# History of the Internet

# Pre-Internet: Telephone

- Basic problem: How to modulate voice onto electrical signals
- Reis (1961 Germany): "Das Pferd frisst keinen Gurkensalat" (The horse does not eat cucumber salad).
- Elisha Gray patents first method for encoding (1876)
- Bell makes first call  "Mr. Watson, come here, I want to see you.“ (1876)

# Pre-Internet: Circuit-Switching

- In January 1878, the first telephone switch went into operation in New Haven Connecticut
- Establish a complete circuit every time there's a communication
- Still the case in cellular!
  - Circuit is established to "packet gateway"

# Issues w/ Circuit Switching

- ?

# Issues w/ Circuit Switching

- Large setup cost
  - Switching costs all along circuit
- Contention
  - Only X links, what if X+1 want to use?
- Inefficient
  - Circuit established even if not in use
- Fragile
  - Intermediary links go down circuit is broken

USAF wanted their networks to survive nuclear strikes… circuits would not.

# Pre-internet: Packetization

The solution focused on three big ideas:

1. use of a decentralized network with multiple paths between any two points
2. dividing user messages into message blocks, later called **packets**
3. delivery of these messages by store and forward switching.

# Pre-Internet: Why Packetization?

- Efficiency
  - Lines only used when trafficked
- Handles contention
  - Queue packets
- Robust
  - Routes can change

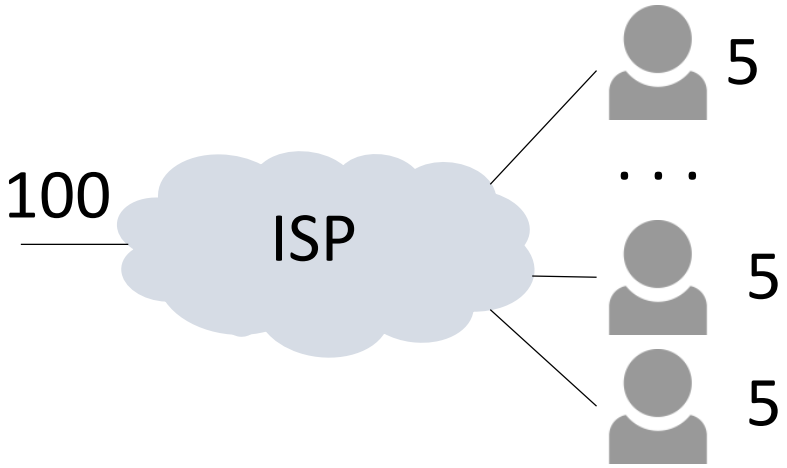
# Efficiency: Statistical Multiplexing

- Sharing of network bandwidth between users according to the statistics of their demand
  - (Multiplexing just means sharing)
  - Useful because users are mostly idle and their traffic is bursty

- Key question:
  - How much does it help?

# Efficiency: Statistical Multiplexing (2)

- Example: Users in an ISP network
  - Network has 100 Mbps (units of bandwidth)
  - Each user subscribes to 5 Mbps, for videos
  - But a user is active only 50% of the time …



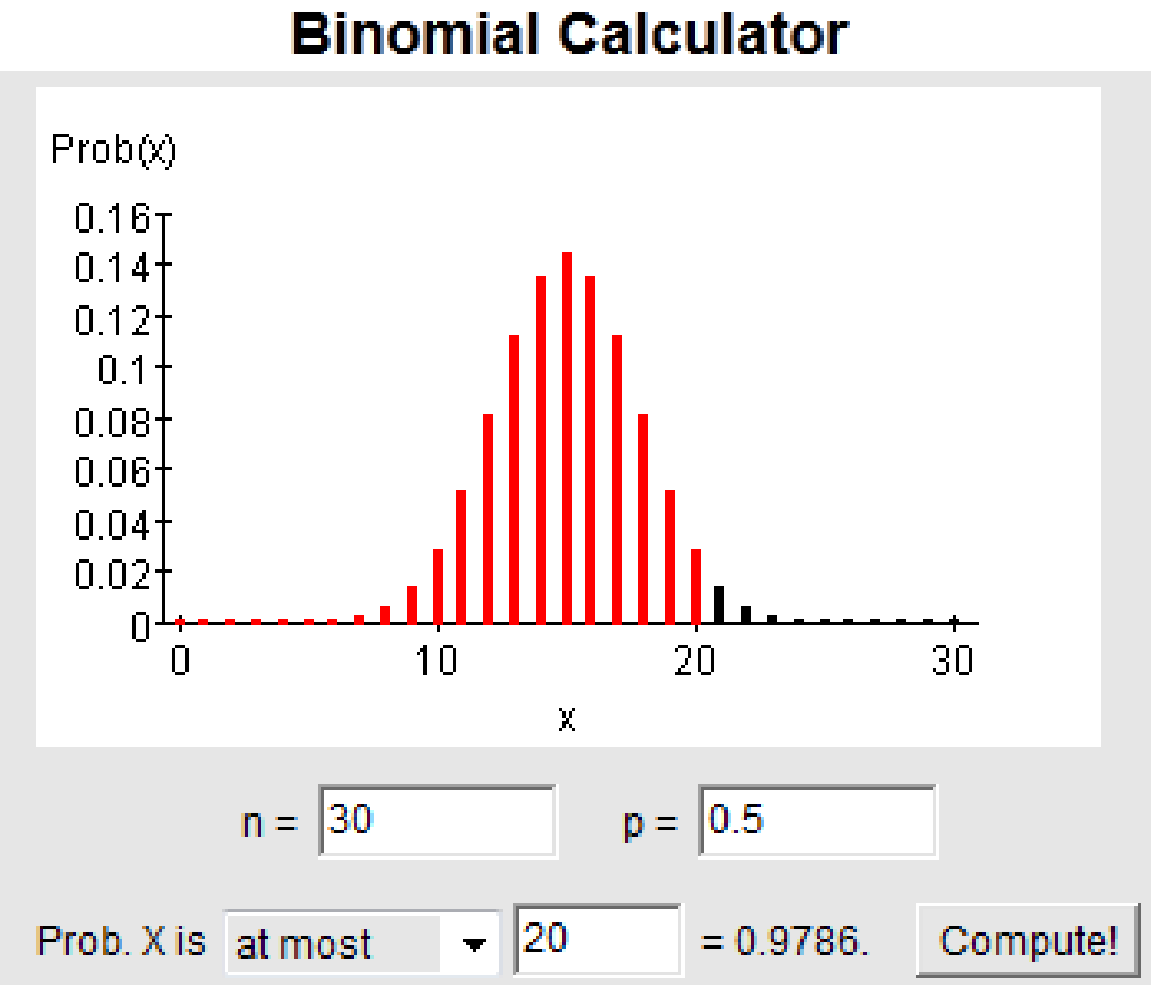

- How many users can the ISP support?
  - With dedicated bandwidth for each user:
  - Probability all bandwidth is used: (assuming independent users)

# Efficiency: Statistical Multiplexing (3)

- With 30 independent users, still unlikely (2% chance) to need more than 100 Mbps!
  - Binomial probabilities

→Can serve more users with the same size network

- <u>Statistical multiplexing gain</u> is 30/20 or 1.5X
- But may get unlucky; users will have degraded service



# Pre-Internet: Networks

Started building individual packet networks at different institutions:

- Octopus Network
  - 4 Machines at the Lawrence Livermore National Lab
- ALOHAnet
  - Wireless packets at University of Hawaii
- CYCLADES
  - French network exploring network responsibilities
- ARPANET
  - First packet network, a few universities online

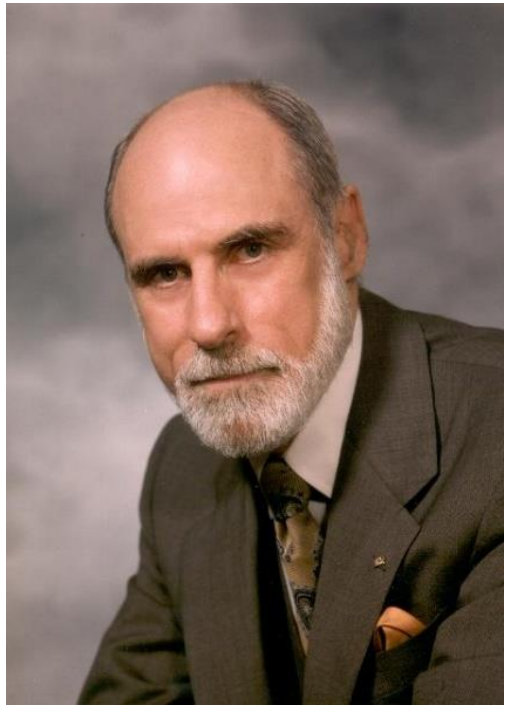
# The Beginning – ARPANET

- ARPANET by U.S. DoD was the precursor to the Internet
  - Motivated for resource sharing
  - Launched with 4 nodes in 1969, grew to hundreds
  - First “killer app” was email

# ARPANET

- In the early ARPANET
  - Internetworking became the basis for the Internet
  - Pioneered by Cerf & Kahn in 1974, later became TCP/IP
  - They are popularly known as the “fathers of the Internet”

Vint Cerf



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Bob Kahn

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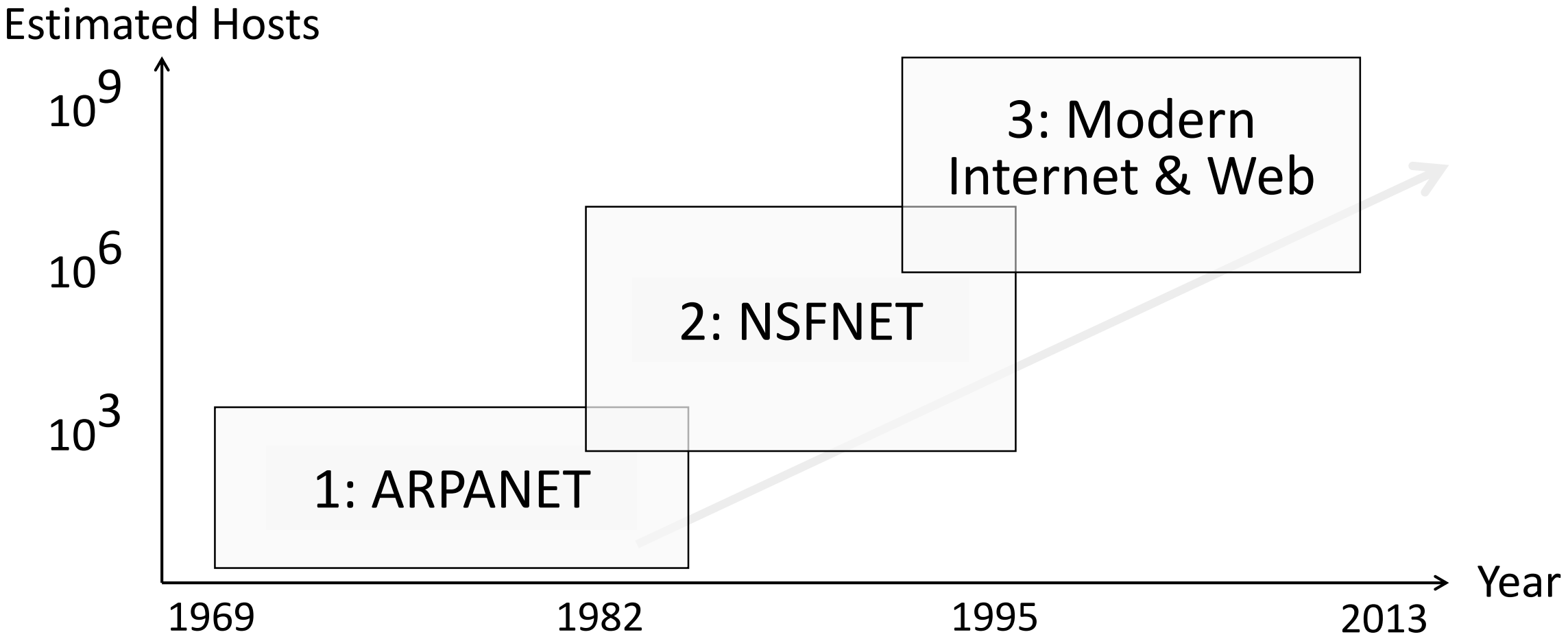
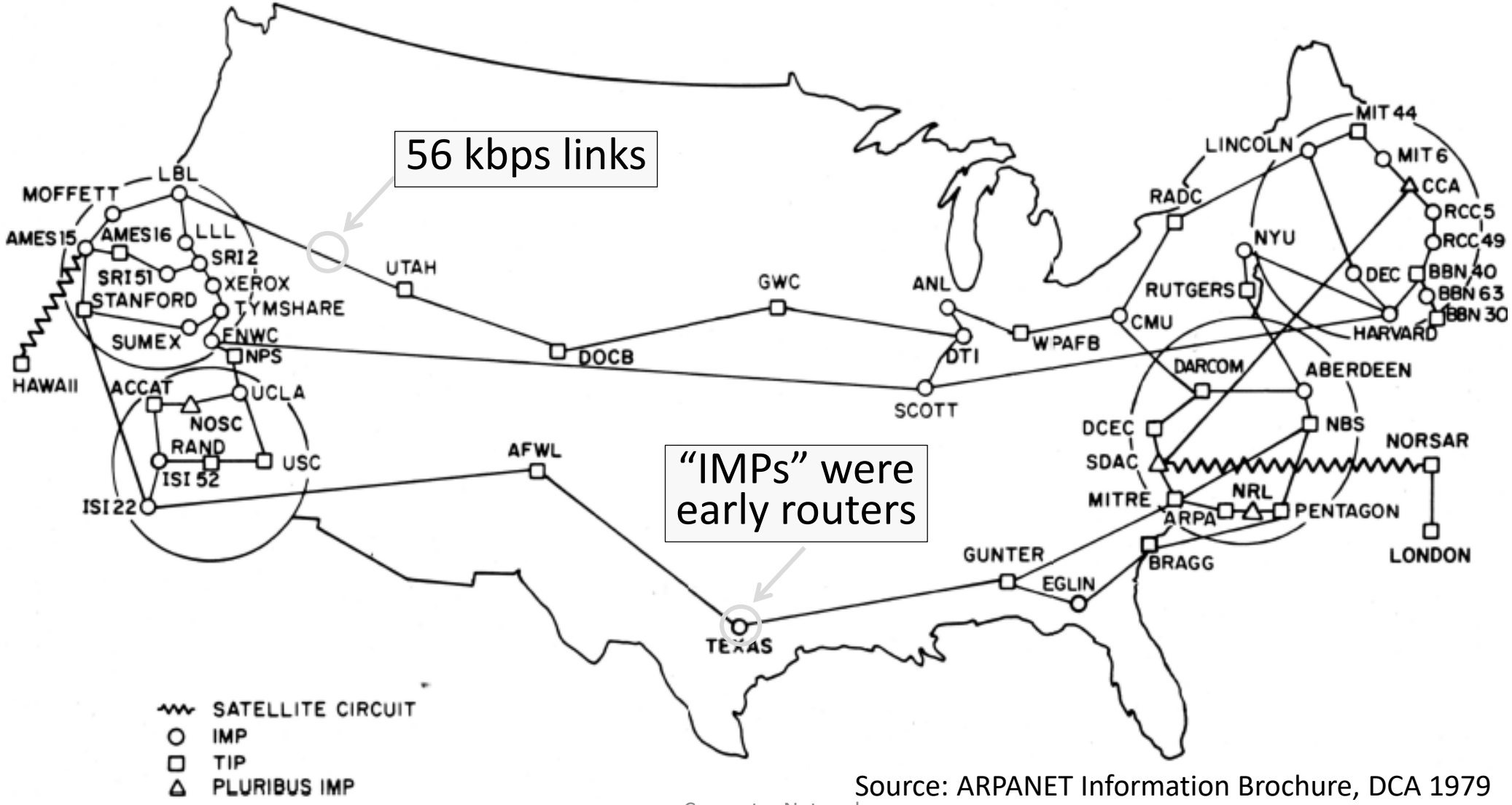
# Rough Internet Timeline



# ARPANET Geographical Map (Dec. 1978)

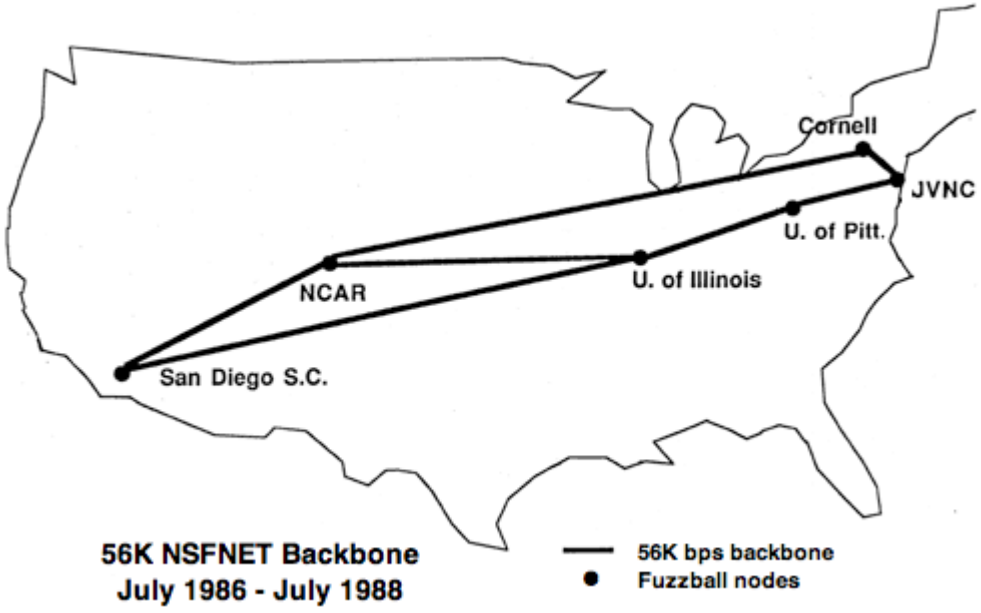



Source: ARPANET Information Brochure, DCA 1979

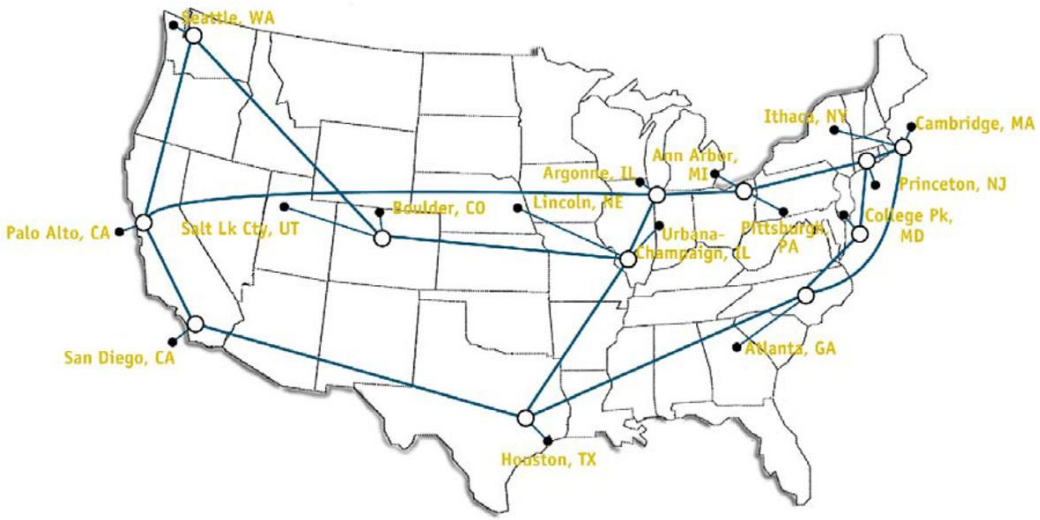
# Growing Up – NSFNET

- NSFNET ’85 supports educational networks
  - Initially connected supercomputers, but became the backbone for all networks
- Classic Internet protocols we use emerged
  - TCP/IP (transport), DNS (naming), Berkeley sockets (API) ’83, BGP (routing) ’93
- Much growth from PCs and Ethernet LANs
  - Campuses, businesses, then homes
  - 1 million hosts by 1993 …

# Growing Up- NSFNET

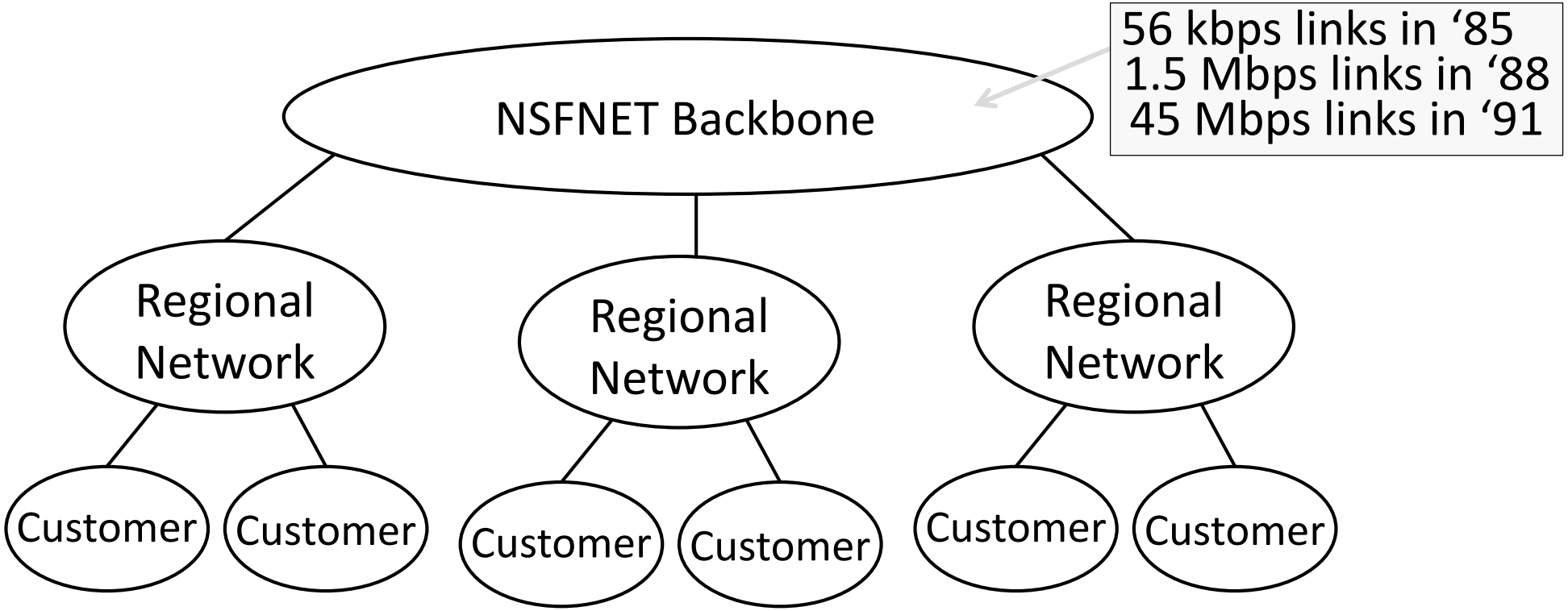



**NSFNET T3 Network 1992**



# Early Internet Architecture

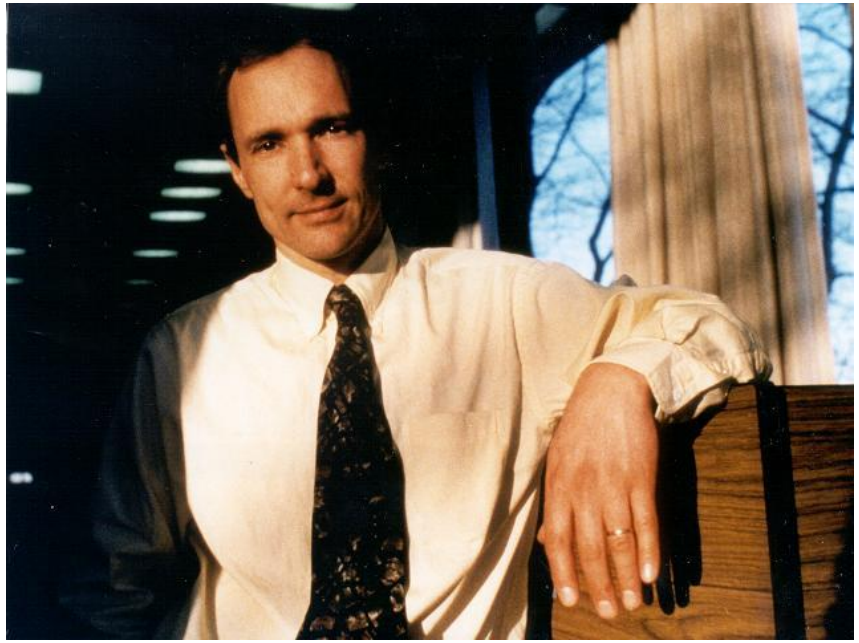
- Hierarchical, with NSFNET as the backbone



# Modern Internet – Birth of the Web

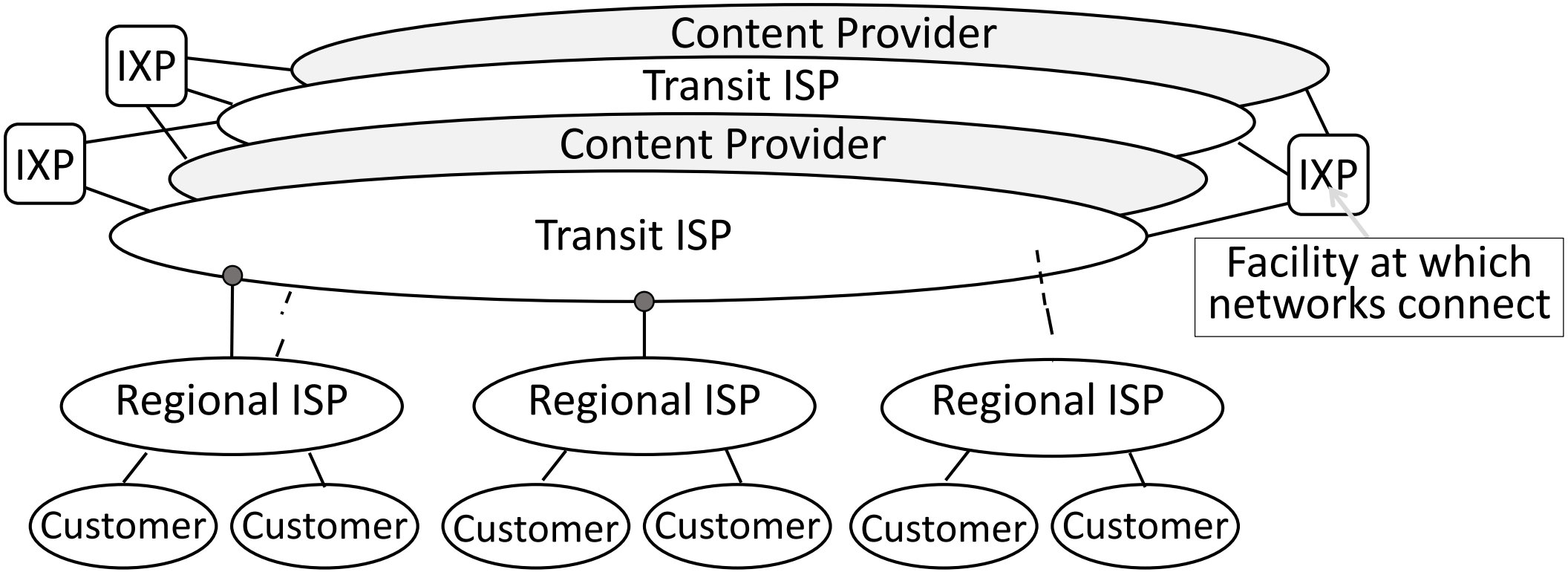
- After ’95, connectivity is provided by large ISPs who are competitors
  - They connect at Internet eXchange Point (IXP) facilities
  - Later, large content providers connect
- Web bursts on the scene in ’93
  - Key idea: Hyperlink
  - Growth leads to CDNs, ICANN in ‘98
  - Most bits are video (soon wireless)
  - Content is driving the Internet

Tim Berners-Lee



# Modern Internet Architecture

- Complex business arrangements affect connectivity
  - Still decentralized, other than registering identifiers



# Modern Internet Architecture (2)

Major Transit ISPs:

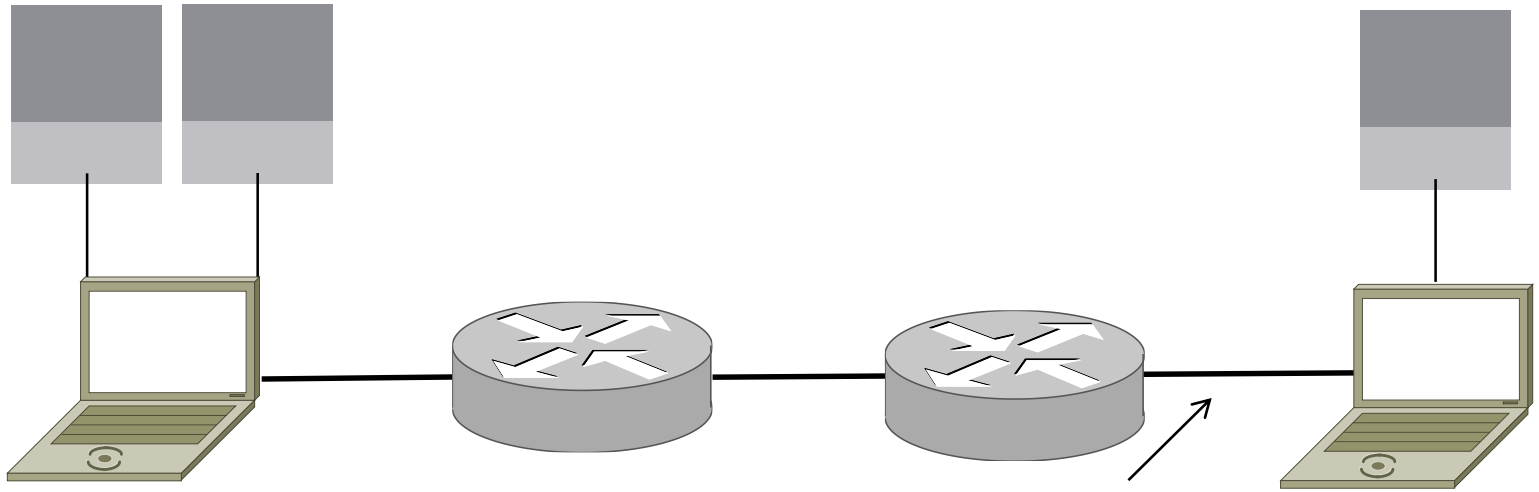
- Level 3 (200,000mi of fiber)
- Century Link (550,000mi)
- ATT (410,000mi)
- Verizon (500,000mi)

Major Regional ISPs

- Dakotanet
- Dixienet
- Local telecoms (e.g., MTA)
- US West

# Network Components

# Parts of a Network



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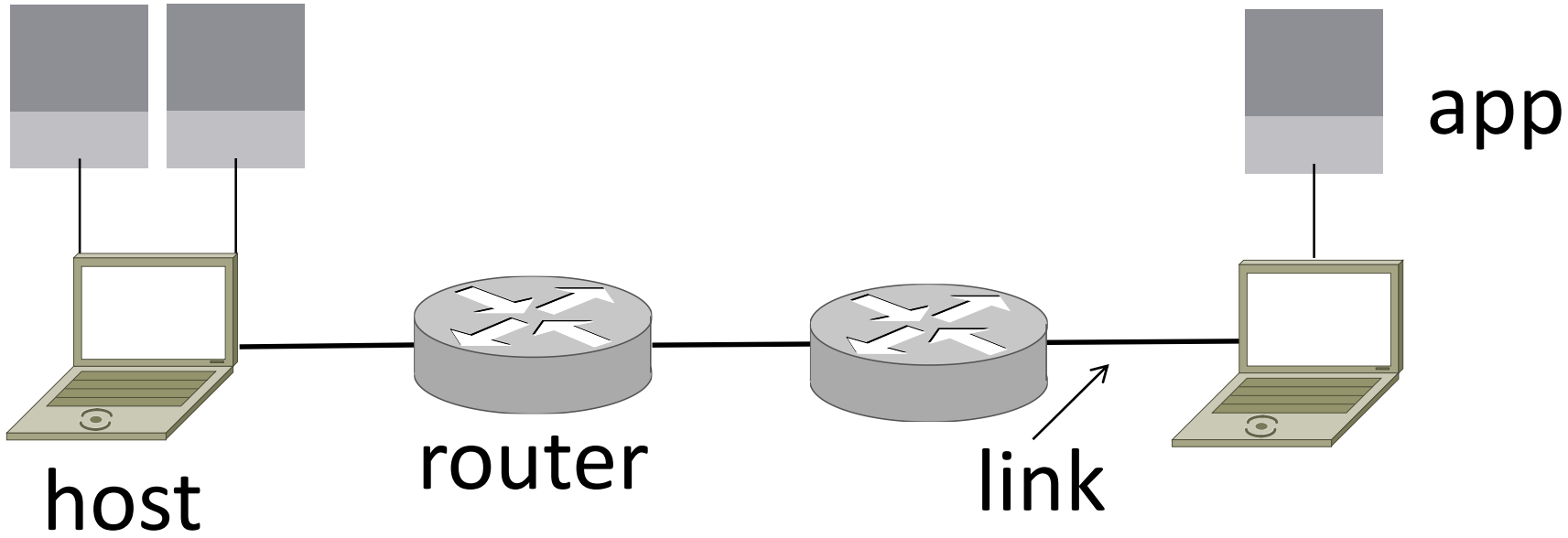


# Component Names

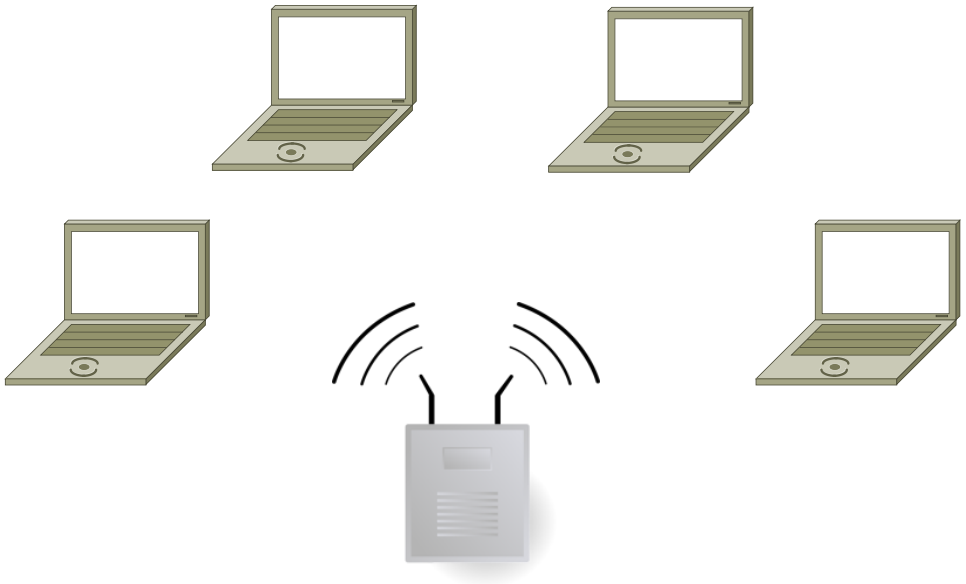
| **Component** | **Function** | **Example** |
|---|---|---|
| Application, or app, user | Uses the network | Skype, iTunes, Amazon |
| Host, or end-system, edge device, node, source, sink | Supports apps | Laptop, mobile, desktop |
| Router, or switch, node, hub, intermediate system | Relays messages between links | Access point, cable/DSL modem |
| Link, or channel | Connects nodes | Wires, wireless |

# Types of Links

- <u>Full-duplex</u>
  - Bidirectional
- <u>Half-duplex</u>
  - Bidirectional
- <u>Simplex</u>
  - unidirectional

# Wireless Links

- Message is <u>broadcast</u>
  - Received by all nodes in range
  - Not a good fit with our model



# Wireless Links (2)

- Often show logical links
  - Not all possible connectivity