# TCP/IP Protocol Suite

Marshal Miller

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# Robert W. Taylor
# (Director of Information Processing Techniques Office at ARPA 1965-1969)

*"For each of these three terminals, I had three different sets of user commands. So if I was talking online with someone at S.D.C. and I wanted to talk to someone I knew at Berkeley or M.I.T. about this, I had to get up from the S.D.C. terminal, go over and log into the other terminal and get in touch with them.*

*I said, oh, man, it's obvious what to do: If you have these three terminals, there ought to be one terminal that goes anywhere you want to go where you have interactive computing. That idea is the ARPANET."*

– New York Times Interview: December 20, 1999

# Overview

- Terminology
- History
- Technical Details:
  - TCP
  - IP
  - Related Protocols
- Physical Media
- Social Implications
- Economic Impact

# Terminology

- Protocol
  - A set of rules outlining the format to be used for communication between systems
- Domain Name System (DNS)
  - Converts an Internet domain into an IP address
- Router
  - A computer or software package used in packet switched networks to look at the source and destination addresses, and decide where to send the packets
- Uniform Resource Indicators
  - Uniform Resource Location (URL)
    - How to find the resource: HTTP, FTP, Telnet
  - Uniform Resource Names (URN)
    - What the resource is:  Not as common as URL

# History: Pre-TCP/IP

- Networks existed and information could be transferred within
- Because of differences in network implementation communication between networks different for each application
- Need for unification in protocols connecting networks

# History: TCP/IP Development

- 1968: Plans develop for using Interface Message Processors (IMPs)
- Dec. 5, 1969: 4 IMPs connected to form ARPANET (UCLA, Stanford, UCSB, Utah)
- Early 70's: DARPA begins work on new networking methods.
- 1972: ARPANET expands to 15 nodes and is showcased at the International Conference on Computer Communications

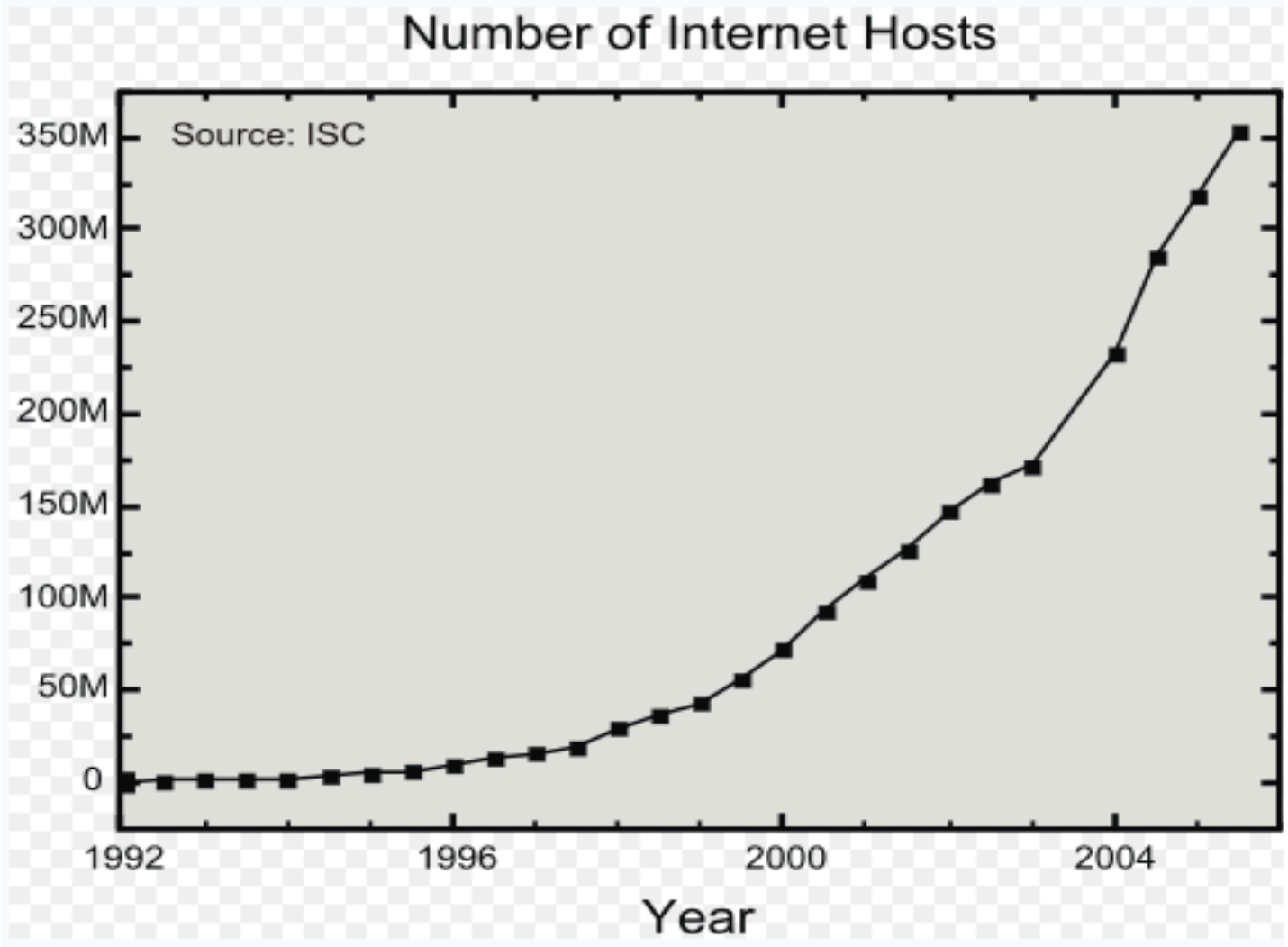
# History: TCP/IP Development

- 1973: Robert Kahn and Vinton Cerf begin development of new protocol
  - Implement common internetwork protocol
  - Shifts burden of reliability from network to host
  - Facilitate adding more networks with different structures
- 1973: 1st out of country connection made to Norway (later converted to TCP/IP in 1982)
- 1974: Kahn and Cerf refer to creating a network of networks as internetting
- 1977: First demonstration of TCP/IP

# History: Expansion of TCP/IP

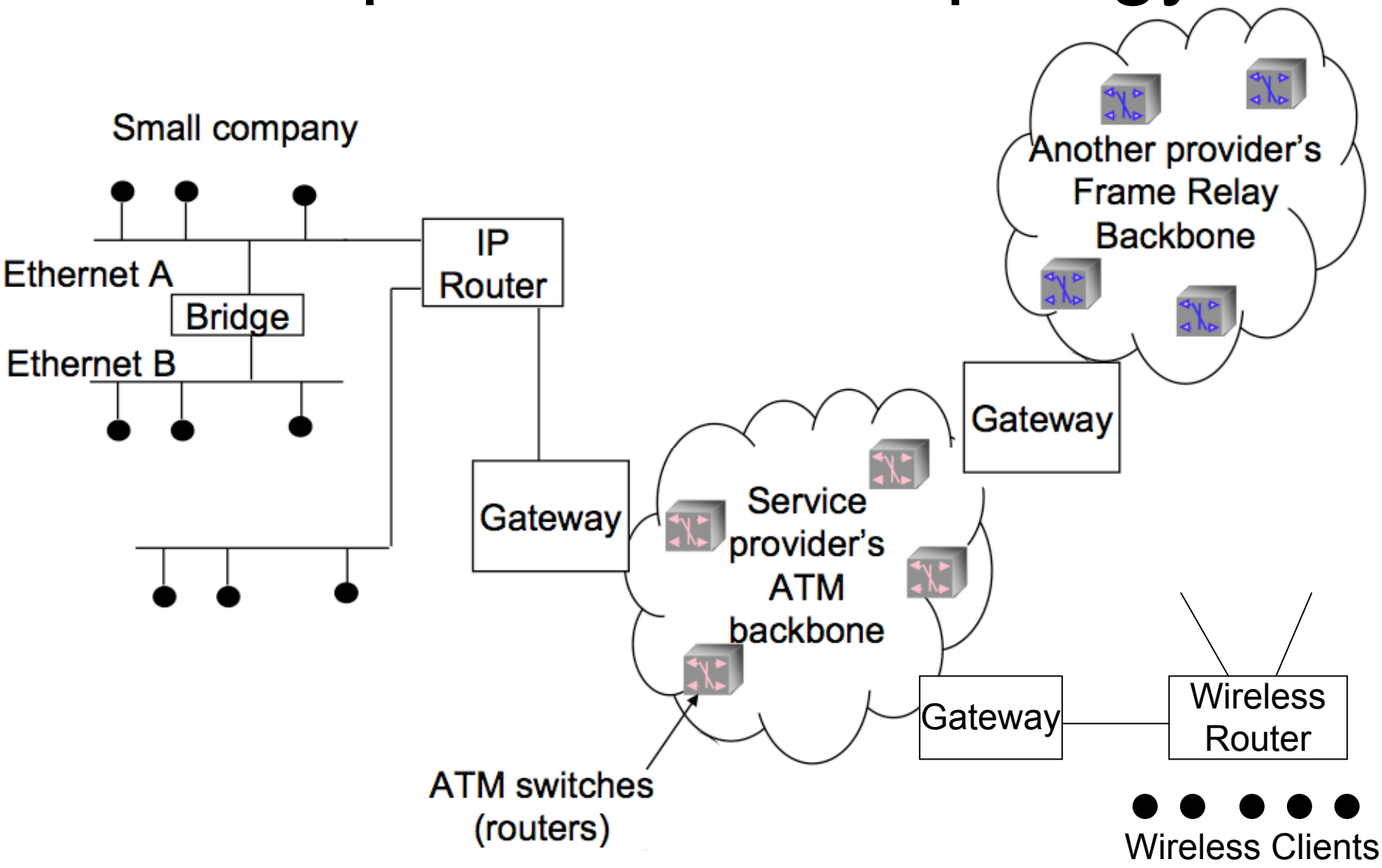
- January 1, 1983: TCP/IP becomes the only approved protocol on ARPANET
- 1984: TCP/IP becomes military standard
- 1986: ARPANET merges with NSFNET to form beginnings of the Internet
  - The Internet refers to the collection of networks using TCP/IP
- 1989: Japan connects to NSFNET followed by Singapore in 1990 and Thailand in 1992 and China in 1994

# Growth

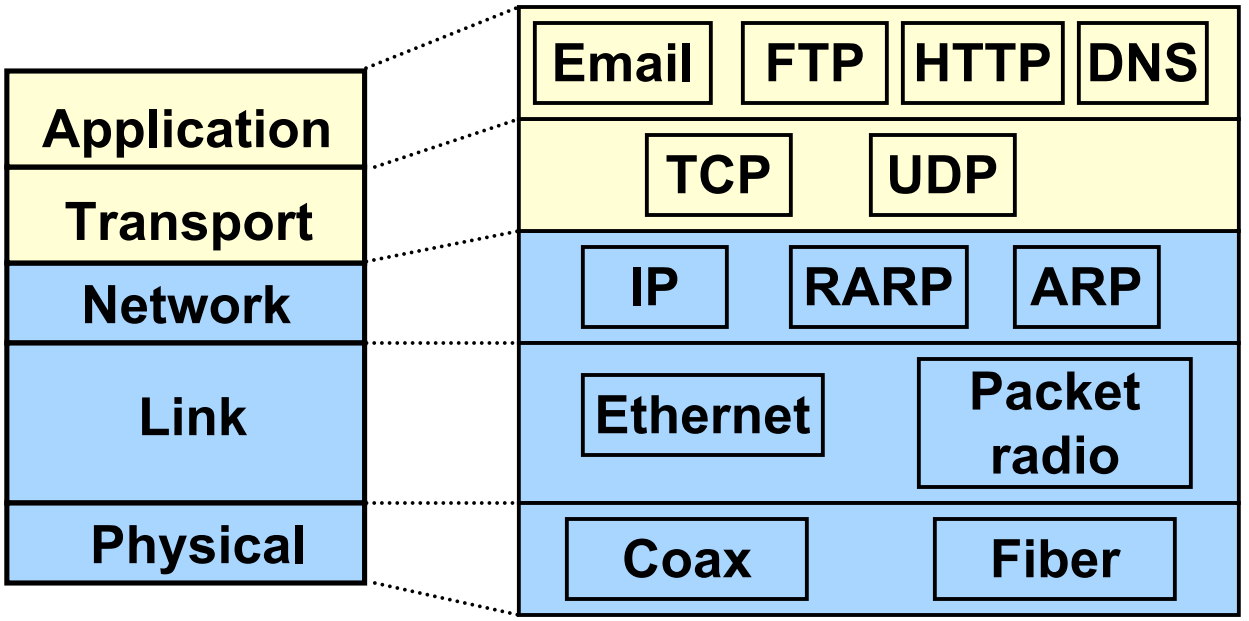



Source: http://www.isc.org/index.pl?/ops/ds/host-count-history.php

# Example Network Topology

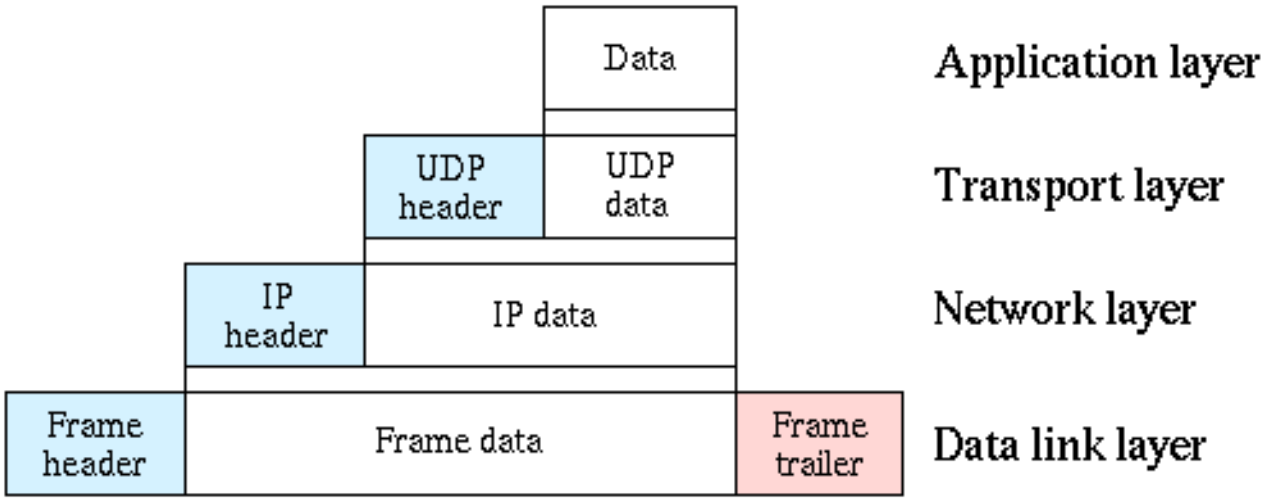


# Network Layers



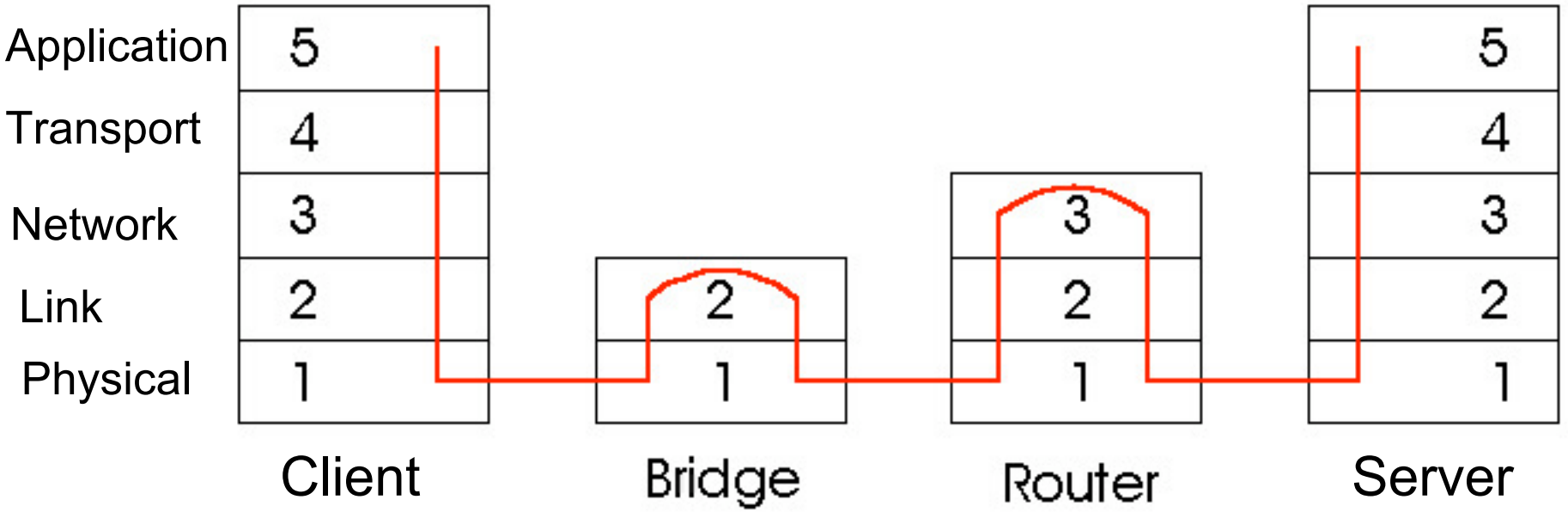

Borrowed from Lecture by Prof. Dina Katabi, MIT

# Layers of Encapsulation in a Modern Network Architecture




(http://en.wikipedia.org/wiki/Image:UDP_encapsulation.png)

# Example of Transmission through the Network Layers



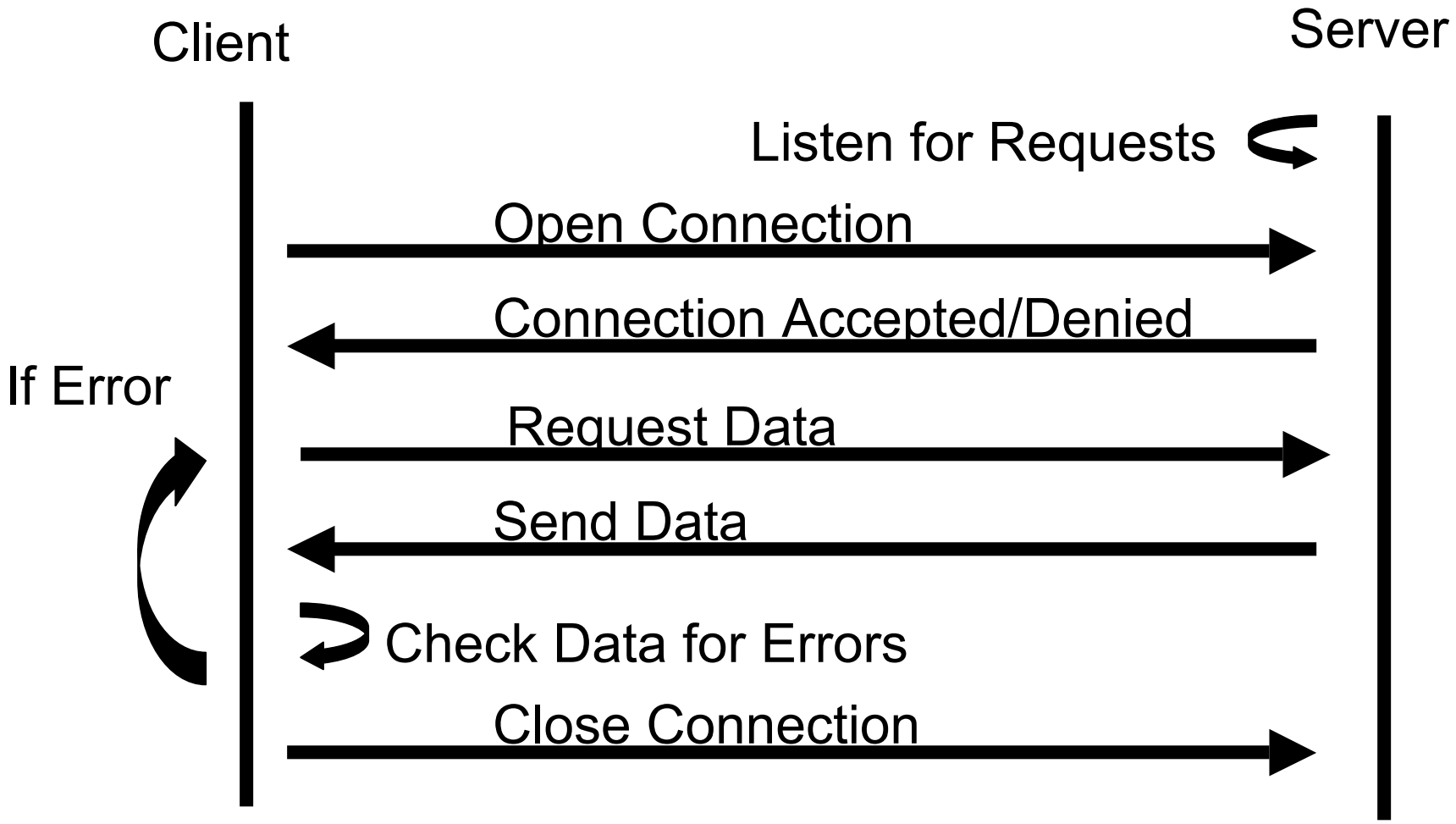
# Application Layer

- HTTP
  - Provides an interface for transmitting web pages and other files
- DNS
  - Maps www.google.com to an IP (I.e. 94.94.94.94)
- DHCP
  - Automatically obtains an IP for a host
- IMAP, POP, SMTP
  - Email interfaces
- FTP
  - File Transfer Protocol
- AIM, MSN Messenger
- BitTorrent, Gnutella

# Transmission Control Protocol (TCP)

- Features
  - Connection establishment/close
  - Differentiates between various applications using the network connection
  - Error checking of data
  - Guaranteed packet delivery (eventually)
  - Breaks data into pieces at transmitter and reassembles at receiver
  - Only handled by the sender and receiver

# Example TCP Session



# TCP Data

**TCP header:**

| 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Source Port | | | | | | | | | | | | | | | | Destination Port | | | | | | | | | | | | | | | |
| Sequence Number | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Acknowledgment Number | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data Offset | | | | reserved | | | | ECN | | | Control Bits | | | | | Window | | | | | | | | | | | | | | | |
| Checksum | | | | | | | | | | | | | | | | Urgent Pointer | | | | | | | | | | | | | | | |
| Options and padding ::: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data ::: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

http://www.networksorcery.com/enp/protocol/tcp.htm

- Port Number indicates the source/destination process on a host
  - Source port is arbitrary
  - Destination port is based on service
    - I.e Port 25=Email, Port 80=http

# TCP Error Correction

- Packets can be lost by:
  - Collision
  - Physical Media Failure
  - Time to Live (TTL) reaches 0
- TCP expects an acknowledgement packet for every packet sent out
- Guaranteed Packet Delivery algorithms were designed to handle data congestion.
- Response to congestion is two-fold:
  - Breaking data into smaller pieces
  - Waiting a long time to retransmit data
- Wireless networks, which have fading, are not optimally dealt with

# TCP/UDP Comparison

- Features of UDP
  - Connectionless
  - Does NOT guarantee delivery
  - Smaller packet sizes
  - Faster (less overhead)

TCP

- Data integrity is most important
  - HTTP
  - FTP
  - Telnet
  - SMTP, POP, IMAP
  - WINS, NFS (file transfer)

UDP

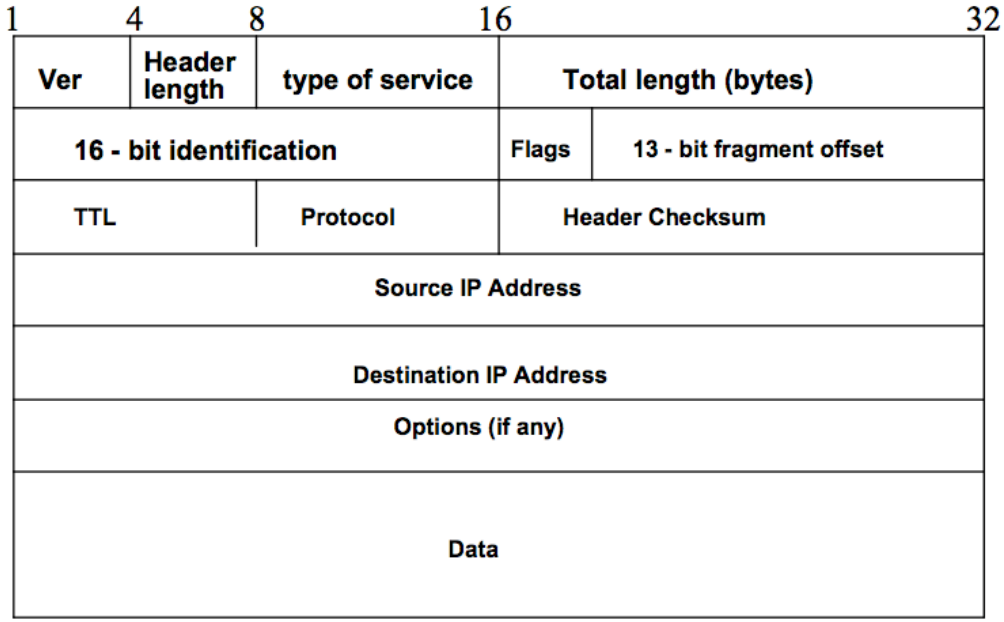
- Data throughput is most important
  - VoIP
  - Videoconferencing
  - Pings
  - DNS
  - Time services

# Internet Protocol (IP)

- Provides addressing of sender and receiver on the internet
- Protocol defines how to route messages through a network
  - Packetized
  - Not continuous
  - Delivery not guaranteed
- Dealt with at every router on the way from sender to receiver

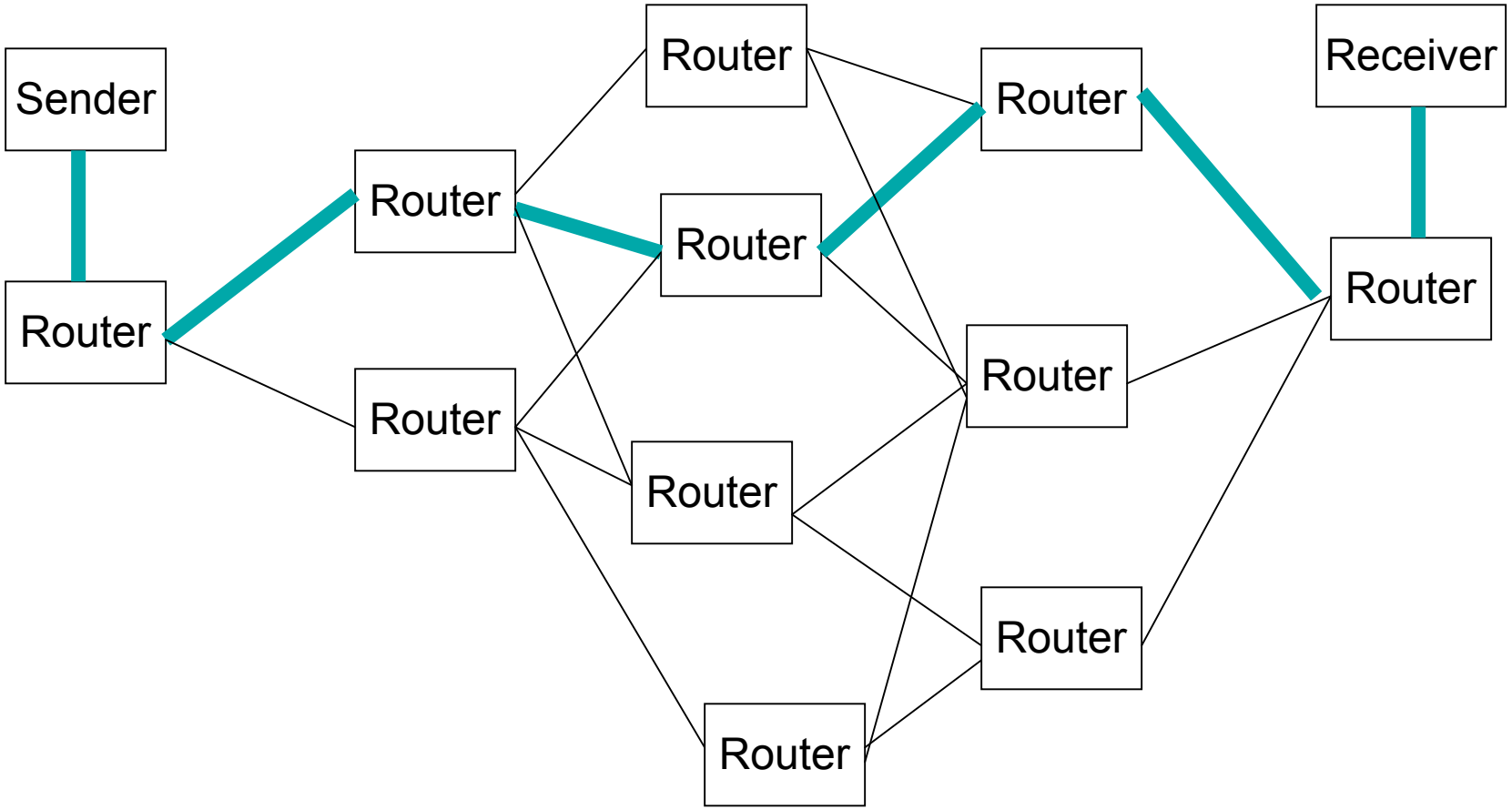
# IP Data

- Addresses of the form: 128.128.101.101 (I.e. 4 8-bit Numbers)

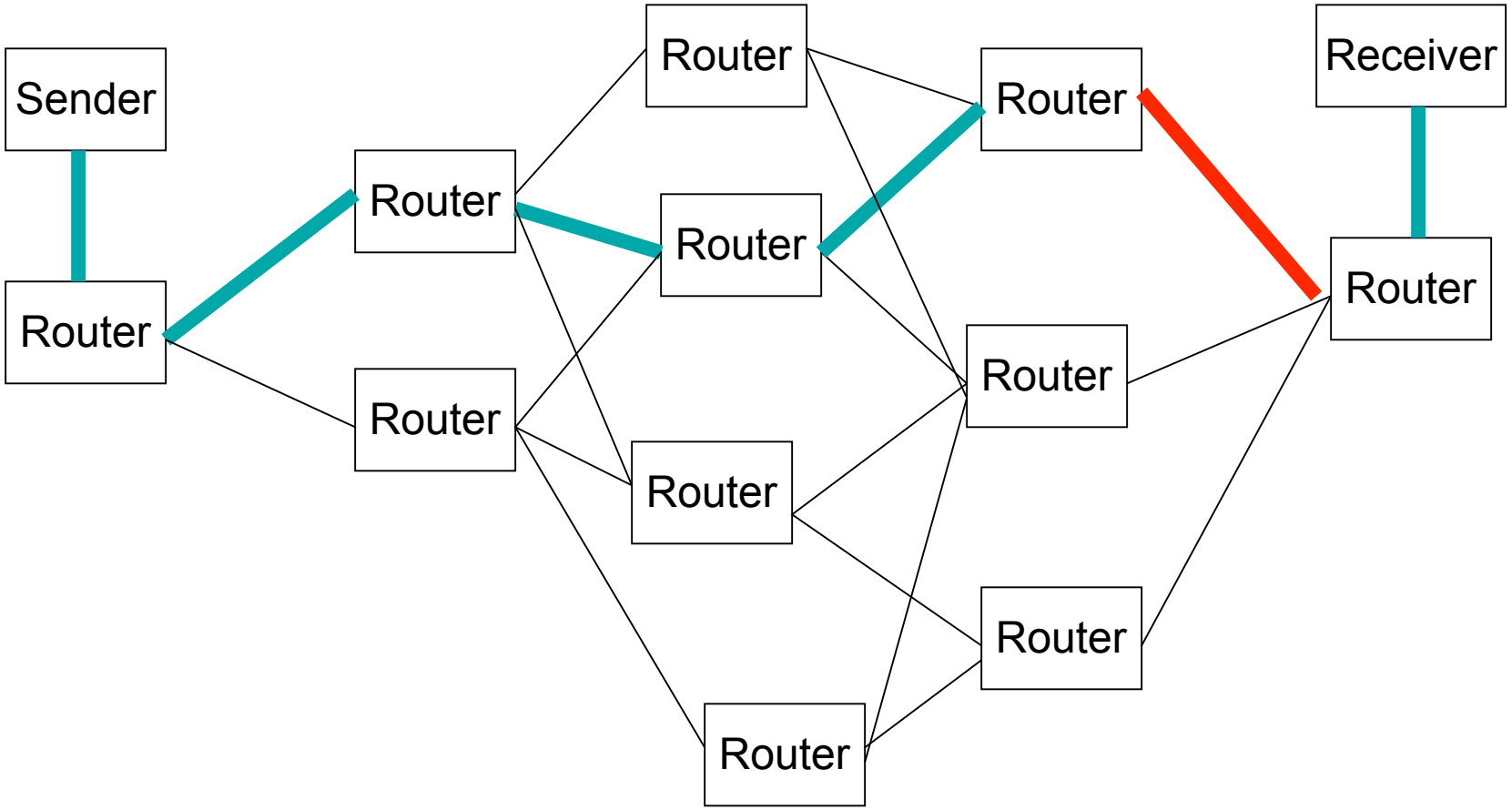



Eyian Modiano, MIT OCW

# IP Routing


Sender
Router
Router
Router
Router
Router
Router
Router
Router
Router
Router
Receiver

# IP Routing


Sender
Router
Router
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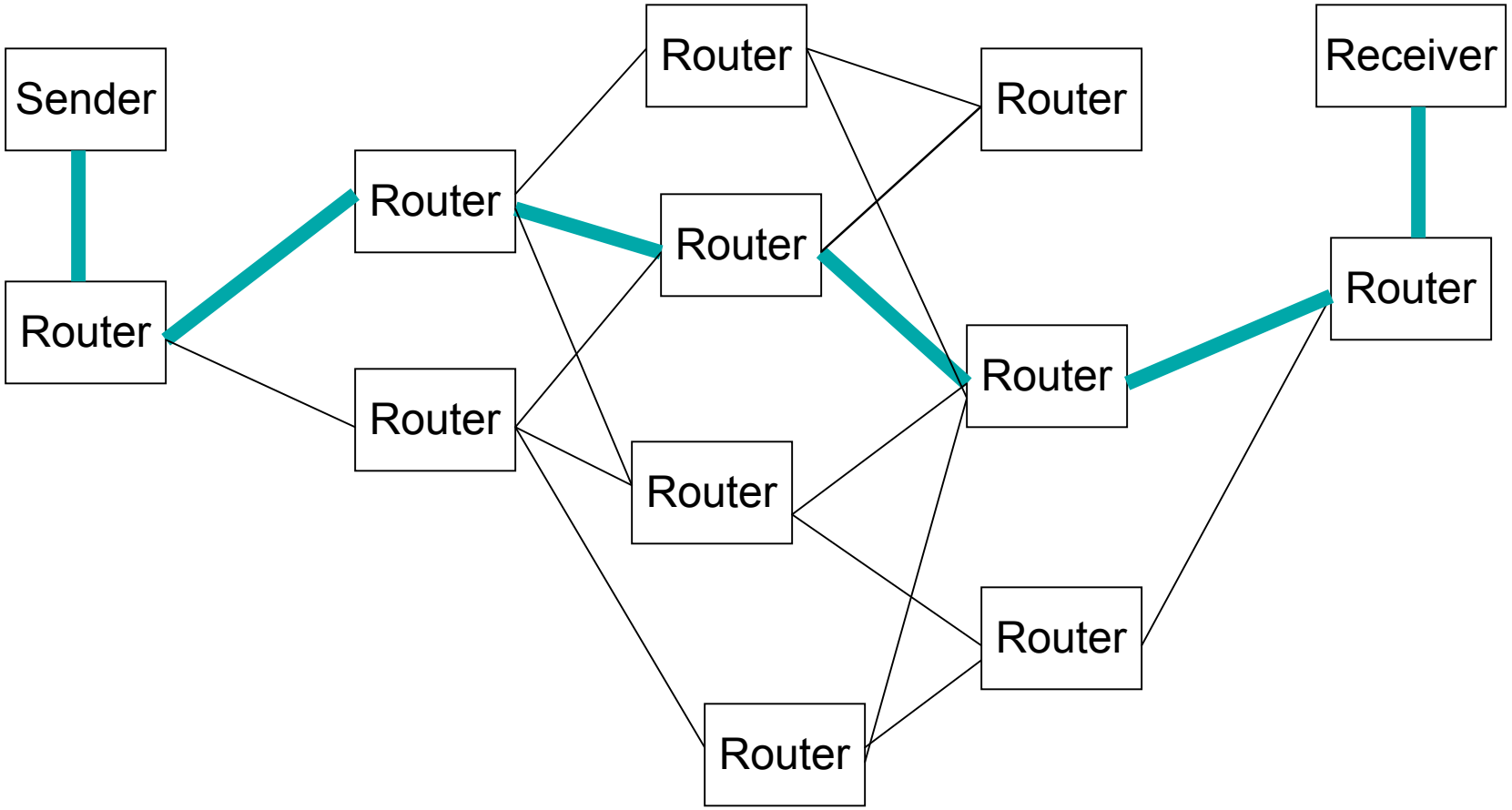
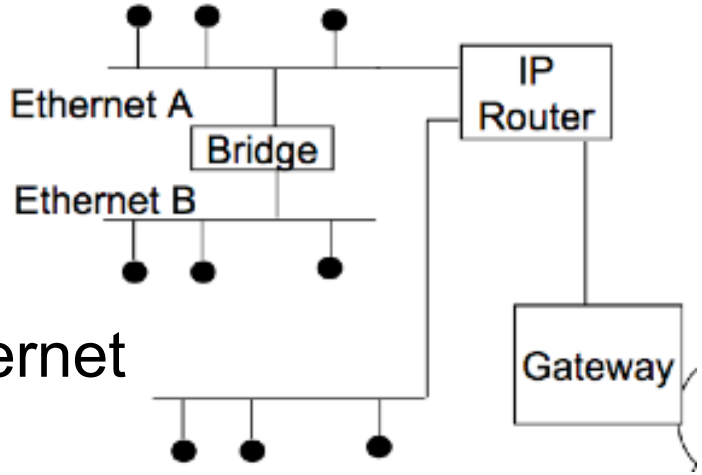
Receiver

# IP Routing

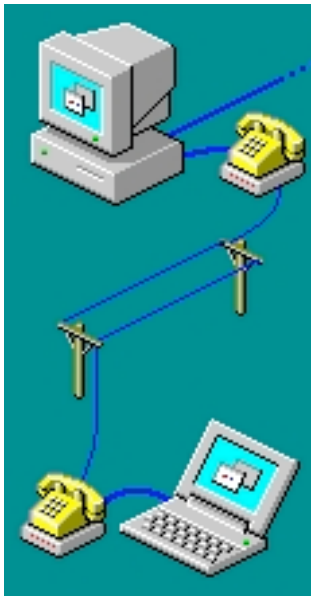

Sender
Router
Router
Router
Router
Router
Router
Router
Router
Router
Router
Receiver
Router

# Link Layer

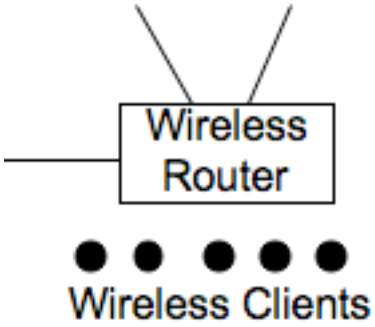



Ethernet

PPP



Microsoft Windows




Wi-Fi

Long Haul Systems: ATM, 100G Ethernet

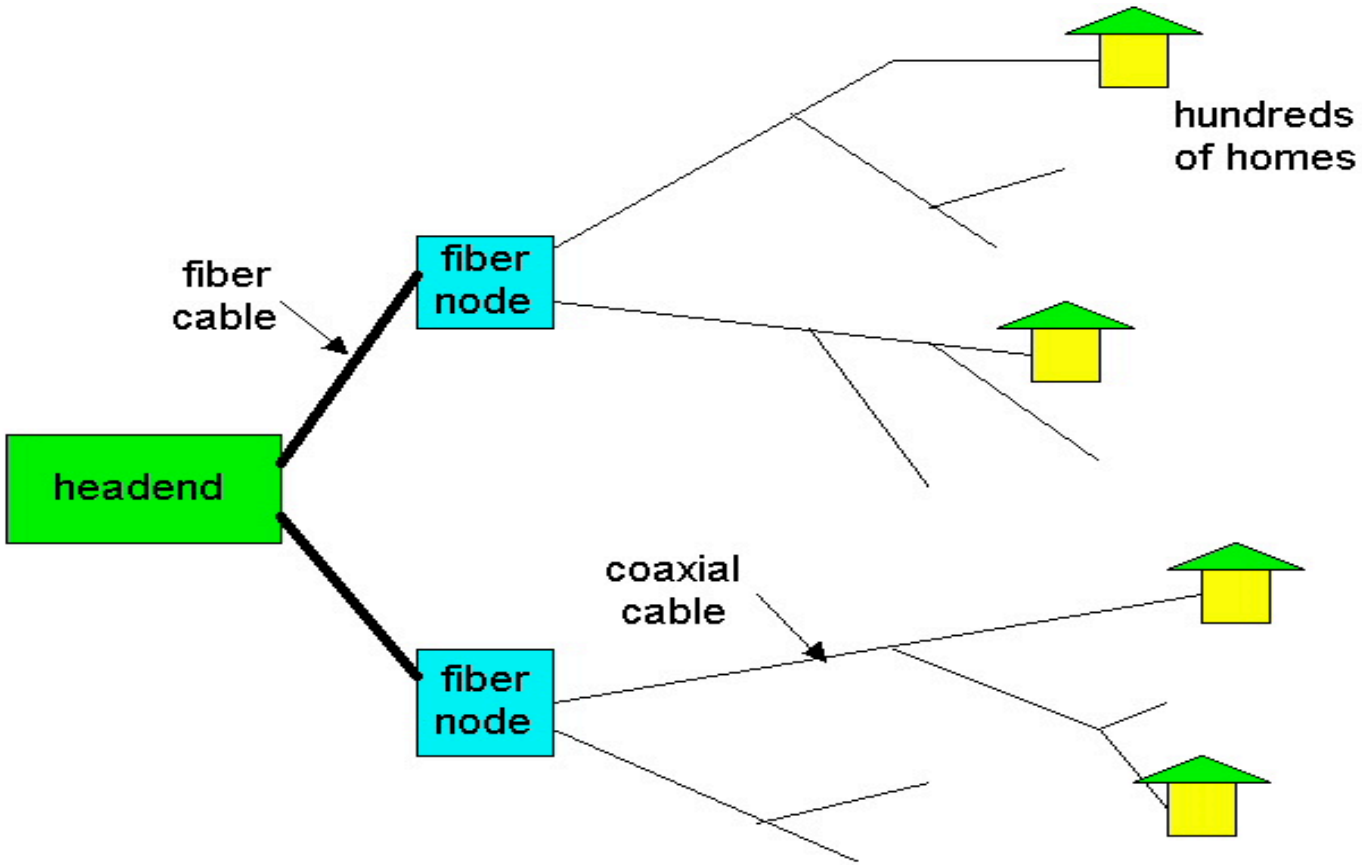
# Physical Media

| Media | Bit Rate | Dist. (m) | Cost (per station) | Misc. |
|---|---|---|---|---|
| Twisted Pair | 16-155Mbps | 100 | $125 | Used in telephone network predating Internet, so wires already in place |
| UTP | 4-100Mbps | 100 | $90 | |
| Coax | 10Mbps | 500 | $50 | Cable TV |
| Fiber | 100Mbps-2Gbps | 2000 | $250 | Preferred for long distance |
| Radio | 56Kbps-54Mbps | 10 - 50000 | $50-$15000 | No physical wire |
| Satellite | 100Mbps | 36,000 km (satellite to earth) | | 239.6 ms delay |



http://www.comptechdoc.org/

# Network Overview



# Economic

- Late 1980's many Internet Service Providers appear (ISPs)
  - PSINet, UUNET, Netcom, Portal
- Low cost goods available on the Internet because of reduced overhead costs
- Website advertising

# Social

- Communication
  - E-mail
  - Instant Messaging
  - Telephone/Video Conferencing
- Information Access
  - Google
  - Wikipedia

The End

# TCP/IP Protocols

- FTP - File Transport Protocol at the application layer.
- Telnet - Remote session at the application layer.
- SMTP - Simple Mail Transport Protocol at the application layer.
- DHCP - Dynamic host configuration protocol is used to assign IP addresses dynamically to network cards. It works at the application layer.
- TCP - Transport Control protocol is a connection oriented reliable protocol working at the transport layer.
- UDP - User Datagram Protocol is a connection less unreliable protocol working at the transport layer.
- ICMP - Internet Control Message Protocol is used to perform network error reporting and status. It works at the transport layer.
- IGMP - Internet Group Management Protocol is used to manage multicast groups and it works at the transport layer.
- IP - Internet Protocol is used for software addressing of computers and works at the network layer.
- ARP - Address Resolution Protocol is used to resolve the hardware address of a card to package the ethernet data. It works at the network layer.
- RARP - Reverse Address Resolution Protocol used for disk less computers to determine their IP address using the network. It works at the network layer.

# Trace of Route to www.state.sd.us

- traceroute to www.state.sd.us (164.154.226.12), 64 hops max, 40 byte packets
- 1 b-wireless-gw (128.32.38.1)
- 2 g3-8.inr-202-reccev.berkeley.edu (128.32.255.169)
- 3 gige4-0-0.inr-666-doecev.berkeley.edu (128.32.0.249)
- 4 inet-lax-isp--ucb.cenic.net (137.164.24.141
- 5 f5.ba01.b003070-1.sfo01.atlas.cogentco.com (38.112.6.225)
- 6 g1-5-102.core01.sfo01.atlas.cogentco.com (38.112.38.253)
- 7 p15-0.core02.sfo01.atlas.cogentco.com (66.28.4.70)
- 8 p10-0.core01.sjc03.atlas.cogentco.com (66.28.4.133)
- 9 pos4-3.br5.sac1.alter.net (204.255.174.209)
- 10 0.so-2-1-0.xl1.sac1.alter.net (152.63.52.226)
- 11 152.63.65.81 (152.63.65.81)
- 12 pos6-0.gw2.msp3.alter.net (152.63.66.57)
- 13 sdncomm-gw.customer.alter.net (65.206.183.214)
- 14 66-231-27-158.sdn-pierre-ddn.sdnet.net (66.231.27.158) 131.426 m
- 15 ddn-pierre-to-internet.core.rt.k12.sd.us (206.176.106.209)
- 16 ddn-state-network-to-pierre.core.rt.k12.sd.us (206.176.70.106)