Data Networks
Introduction

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Introduction

- The course introduces the underlying concepts and principles of data networks.
- It presents different components of a network and how these components fit together.
- The layers of functionalities implemented in network nodes are investigated and the underlying design concepts are discussed.
- The course is designed at a graduate level with practical assignments and short projects

General Information

- Lecturer: Dr. Mohammad Reza Pakravan
- Contact info:
  - E-mail: pakravan@sharif.edu
  - Office: Room 605
  - Office Phone: 6616-5922
- Course Schedule and Location:
  - Sunday /Tuesday, 9:00-10:30
  - Location: Bargh 5

Text References

- Required Textbook
  - Andrew Tanenbaum. Computer Networks, Sixth Edition, Prentice Hall
- Additional textbooks and References
  - A. Leon-Garcia & I. Widjaja, Communication Networks, McGraw Hill
  - W. Stallings. Data and Computer Communications. Prentice Hall.
  - J. Walrand. Communication Networks: First Course. Aksen Associates.
  - D. Comer. Internetworking with TCP/IP, Volume I, Prentice Hall.
  - W. Stevens. TCP/IP Illustrated: The Protocols, Vol 1. Addison-Wesley.
  - D. Comer. Computer Networks and Internets. Prentice Hall.
  - L. Peterson and B. Davie. Computer Networks: A Systems Approach. Morgan Kaufman.
- Some of the course material are presented from other sources

Course Outline

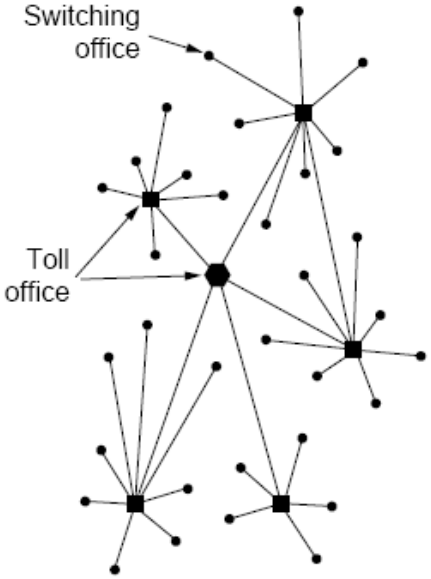
- Introduction.
- The Physical Layer.
- The Data Link Layer.
- The Multiple Access Sub-Layer.
- The Network Layer.
- The Transport Layer.
- The Application Layer.

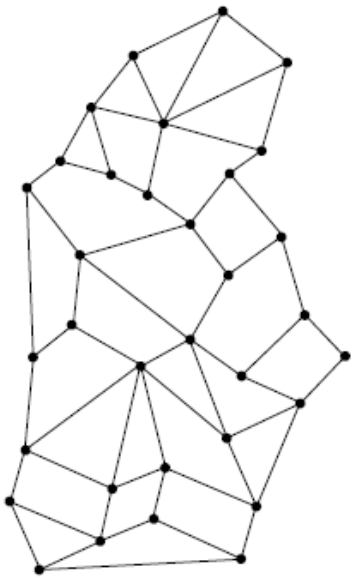
Course load

- Course work consists of
  - Following up on presented lectures
  - Reading textbook
  - Learning how to use network simulation and modeling tools
  - Preparing reports on course labs, assignments and project
- Grading Policy
  - Course Labs, Assignments and Projects: 30%
  - Exams: 70%

Brief History of Data Networks

- 1961-1964 Idea of store and forward distributed communication in packet networks by L. Kleinrock, D. Watts and P. Baran
  - More suitable for computer communication
  - More resilient to node failure
- Creation of ARPANET in late 1960's
  - To build a network that withstands destruction of some of its nodes
  - First Network started operation in 1969





History of Internet

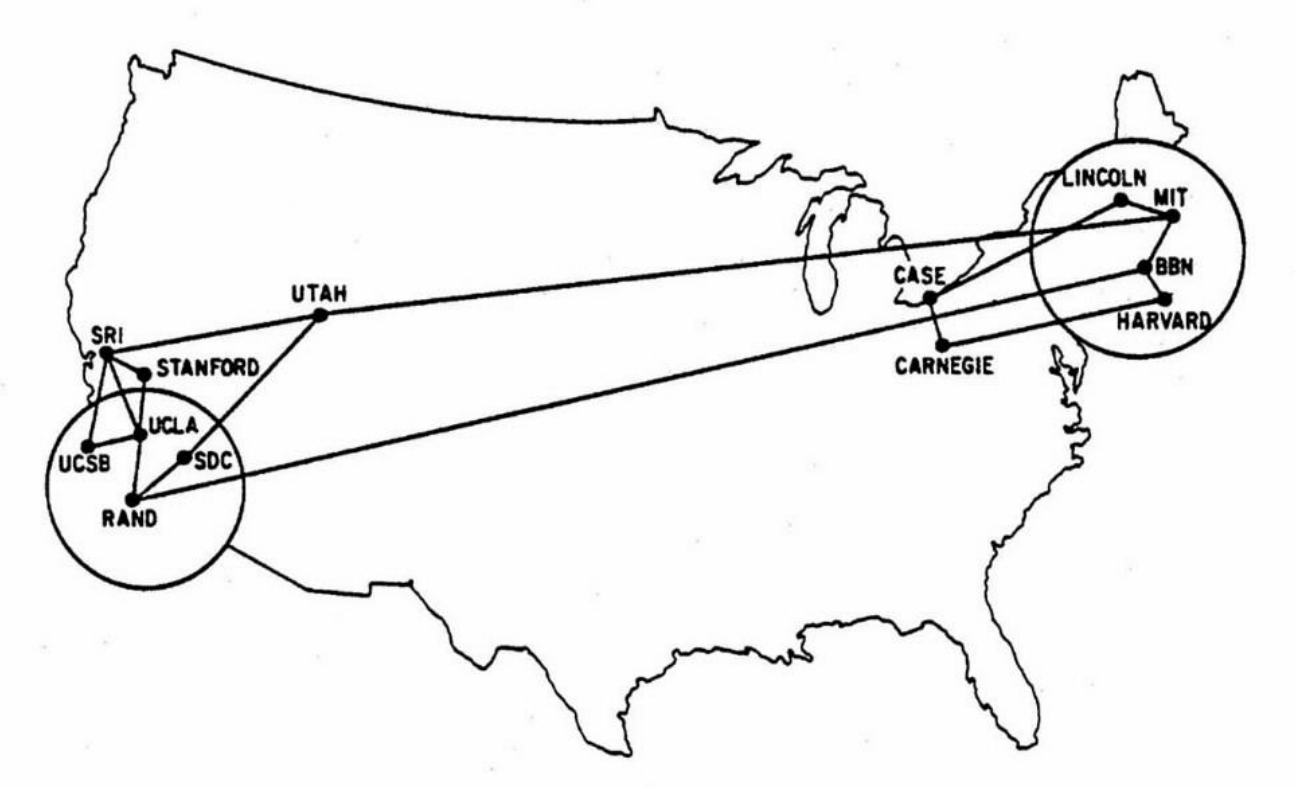
- ARPANET, the precursor to the modern internet, was an academic research project funded by the Advanced Research Projects Agency, a branch of the military known for funding ambitious research projects without immediate commercial or military applications

The ARPANET in December 1969

https://www.vox.com/a/internet-maps

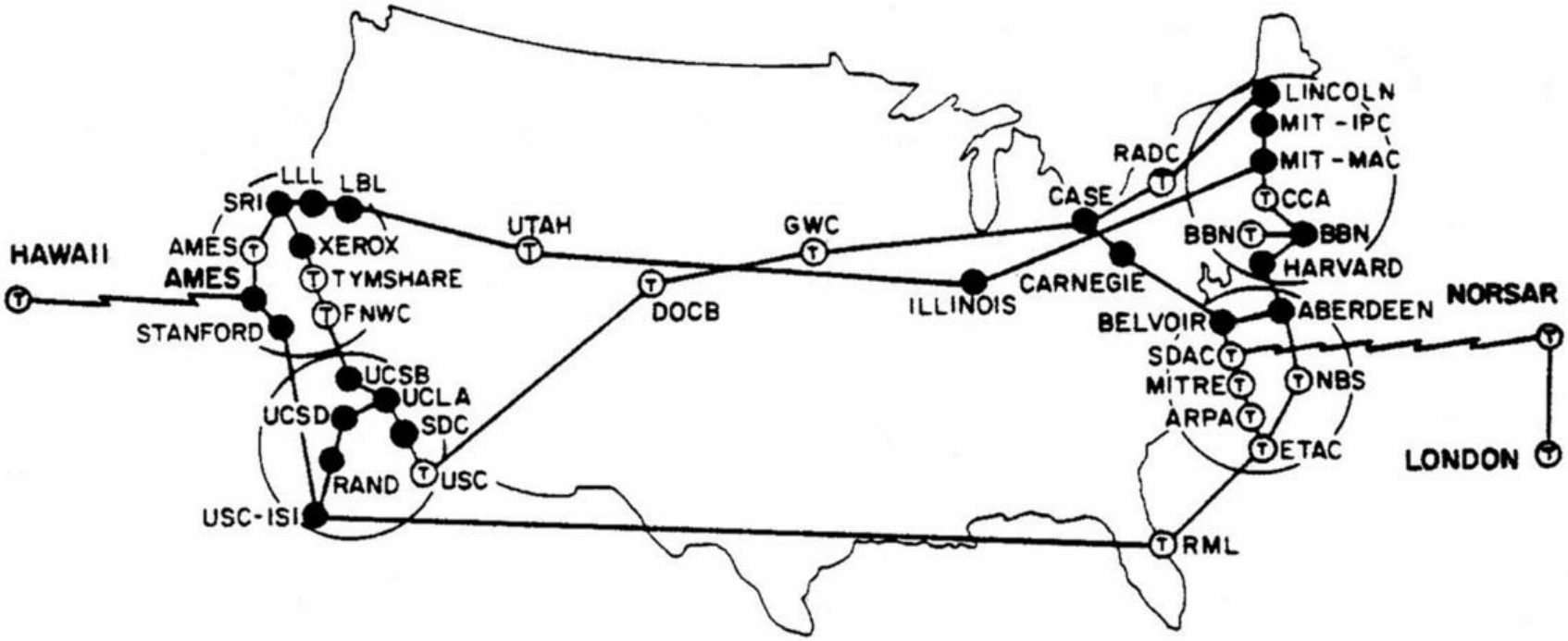
1970: ARPANET expands

- By the end of 1970, ARPANET had grown to 13 nodes



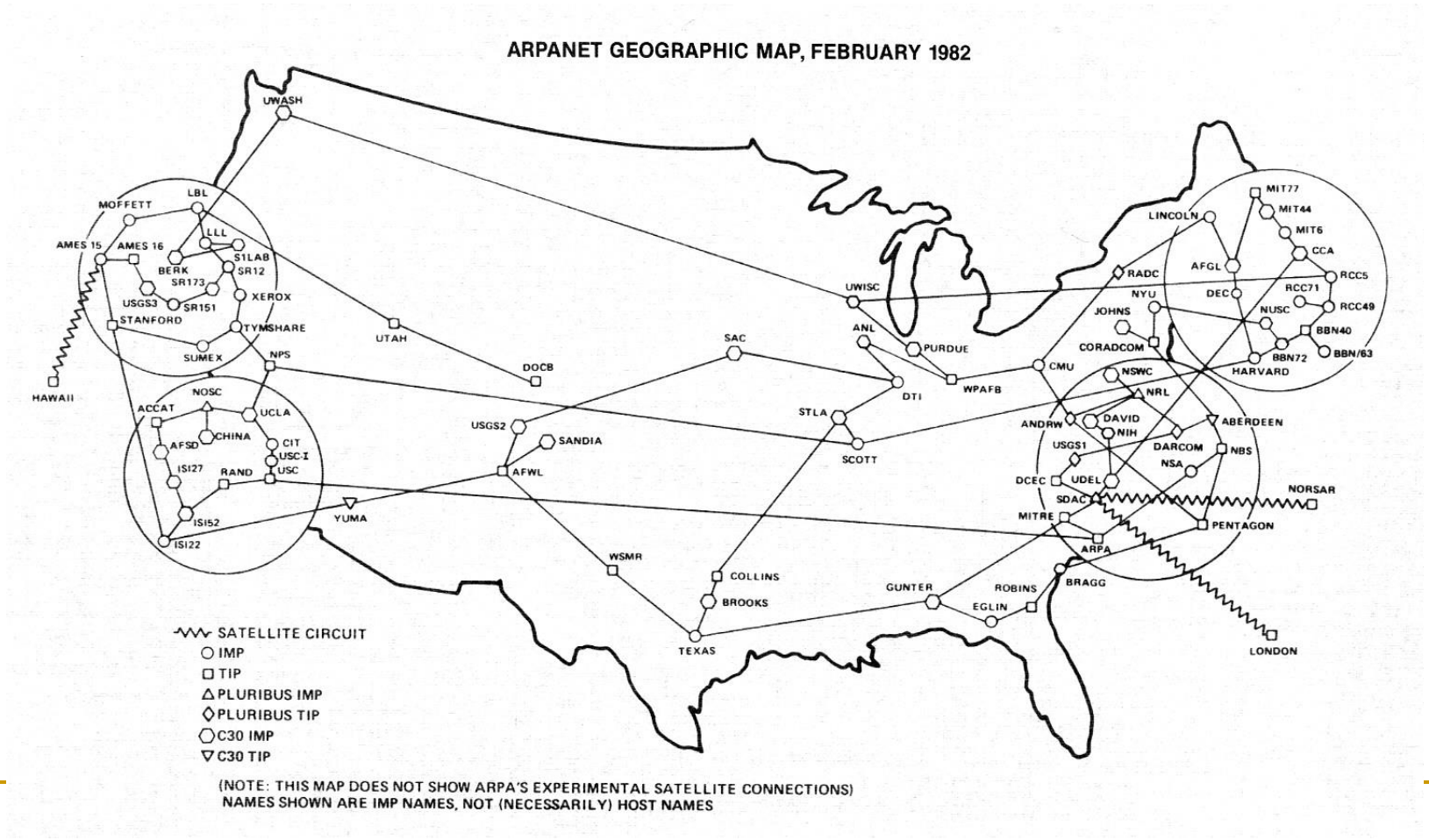
1973: ARPANET goes international

- In 1973, the ARPANET became international, with a satellite link connecting Norway and London to the other nodes in the United States. Hawaii also joined the network by satellite. At this point, the network had around 40 nodes.



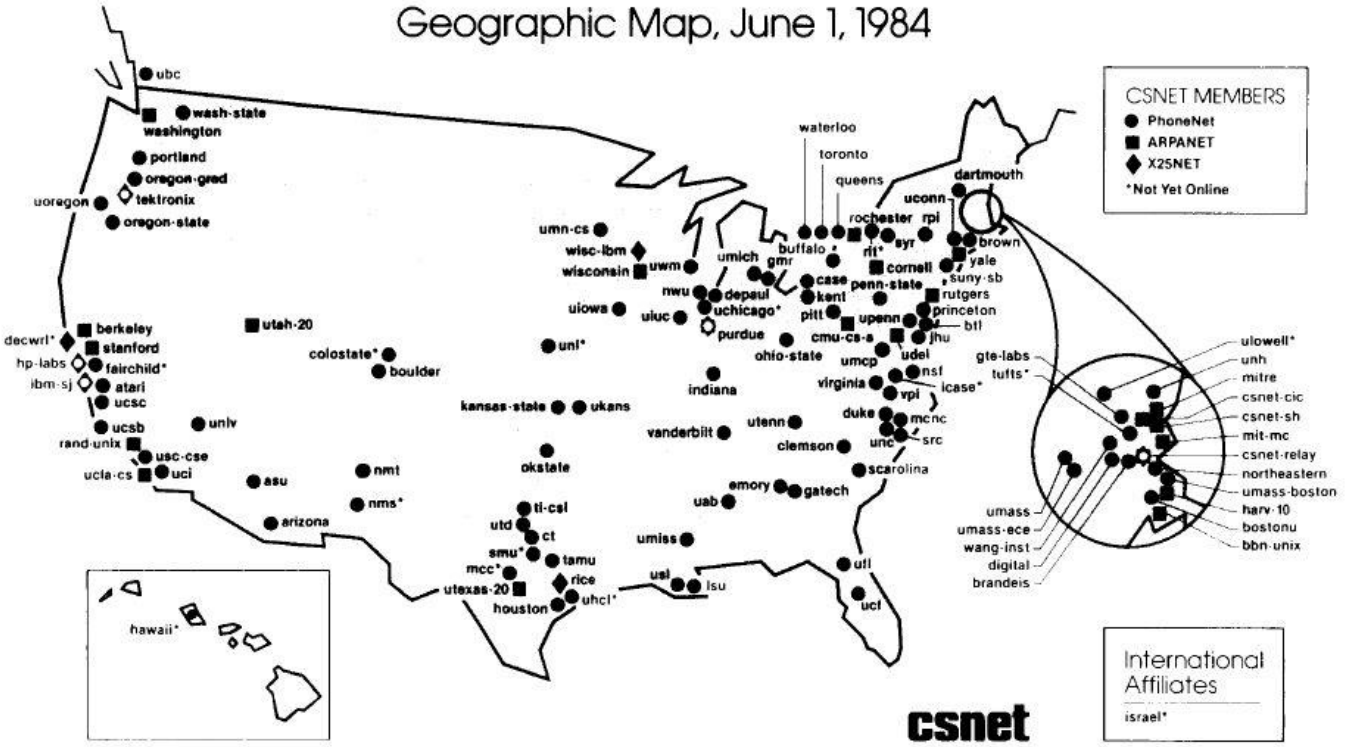
1982: the ARPANET community grows

- By 1982, the network had about 100 nodes.



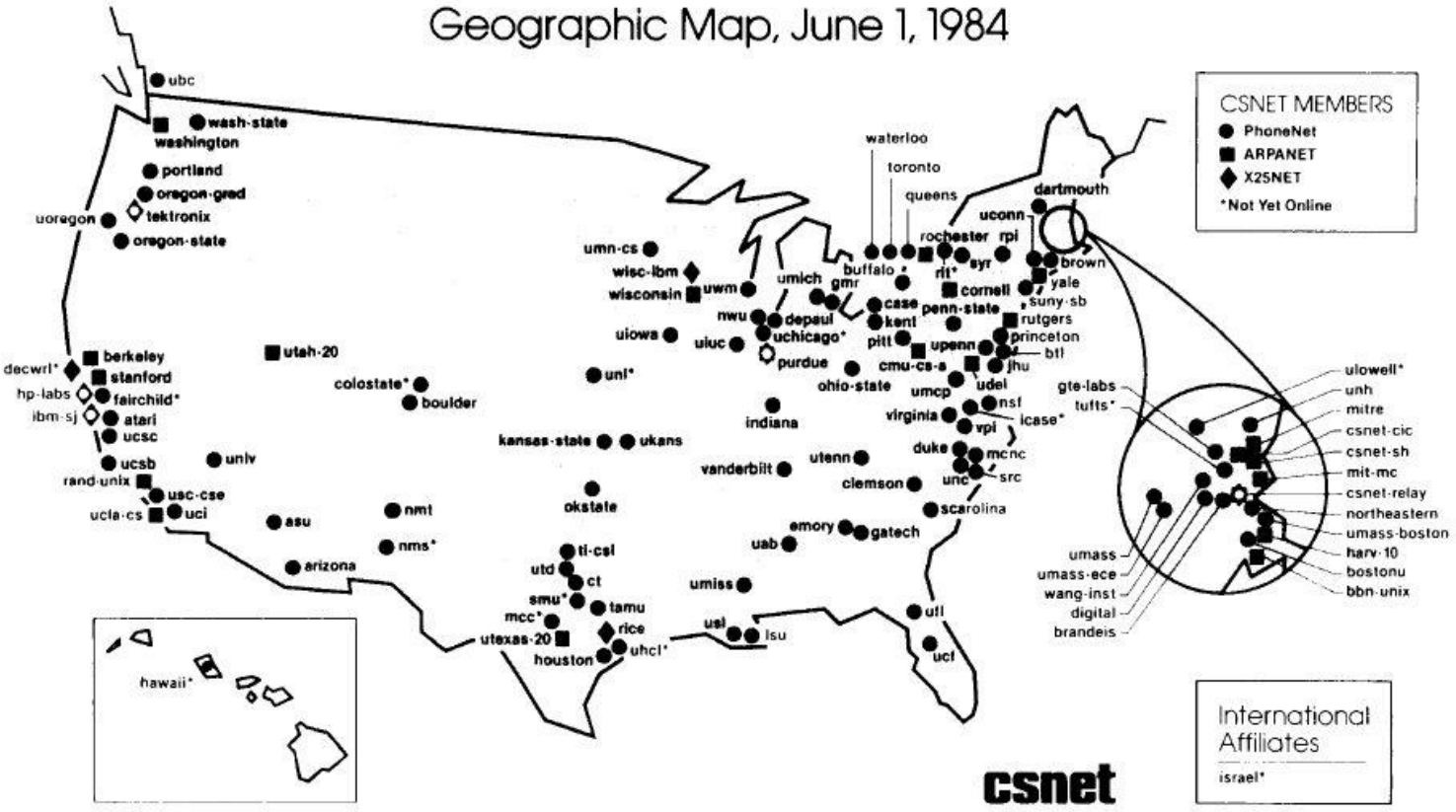
1984: ARPANET becomes the internet

- In 1984, ARPANET network operators decided that the network should be reorganized as a decentralized "network of networks."
- Under this scheme, different networks would be controlled by different organizations, but all the networks able to communicate using shared standards, forming a shared "internet."



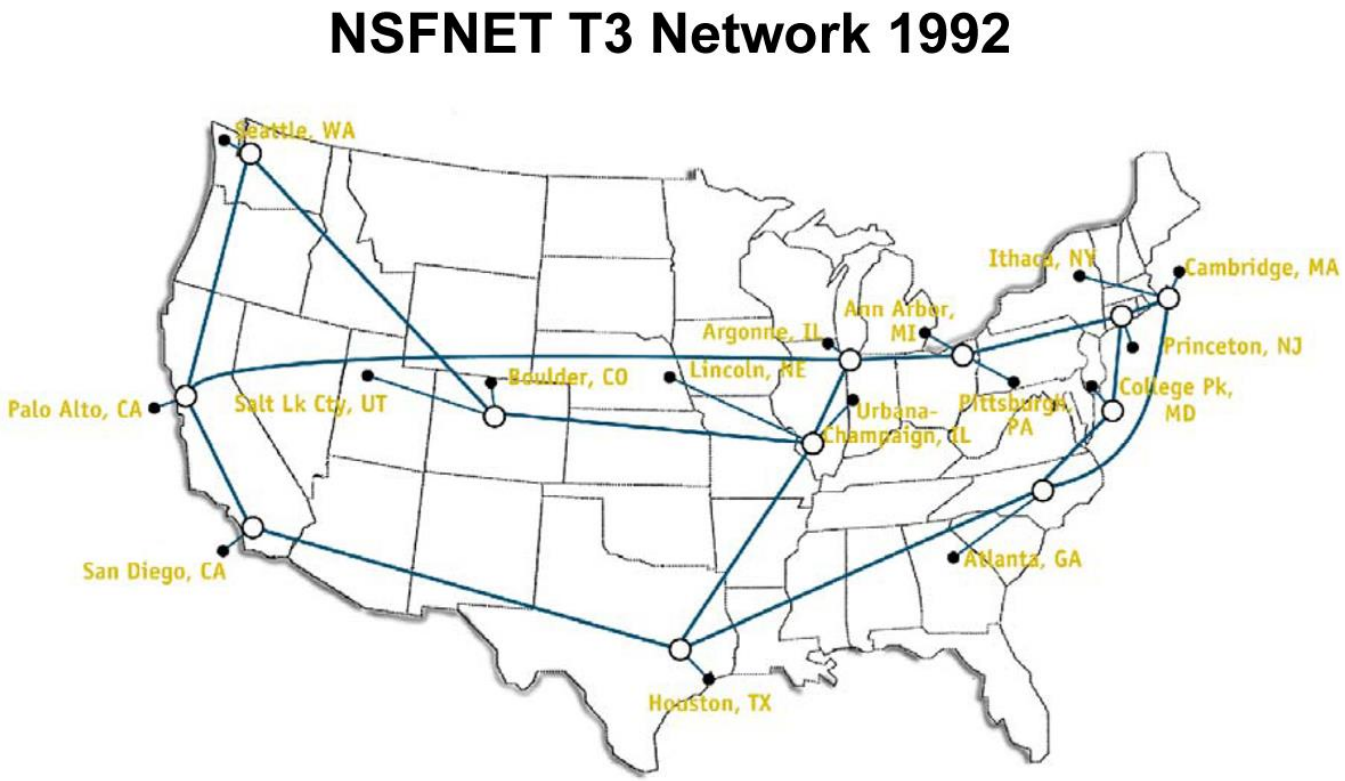
1984: ARPANET becomes the internet

- A set of standards known as TCP/IP was developed.
- On January 1, 1983, the ARPANET switched to using TCP/IP, marking the birth of the modern internet.



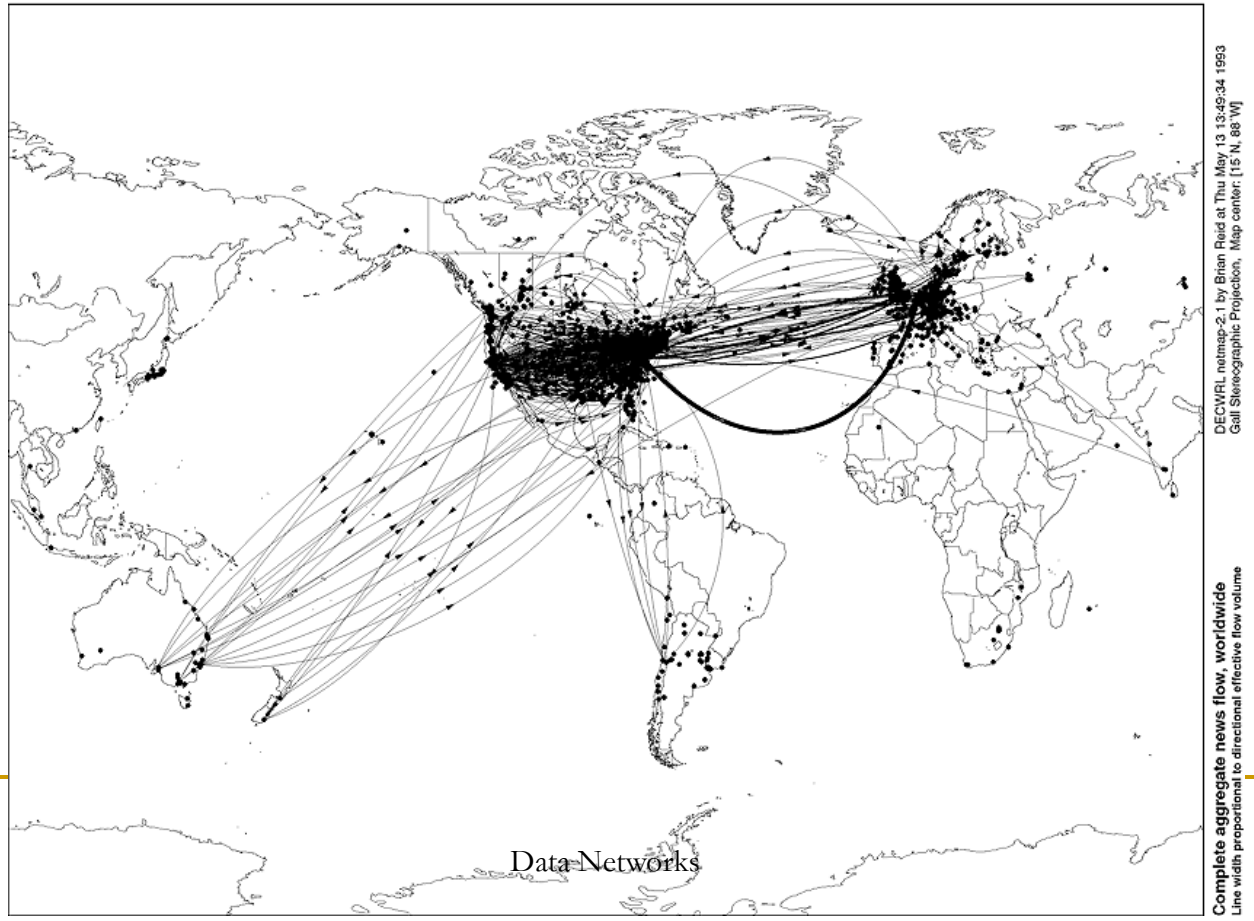
NSFNET: The first internet backbone

- In 1986, the US National Science foundation agency created a TCP/IP-based network called NSFNET to link supercomputing centers together and allow researchers across the country to use them.
- The NSFNET became the internet's "backbone," the high-speed, long-distance network that allowed different parts of the internet to communicate.



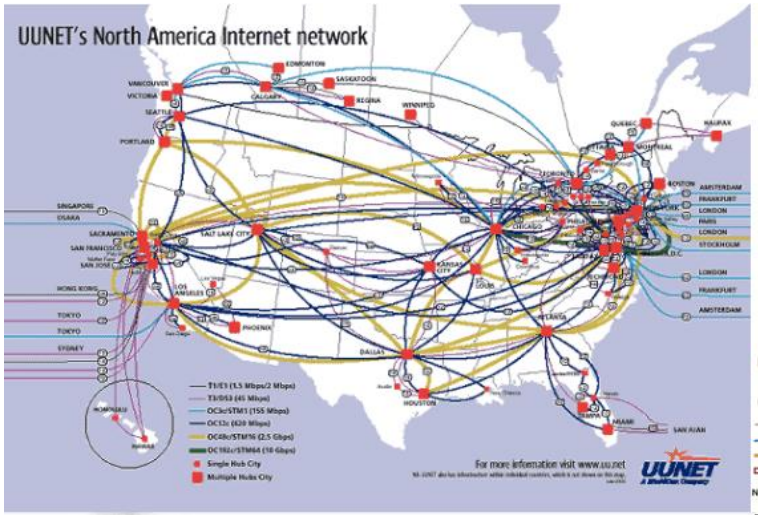
The internet becomes a global network

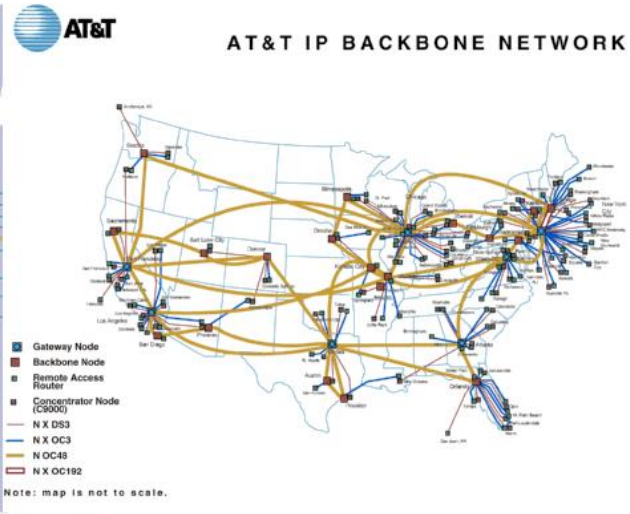
- In 1993, the internet was still dominated by the United States, but it was becoming a truly global network. This is a map of information flow on Usenet, a bulletin board application.

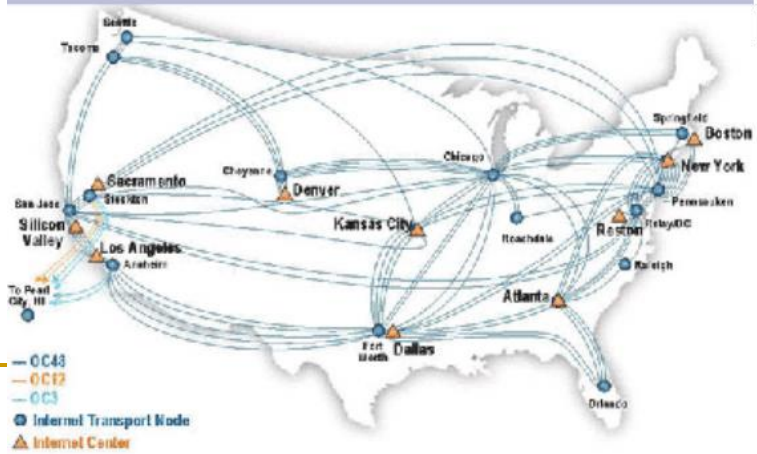


The privatization of the internet backbone

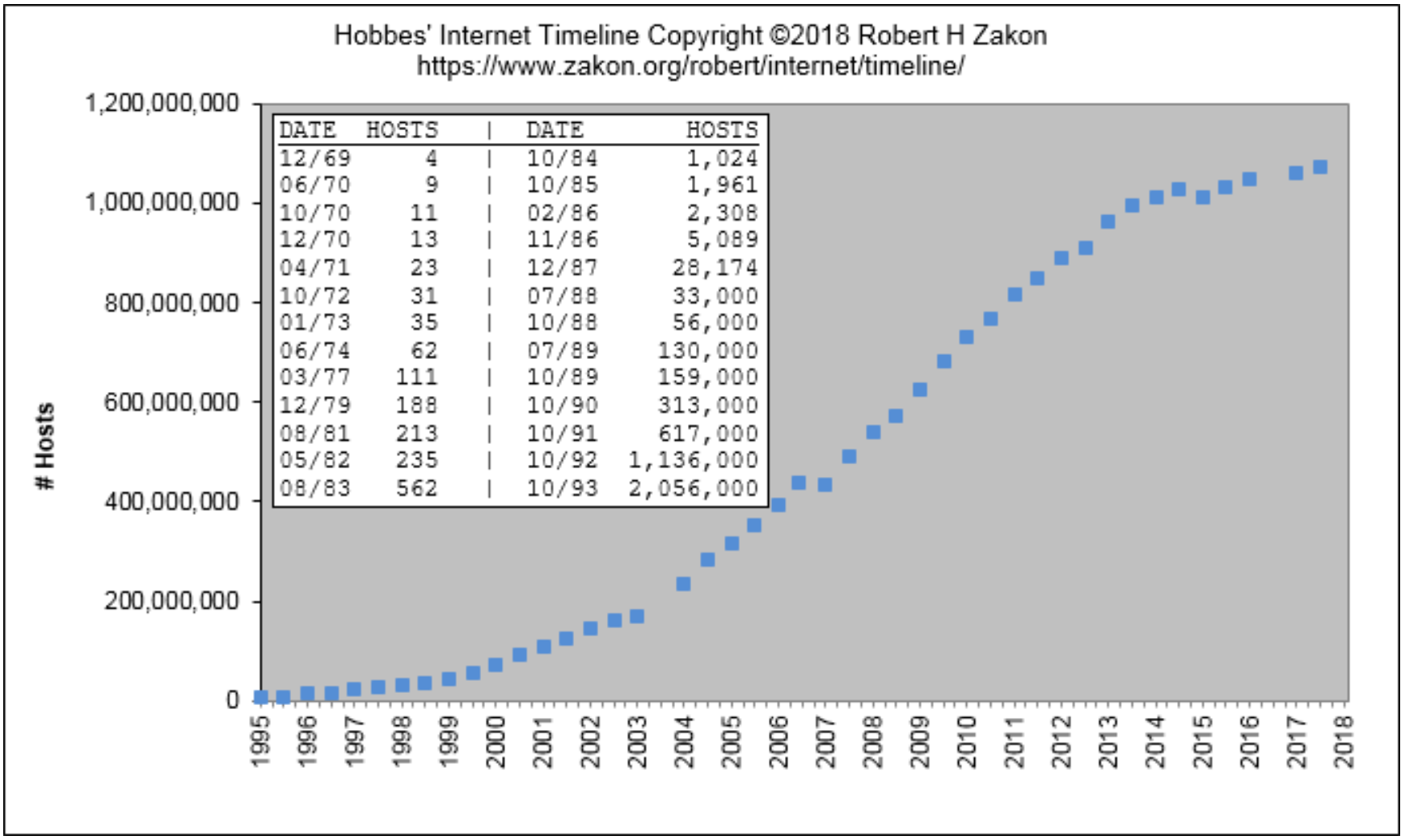
- In 1994, the internet backbone was privatized to several competitive service providers.





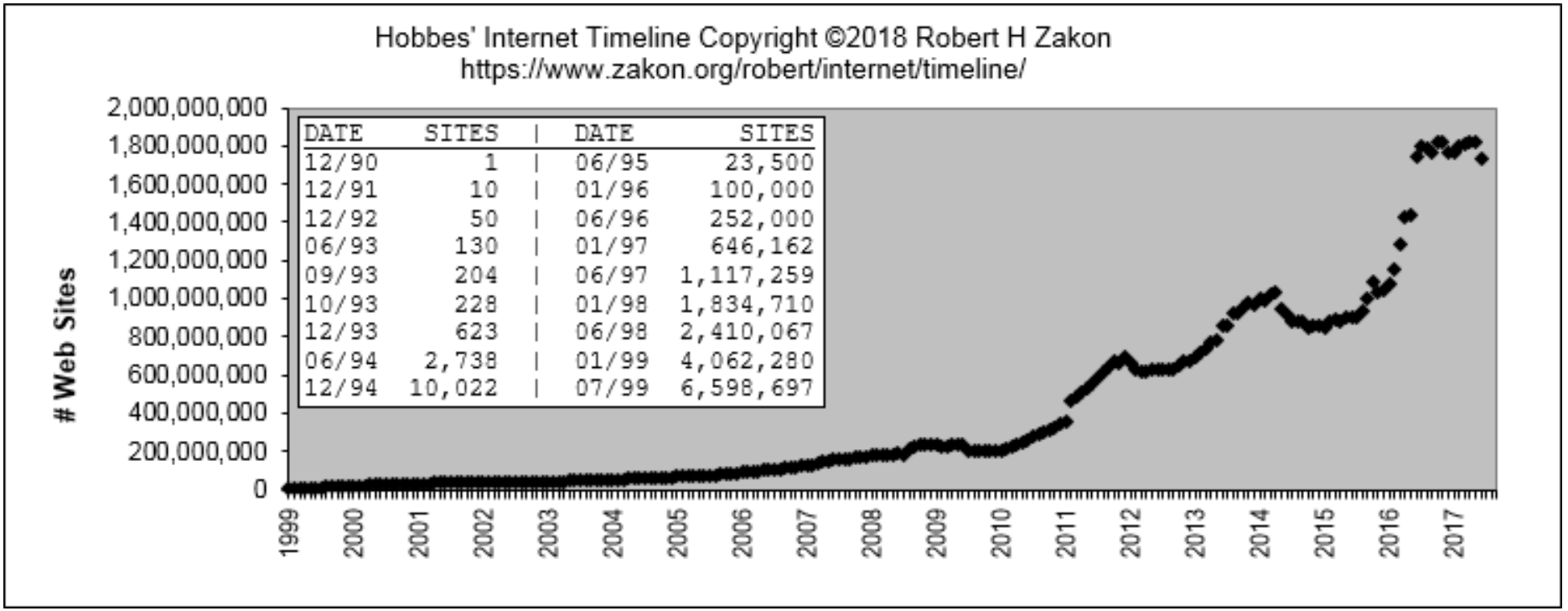


Internet Growth



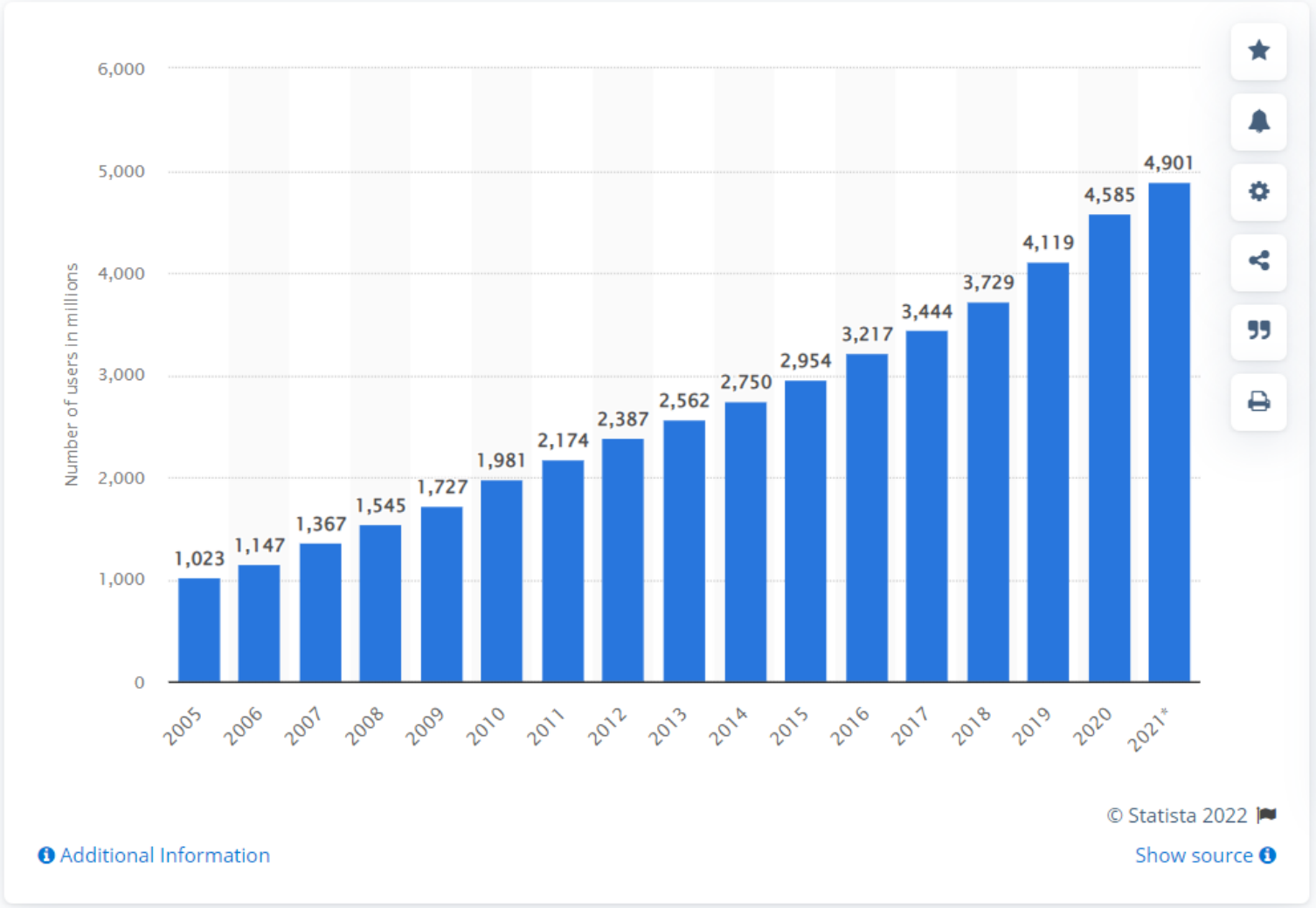
DATE	HOSTS	DATE	HOSTS
12/69	4	10/84	1,024
06/70	9	10/85	1,961
10/70	11	02/86	2,308
12/70	13	11/86	5,089
04/71	23	12/87	28,174
10/72	31	07/88	33,000
01/73	35	10/88	56,000
06/74	62	07/89	130,000
03/77	111	10/89	159,000
12/79	188	10/90	313,000
08/81	213	10/91	617,000
05/82	235	10/92	1,136,000
08/83	562	10/93	2,056,000

Internet Growth



DATE	SITES	DATE	SITES
12/90	1	06/95	23,500
12/91	10	01/96	100,000
12/92	50	06/96	252,000
06/93	130	01/97	646,162
09/93	204	06/97	1,117,259
10/93	228	01/98	1,834,710
12/93	623	06/98	2,410,067
06/94	2,738	01/99	4,062,280
12/94	10,022	07/99	6,598,697

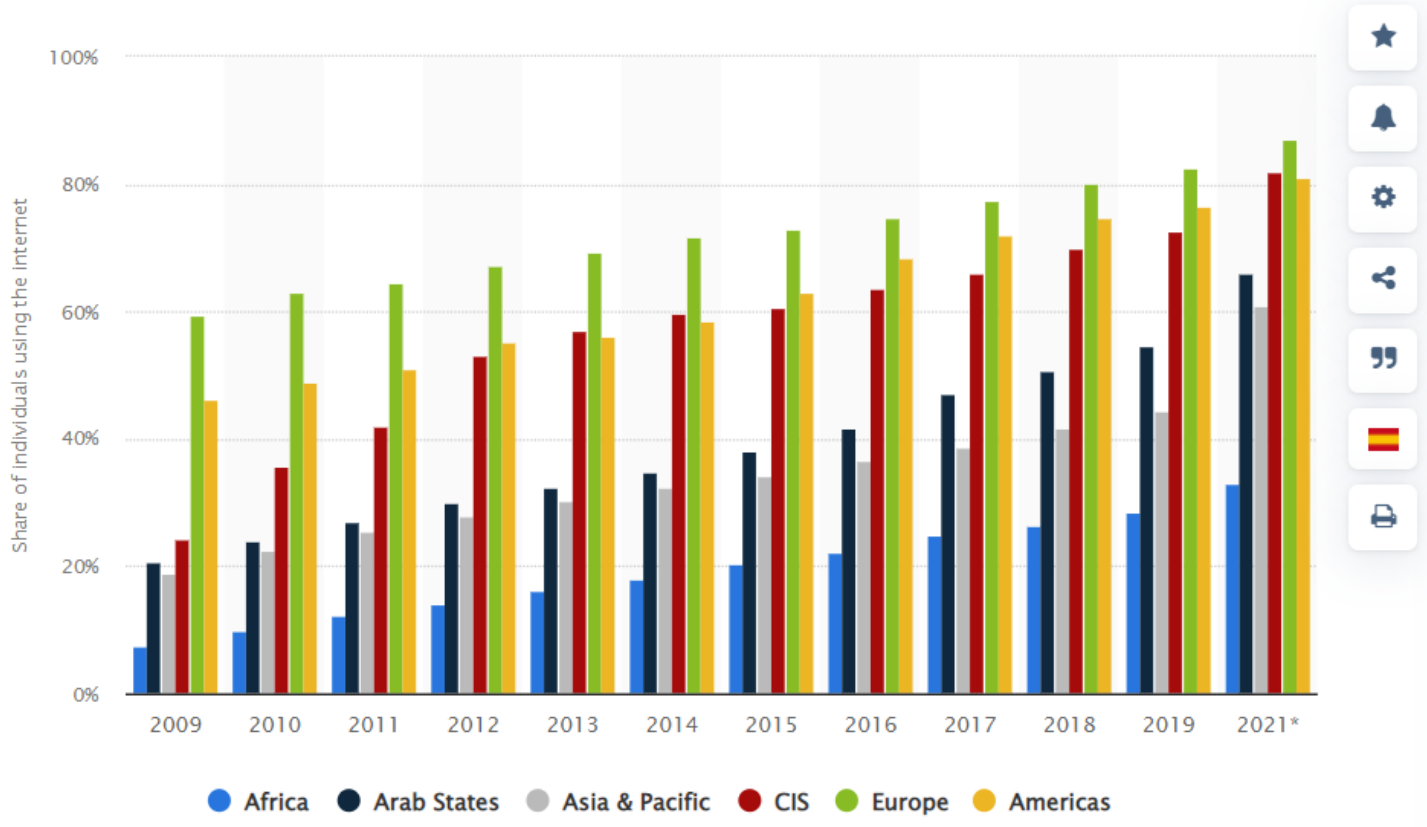
Global Usage of Internet



Global Usage of Internet

Internet › Demographics & Use

Global internet penetration rate from 2009 to 2021, by region

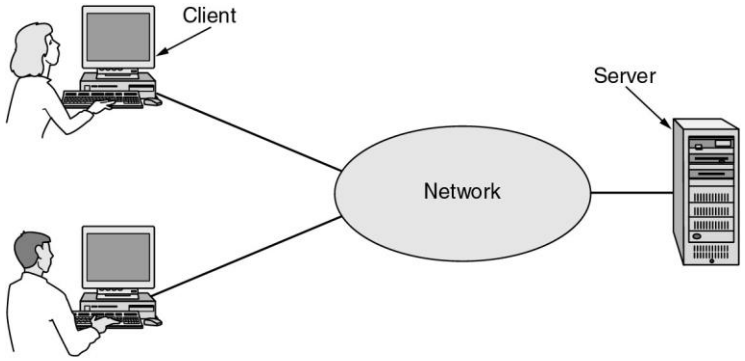


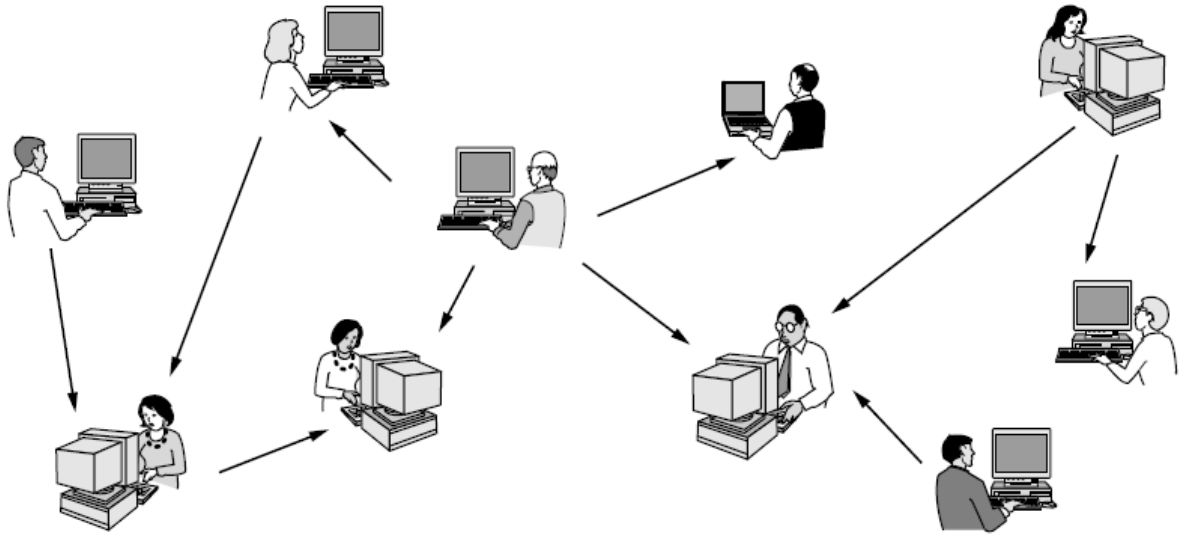
Additional Information

Show source

Computer Networks

- Old: Single powerful computer, many local terminals for interaction
- Now: Many autonomous computers interconnected to do the job





Applications of Computer Networks

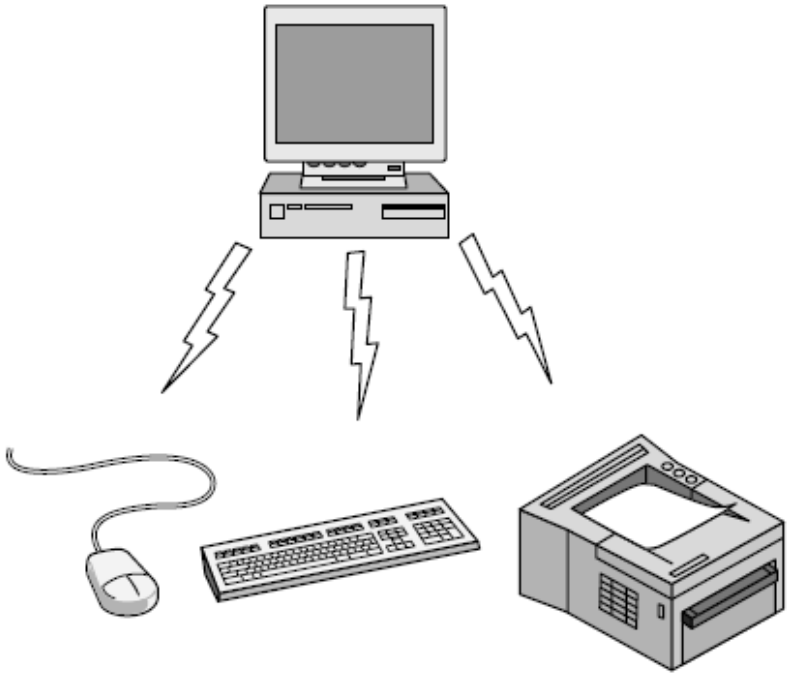
- Access to Information
  - Web Browsing
  - Online navigation
- Person to Person Communication
  - Instant Messaging
  - Social Networks
  - Video Calling
- Electronic Commerce
  - Business to Consumer (B2C)
  - Business to Business (B2B)
  - Government to consumer (G2C)
- Entertainment
  - IPTV
- Internet of Things

Types of Data Networks

- Broadband Access Networks
- Mobile and Wireless Access Networks
- Content Provider Networks
- Transit Networks
- Enterprise Networks

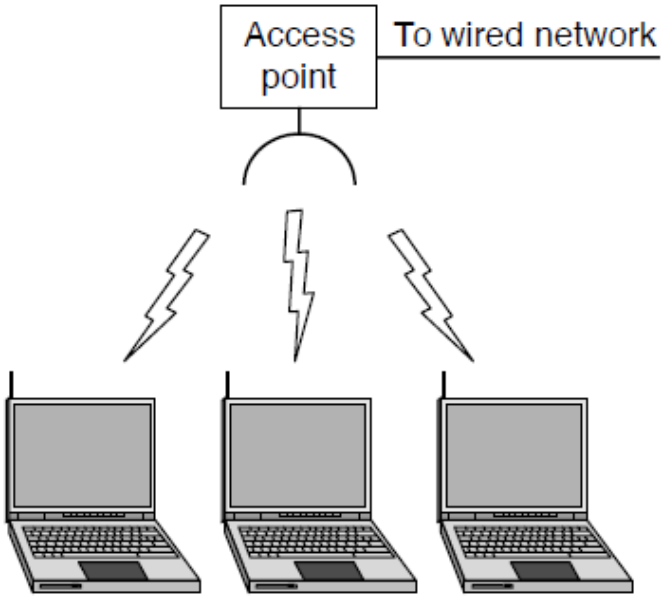
Types of Networks

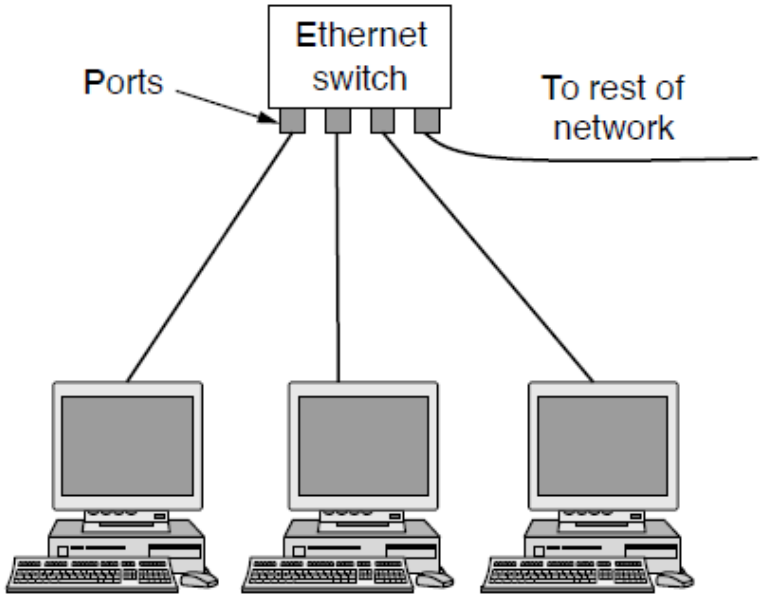
- PAN (Personal Area Network)
  - Network with a short range
  - Example: Bluetooth connections



Types of Networks

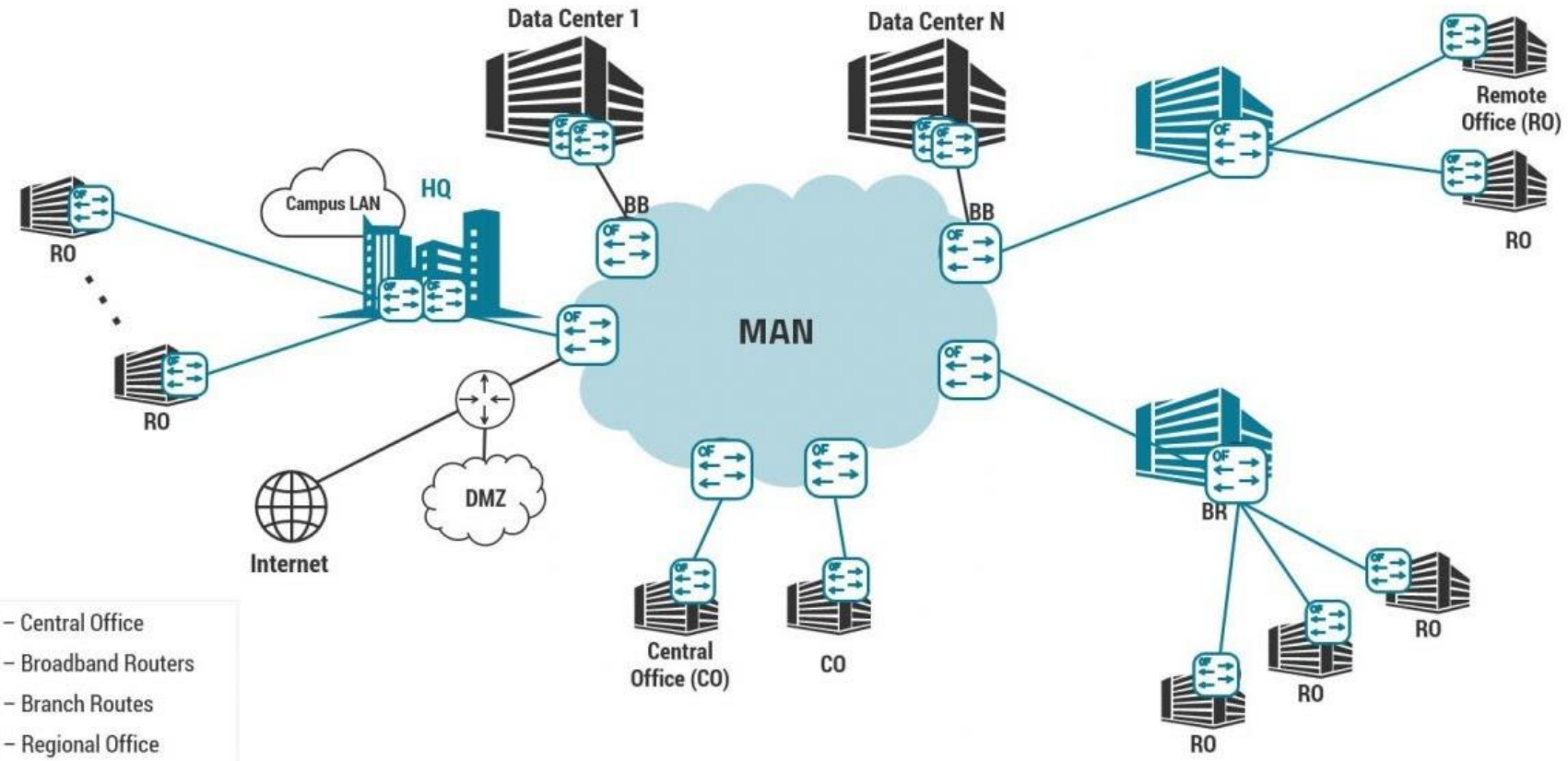
- LAN (Local Area Network)
  - Network usually within a building
  - Restricted Size, delay
  - Rate: 10Mbps to 10Gbps
  - Channel allocation: Static or dynamic
  - Examples: Ethernet (IEEE 802.3),





Types of Networks

- MAN (Metropolitan Area Network)
  - A network within a city

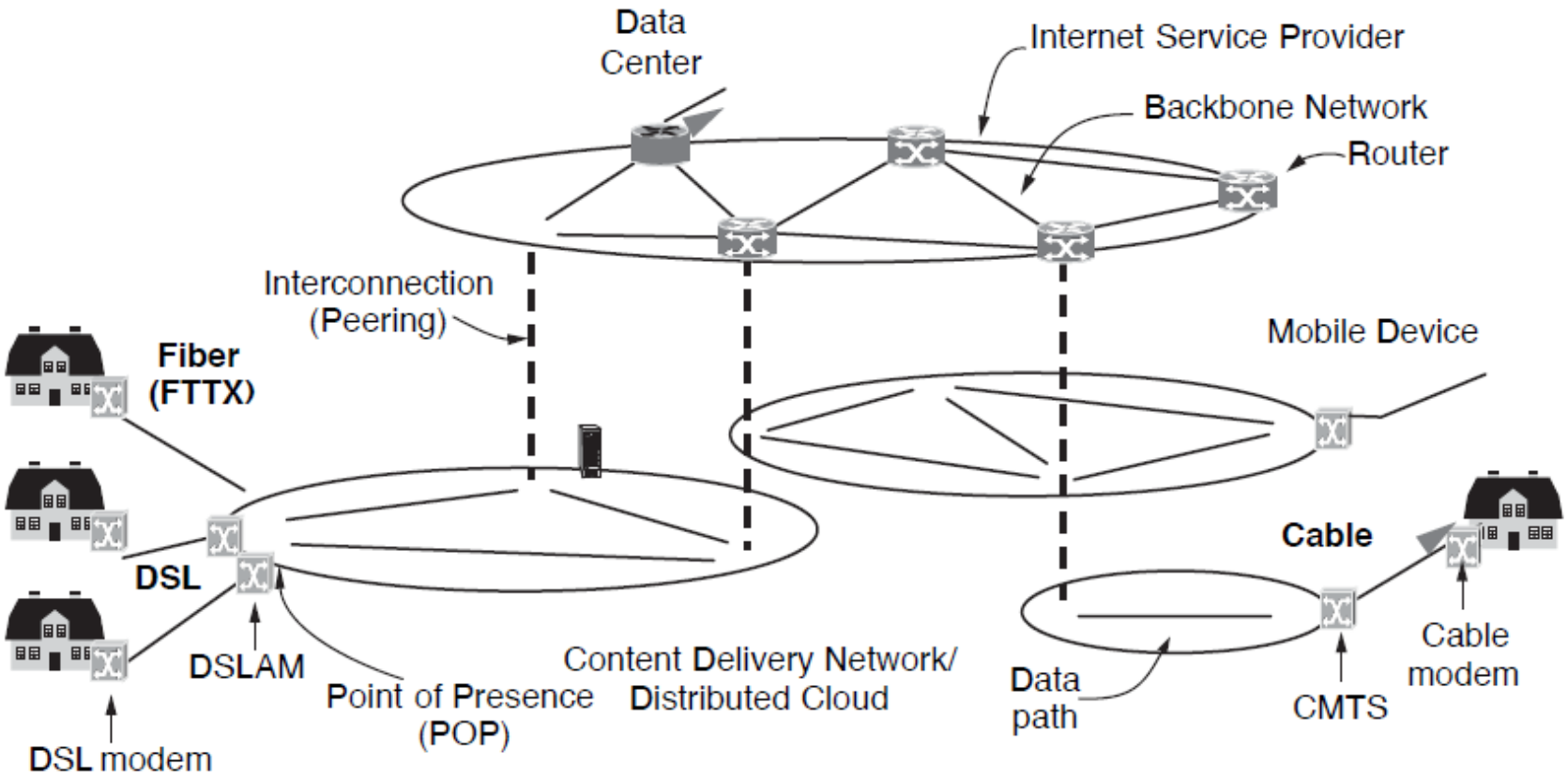


Types of Networks

- WAN (Wide Area Network)
  - A network with large area
  - A WAN can span a country, several countries or a it can have a global coverage
  - Example:
    - FLAG Network (Global)
    - See: https://www.submarinecablemap.com/

FLAG Europe-Asia (FEA)

Overview of Internet Architecture



Network Protocol Design Goals

Reliability

- Resist bit errors
- Find a path to destination

Resource Allocation

- Properly share resources
- Flow control
- Manage the quality of service

Evolvability

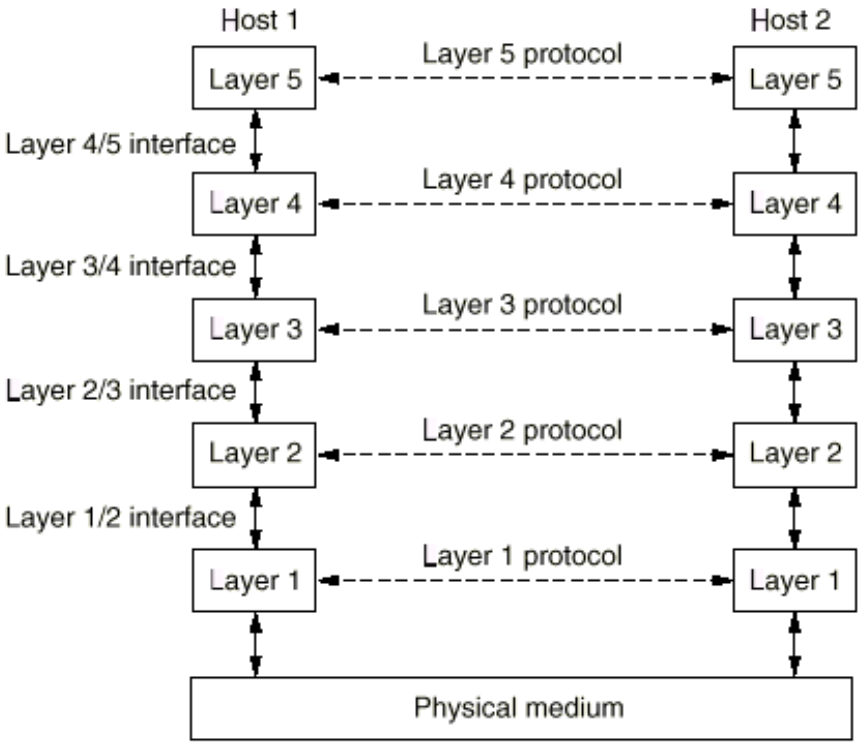
- Cope with growth

Security

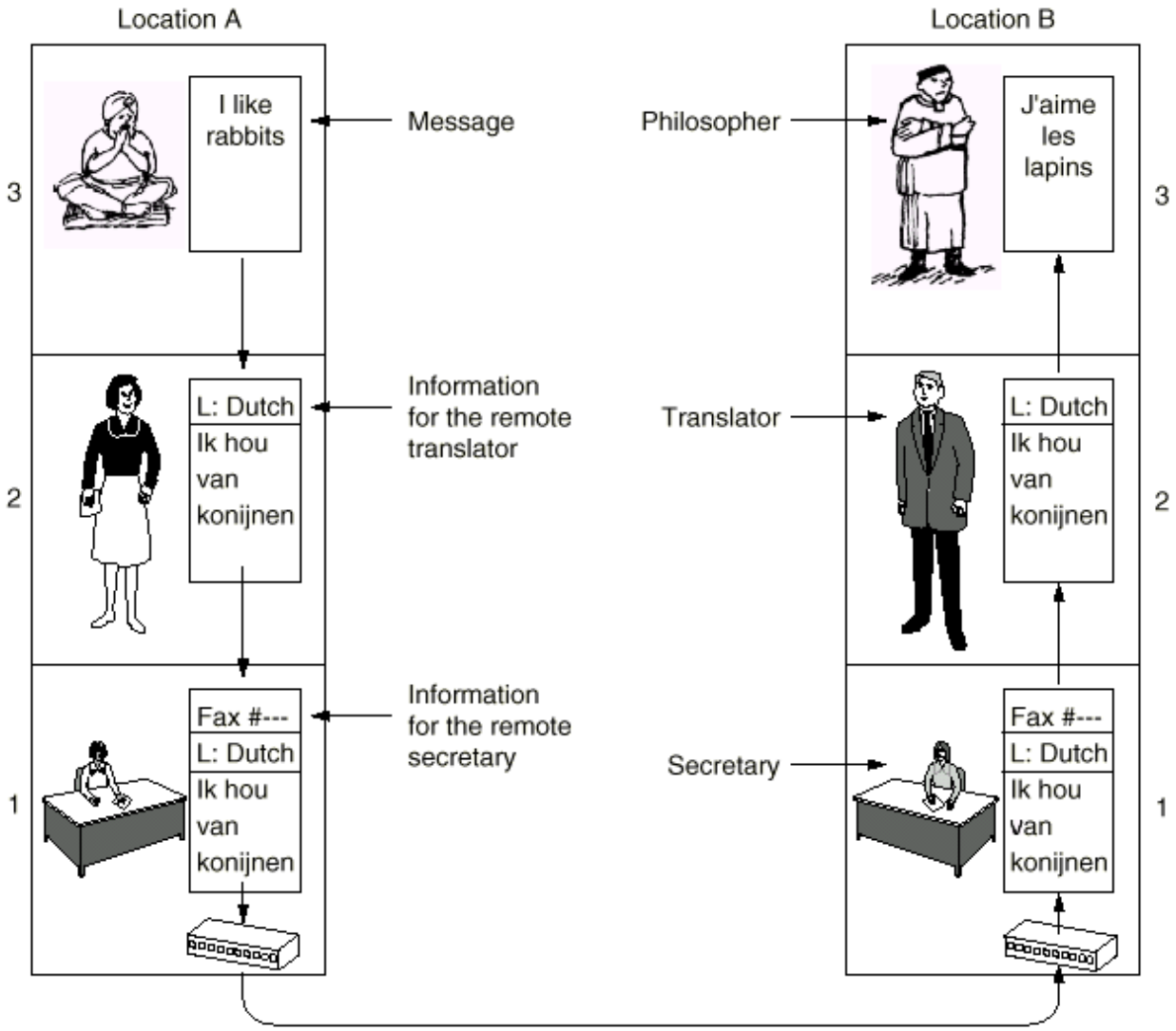
- Confidentiality
- Authentication

Network Operation Principles

- Functionality of most networks are organized as a series of layers
- Each layer is implemented by an entity
- Peers: two communicating entities (within the same layer)

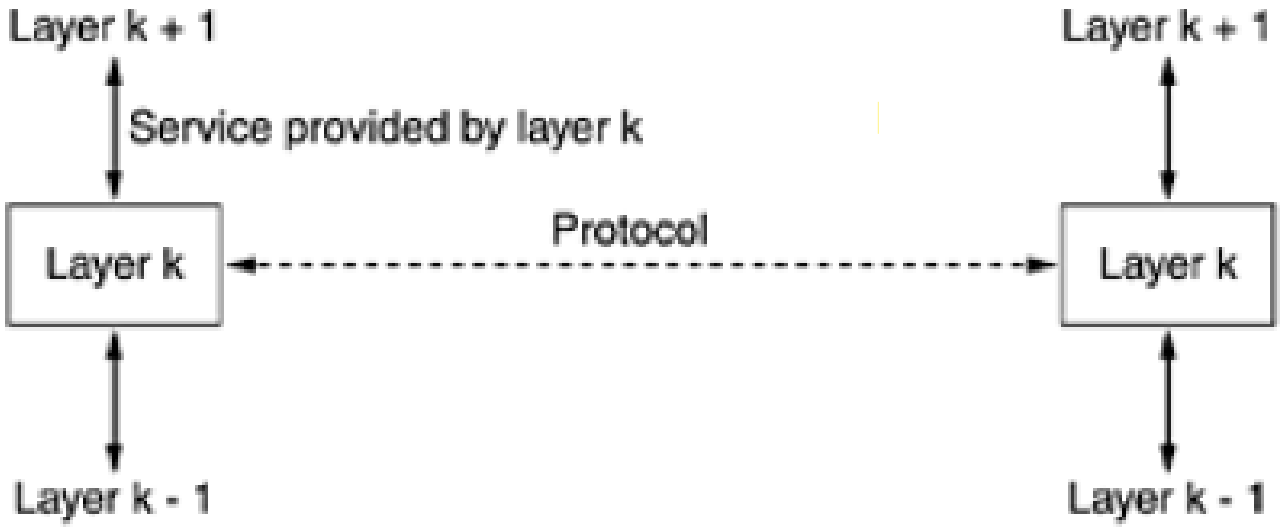


Network Operation Principles



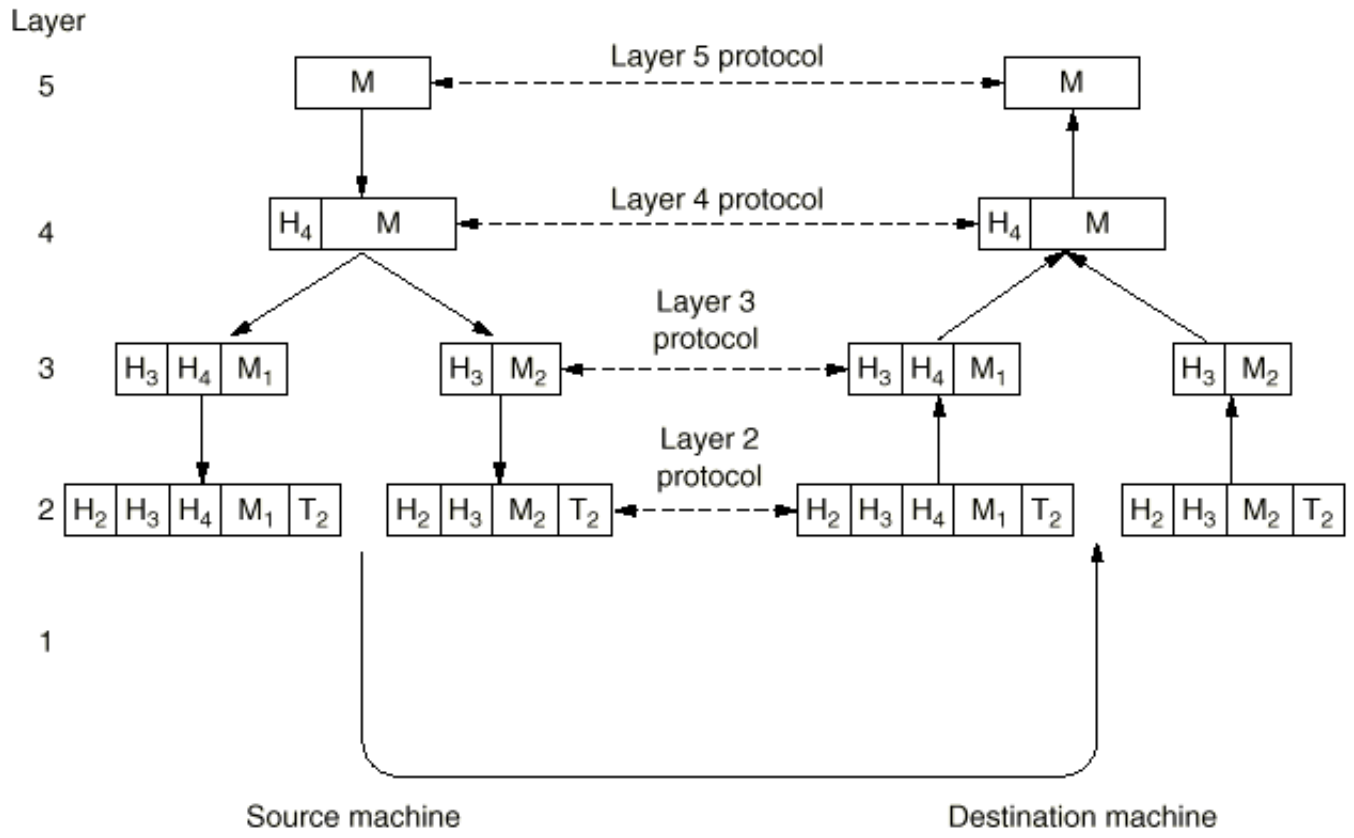
Network Software

- Protocol: An agreement on rules and procedures between two communicating parties on how the communications is to proceed.
- Service: set of primitives (operations) that a layer provides to the above layer



Network Software

- Headers/Trailers may be needed to allow implementation of a protocols



Service Categories and Reliability

- Service Categories:
  - Connection oriented
    - Phone conversation
    - Telnet / remote login / FTP
  - Connectionless
    - Postal system
    - Email
- Service Reliability
  - Reliable: never loose data
    - Acknowledgements / retransmission
  - Unreliable: data may be lost
    - No acknowledgements
    - Datagram service

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
	Unreliable connection	Digitized voice
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

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Open System Interconnect (OSI) Reference Model

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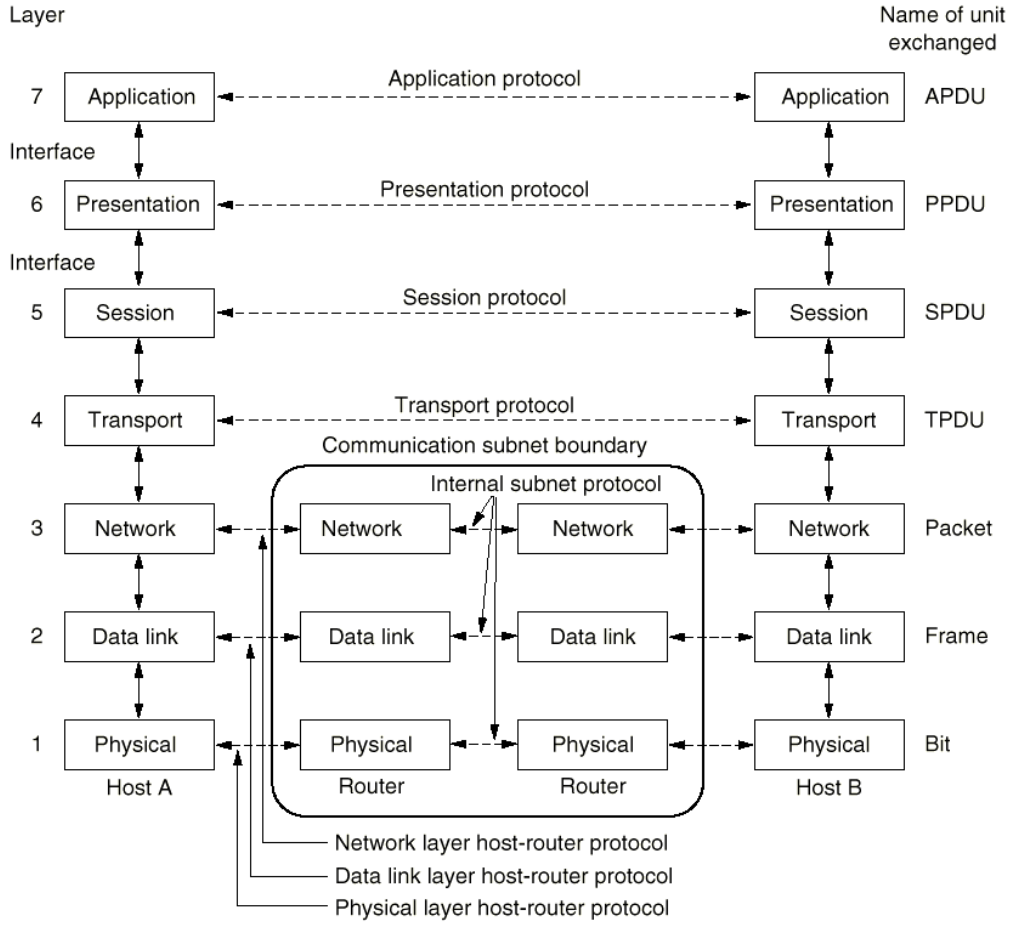
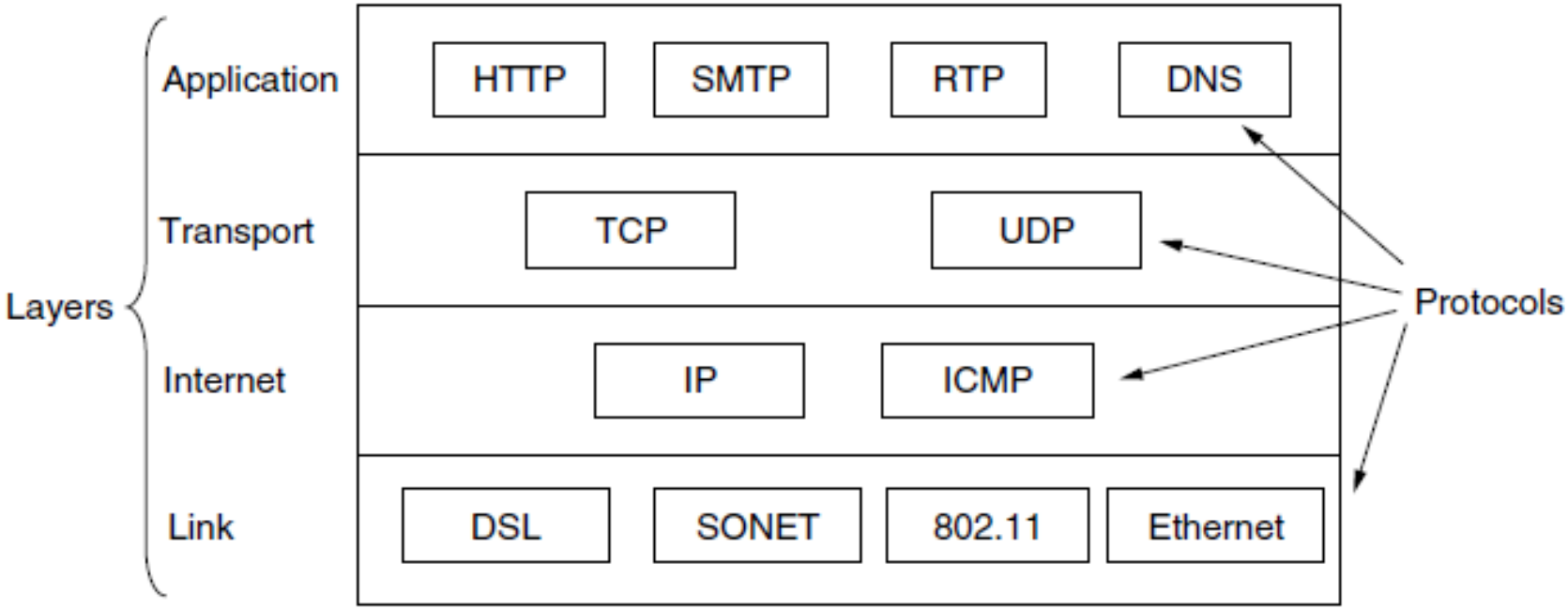


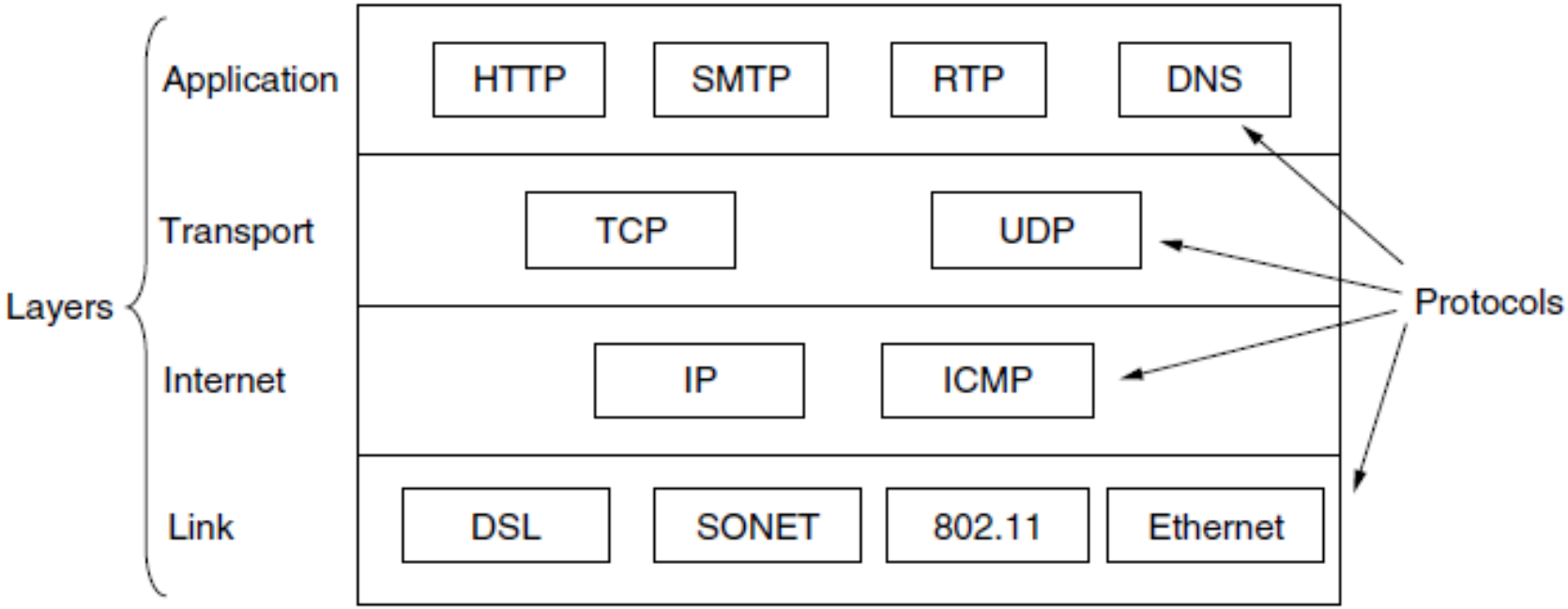
TCP/IP Reference Model

- Originated from ARPANET



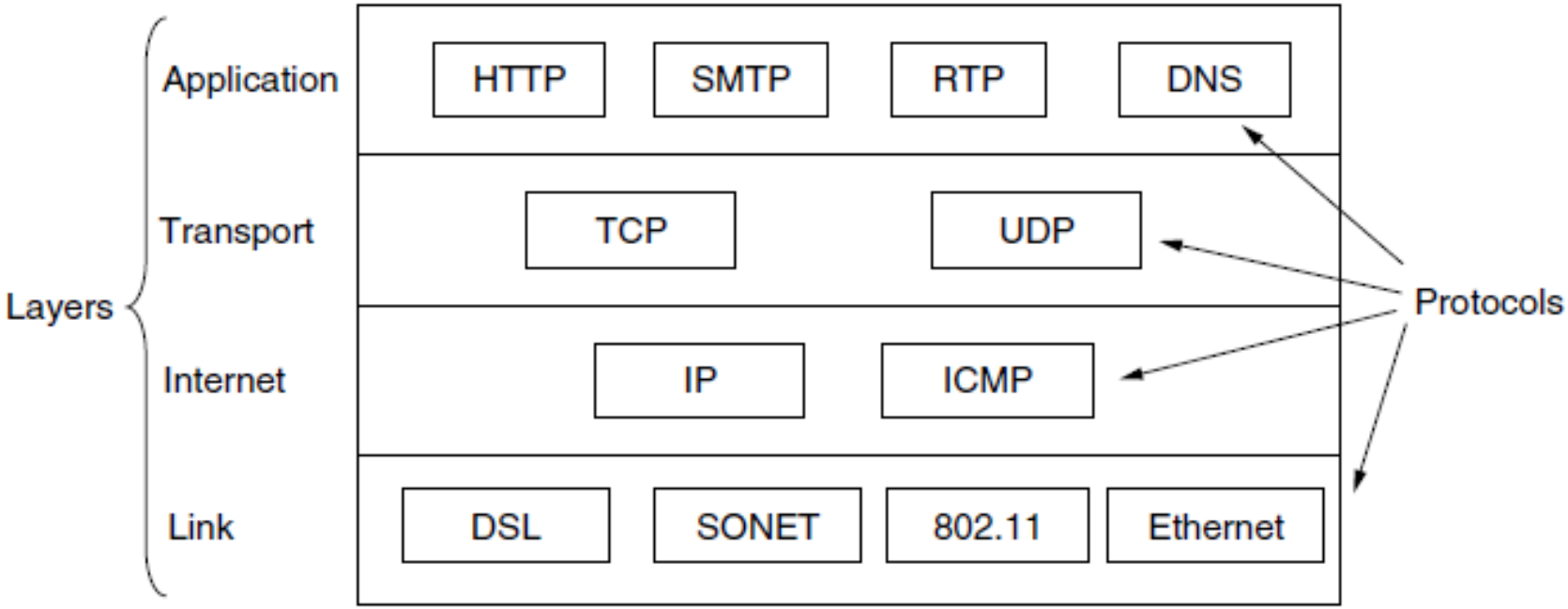
TCP/IP Reference Model

- Link Layer: Move packets from one node to the next.



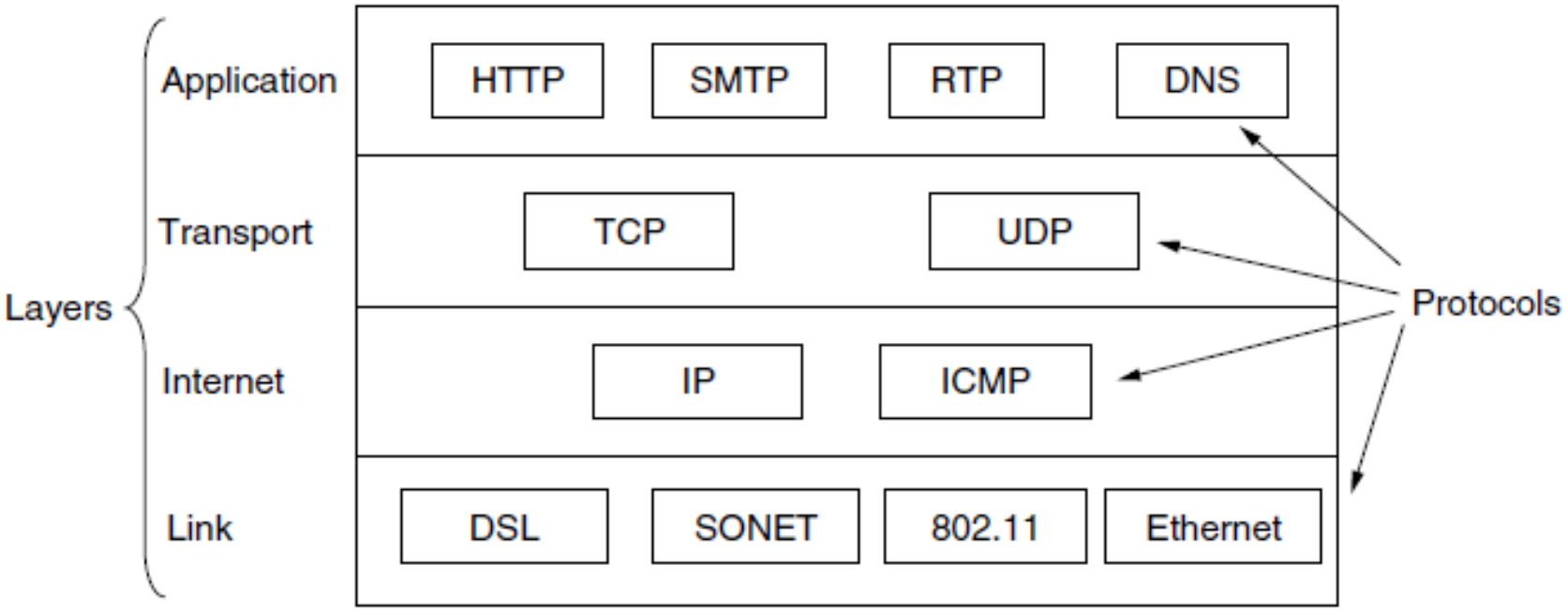
TCP/IP Reference Model

- Internet Layer: Find the best path for packets to reach their destination.



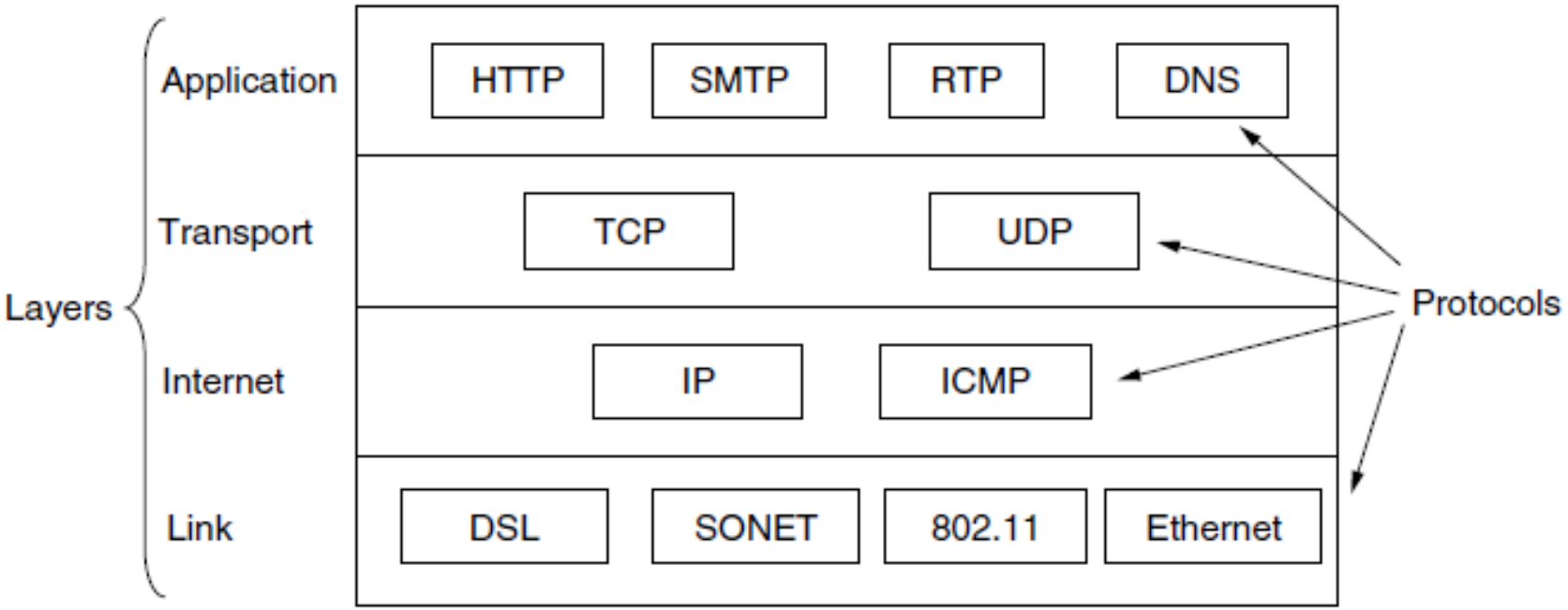
TCP/IP Reference Model

- Transport Layer: It is designed to allow peer entities on the source and destination hosts to carry on a conversation.
- Transport of data can be “Reliable” or “Un-Reliable”.



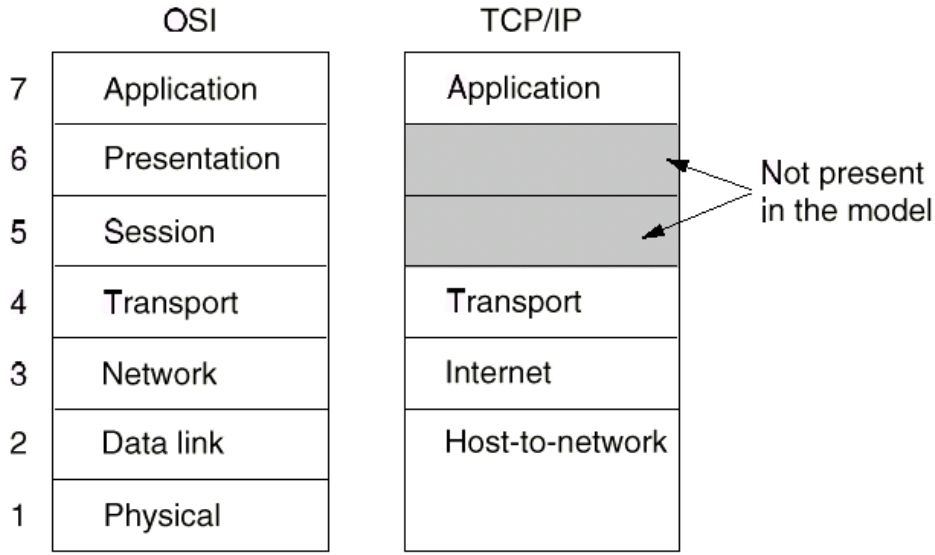
TCP/IP Reference Model

- Application Layer: E-mail, Web, Remote Connection and many other protocols.

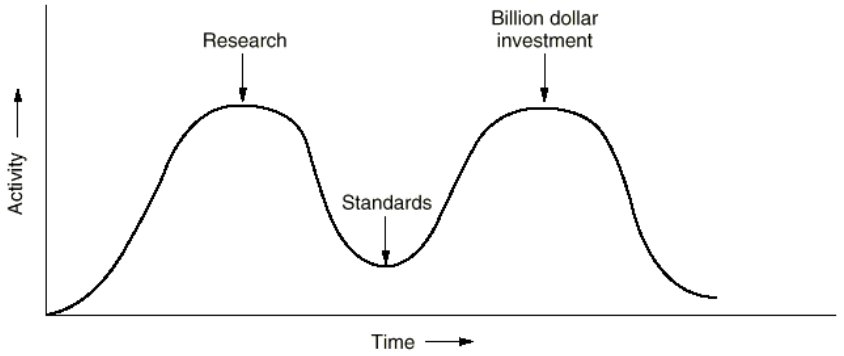


Comparing OSI and TCP/IP

- OSI:
  - Top-down design methodology
  - The concepts clearly distinguishes
    - Services (specification)
    - Interfaces
    - Protocols (implementation)
  - Network layer supports both connectionless and connection-oriented communication
  - Transport layer supports only connection-oriented service !! it's support now
- TCP / IP
  - Bottom-up approach; grew out of practice
  - Not a general protocol stack
  - Host-to-network layer is actually an interface description



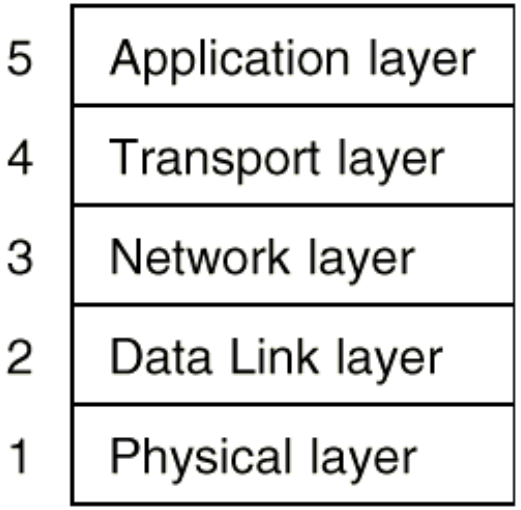
Critics on OSI model



- Bad timing.
- Bad technology.
  - Too many layers (Competition with 7 layer IBM SNA! stack)
  - Overloaded (L2, L1) and empty (L5, L6) layers
  - Too difficult to understand and implement
  - Initially ignored connectionless protocols
- Bad implementations.
  - Early implementations were huge, unwieldy, and slow.
- Bad politics
  - TCP/IP as part of UNIX, widely available, useful and open
  - OSI as a creature of telecom ministers/big telecom companies

Model of Choice

- We will follow a hybrid, 5-layer model in this course
- Data Link Layer includes Multiple Access Control (MAC) functionalities, but noting the importance of MAC, we will devote a special section to it.



Standardization: Who's Who

- Telecommunication world
  - ITU: International Telecommunication Union
- International standards
  - ISO: Int. Organization for Standardization (1946)
  - ANSI: American National Standards Institute
  - IEEE: Inst. of Electrical and Electronic Engineers
- Internet
  - IAB: Internet Activities Board
  - IETF: Internet Engineering Task Force
  - IRTF: Internet Research Task Force