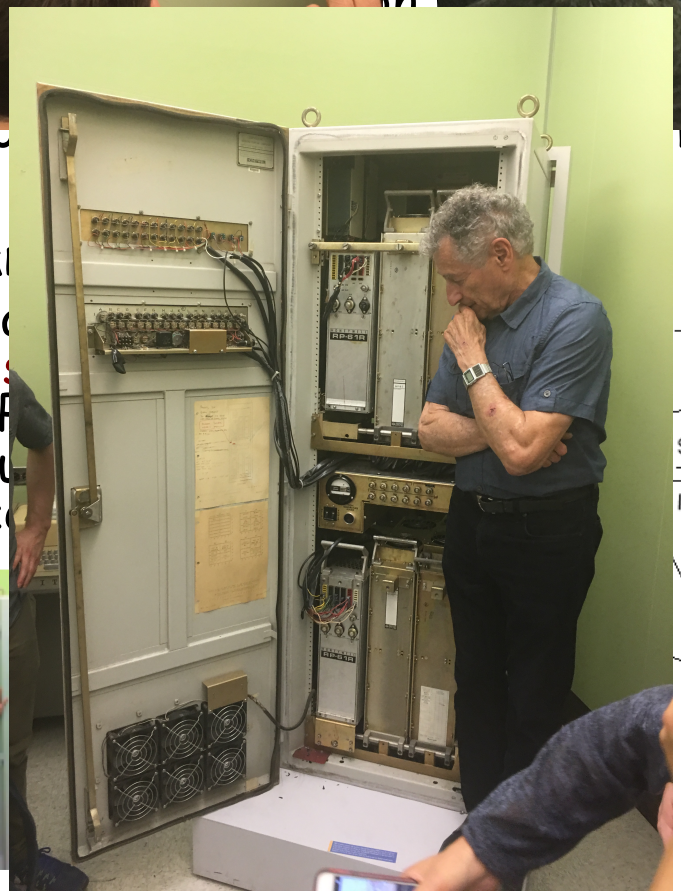


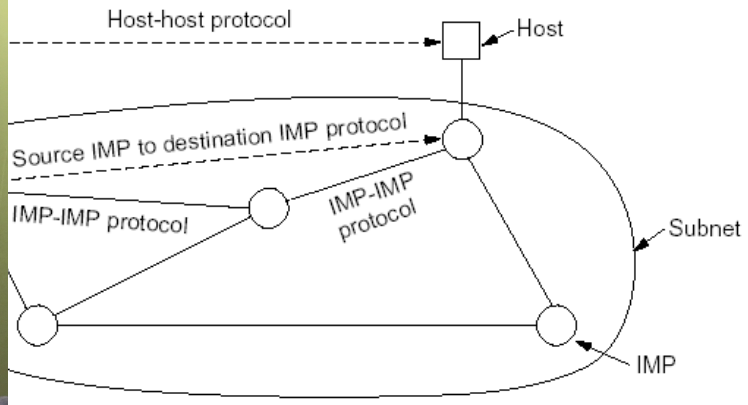




- Paul Baran [illegible] switching networks
- **1965-1968**
  - ARPANET pla[illegible]
  - Bolt Beranek [illegible] Inc. (BBN), a [illegible] was awarded [illegible] contract to bu[illegible] Message Proc[illegible]

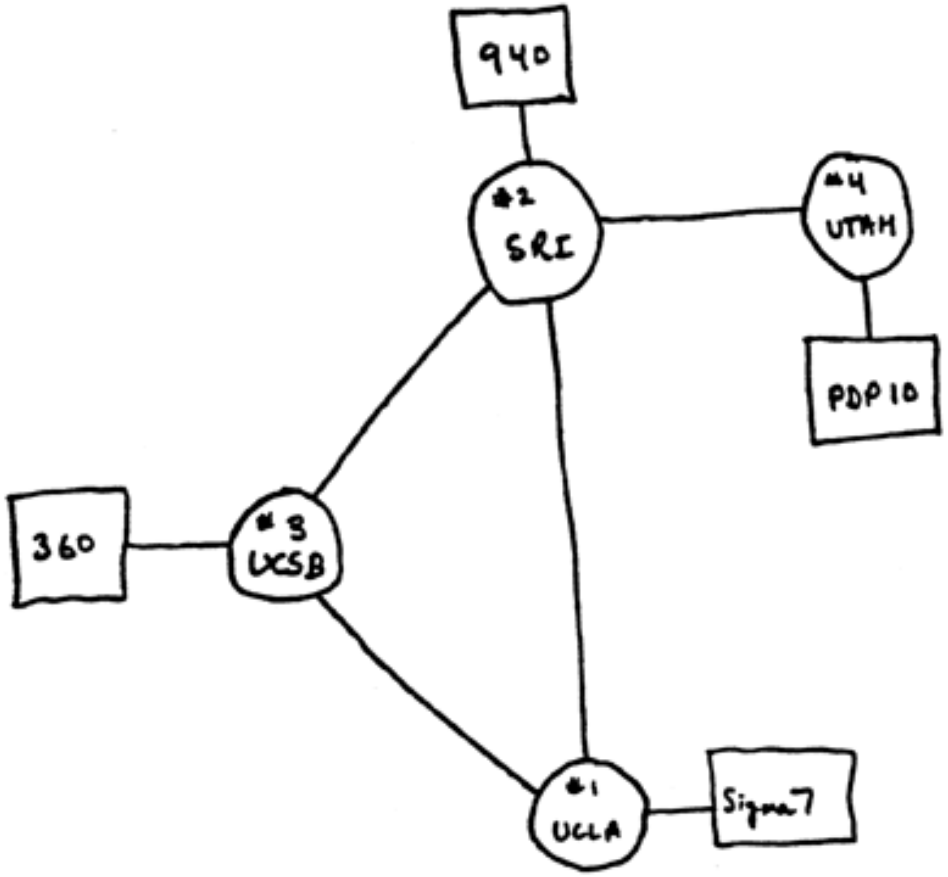




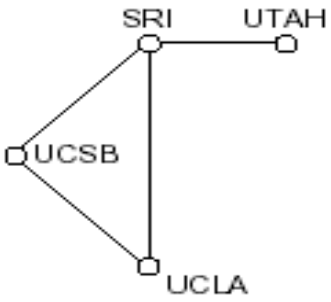


Internet 1.0: Initial ARPANET

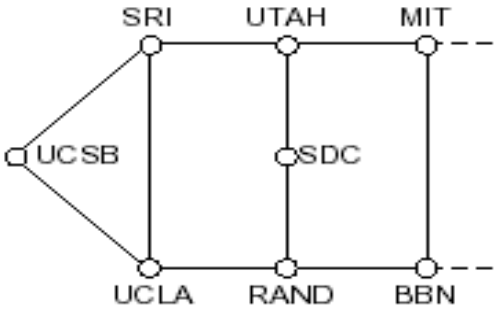
- 1969
  - ARPANET commissioned: 4 nodes, 50kbps



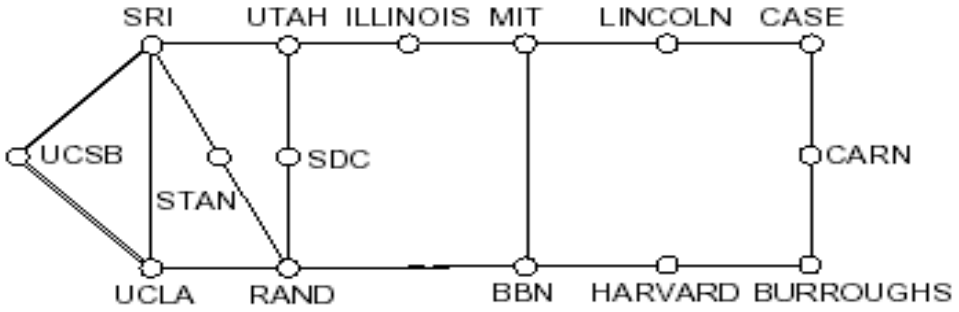
Initial Expansion of the ARPANET



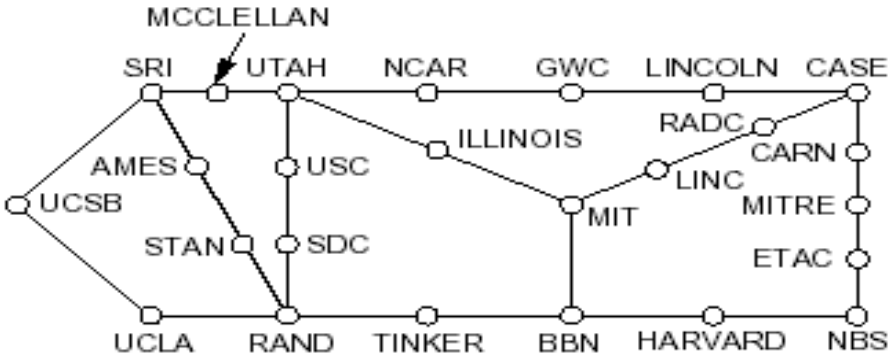
Dec. 1969



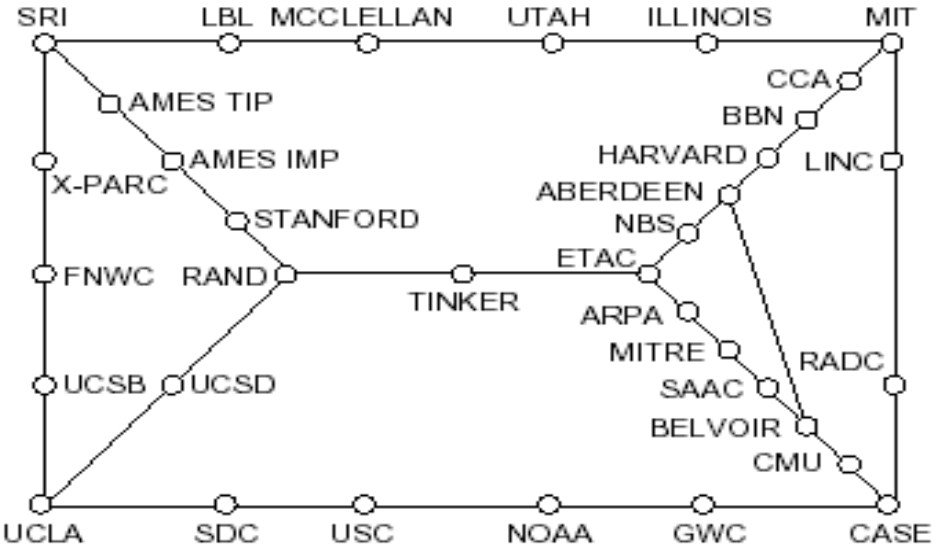
July 1970



Mar. 1971



Apr. 1972



Sept. 1972

RFC 527: ARPAWOCKY; RFC 602: The Stockings Were Hung by the Chimney with Care

The Internet Becomes a Network of Networks

- 1970: ALOHAnet, the first packet radio network, developed by Norman Abramson, Univ of Hawaii, becomed operational
- 1973: Bob Kahn posed the Internet problem---how to connect ARPANET, packet radio network, and satellite network
- 1974: Vint Cerf, Bob Kahn published initial design of TCP (NCP) to connect multiple networks
  - 1978: TCP (NCP) split to TCP/IP
  - 1983: TCP (NCP) converted to TCP/IP (Jan. 1)

Growth of the Internet

- 1981: BITNET (Because It's Time NETwork) between CUNY and Yale
- 1986: NSF builds NSFNET as backbone, links 6 supercomputer centers, 56 kbps; this allows an explosion of connections, especially from universities
- 1987: 10,000 hosts
- 1987: China's first email "Across the Great Wall we can reach every corner in the world" sent to Germany
- 1988: Internet congestion collapse; TCP congestion control
- 1989: 100,000 hosts

RFC 1121: Act One – The Poem
WELCOME by Leonard Kleinrock

We've gathered here for two days to examine and debate
And reflect on data networks and as well to celebrate.
To recognize the leaders and recount the path we took.

We'll begin with how it happened; for it's time to take a look.
Yes, the history is legend and the pioneers are here.
Listen to the story - it's our job to make it clear.
We'll tell you where we are now and where we'll likely go.
So welcome to ACT ONE, folks.

Sit back - enjoy the show!!

Internet 2.0: Web, Commercialization, Social Networking of the Internet

- 1990: ARPANET ceases to exist
- 1991: NSF lifts restrictions on the commercial use of the Net; Berners-Lee of European Organization for Nuclear Research (CERN) released World Wide Web
- 1992: 1 million hosts (RFC 1300: Remembrances of Things Past)
- 1994: China's first 64K dedicated circuit to the Internet
- 1998: Google was founded
- 2004: Facebook was founded
- 2006: Amazon AWS cloud computing

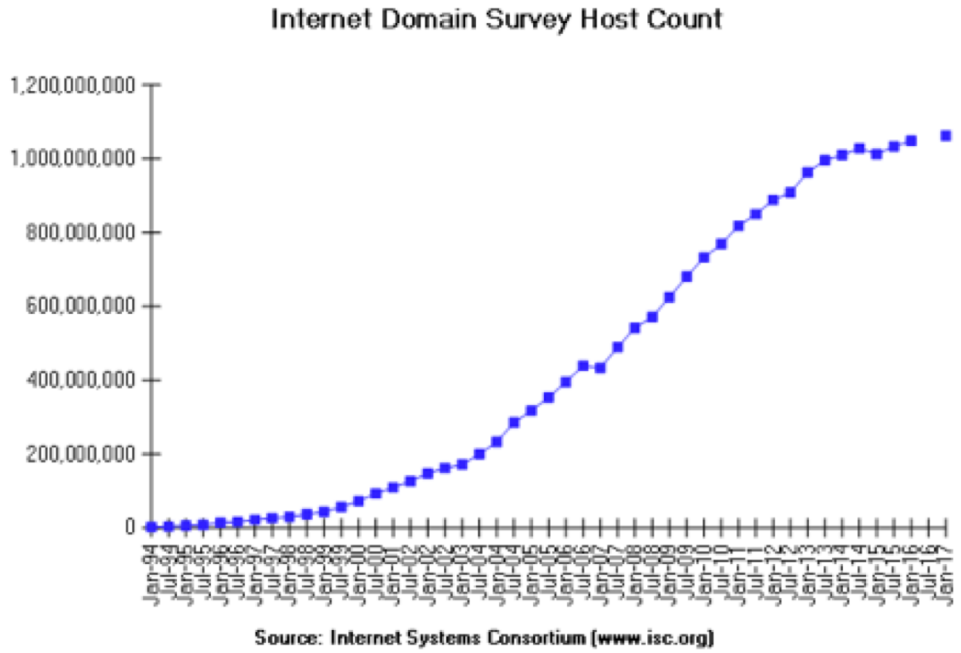
For a link of interesting RFCs, please see
http://qiaoxiang.me/courses/cnns-xmuf21/readings/interestingrfcs.html

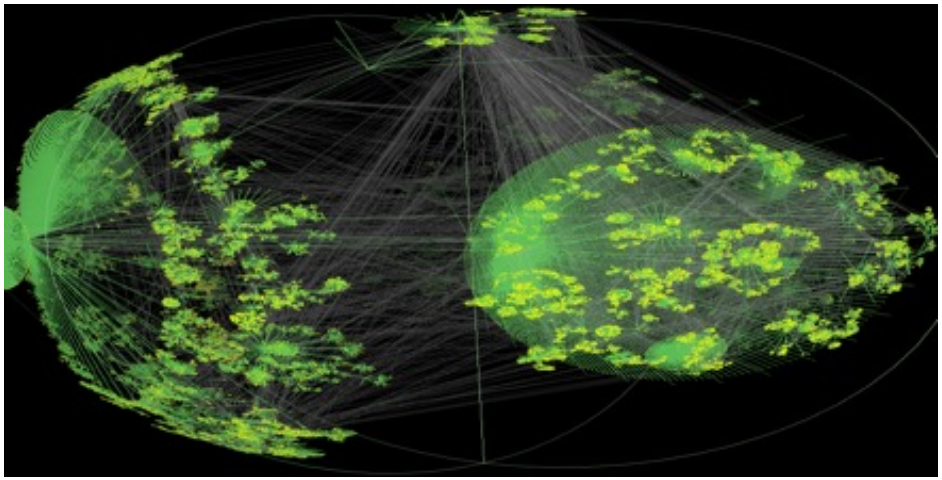
For more on Internet history, please see
http://www.zakon.org/robert/internet/timeline/

Growth of the Internet in Terms of Number of Hosts

Number of Hosts on the Internet:

Aug. 1981	213
Oct. 1984	1,024
Dec. 1987	28,174
Oct. 1990	313,000
Jan. 1993	1,313,000
Jan. 1996	9,472,000
Jan. 1999	43,218,000
Jan. 2002	147,344,723
Jan. 2005	317,646,084
Jan. 2007	433,193,199
Jan. 2010	732,740,444
Jan. 2013	963,518,598
Jan. 2016	1,048,766,623
Jan. 2017	1,062,660,523

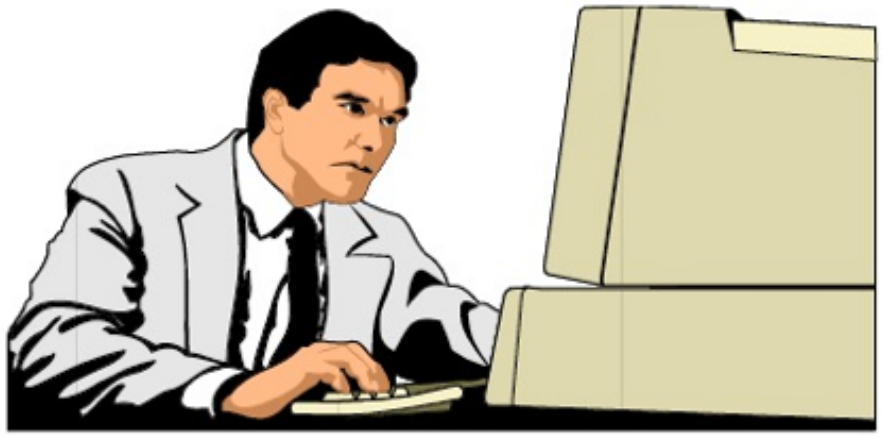




CAIDA router level view

http://ftp.isc.org/www/survey/reports/current/

Internet 3.0: Always-Connected, Virtualized Life



- Office => Virtual workspace
- Shopping => Online shopping
- Education => Remote education
- Entertainment ⇒ Online media/games
- Environment ⇒ Internet of things

Internet in China

- 5 major networks: CHINANET, UNINET, CMNET, CERNET, CSTNET
- International exit bandwidth: 8.8Tbps, 2019
- 4G base stations: >5.5 million (<9 million globally)
- 5G base stations: ~0.7 million (~70% of the world), 2020

What Will We Cover?

- Network architecture and design principles
  - Layered network arch; e2e principle
- Application architecture and design principles
  - application paradigms; high performance network app.
  - HTTP/Web, Email, DNS, P2P, Blockchain, Content distribution
- Transport
  - transport services
  - reliability; distributed resource allocation; primal-dual
  - transport protocols: TCP/UDP

What Will We Cover?

- Network and link layers
  - distributed, asynchronous, autonomous routing algorithms; scalable router design; IP/IPv6; mobile IP; cellular networks
  - multiple access; queueing analysis; capacity analysis
- Next-generation network:
  - Cloud and data center design, programmable networks, RDMA
- Physical layer
- Wireless Networks
- Network security
  - security primitives; BAN logic, SSL

Summary

- Course administration
- A protocol defines the format and the order of messages exchanged between two or more communicating entities, as well as the actions taken on the transmission and/or receipt of a message or other events.
- The past:
  - facts:
    - The Internet started as ARPANET in late 1960s
    - The initial link bandwidth was 50 kbps
    - The number of hosts at the end of 1969 was 4
  - some implications of the past:
    - ARPANET is sponsored by ARPA → design should survive failures
    - The initial IMPs were very simple → keep the network simple
    - Many networks → need a network to connect networks
- Current:
  - The number of hosts connected to the Internet is around 1 billions
  - The backbone speed of the current Internet is about 40/100 Gbps
  - The Internet is roughly hierarchical where ISPs interconnect at PoP and IXP
  - Needs to handle scale, complexity, decentralization, security

Preview

- We have only looked at the topology/connectivity of the Internet
  - a communication network is a mesh of interconnected devices

- *A fundamental question:* how is data transferred through a network?