CS3600 — Systems and Networks

NORTHEASTERN UNIVERSITY

Lecture 15: Networking overview

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What is a network?

What is a network?

Wikipedia:

A telecommunications network is a network of telecommunications links and nodes arranged so that messages may be passed from one part of the network to another over multiple links and through various nodes.

What are messages?

- Information

Why is networking interesting?

Many people use it, few understand

Scale

Billions of users, thousands of apps, millions of end hosts

Complexity

Many functions, many technologies, complex structure

Distribution

Shared, no central coordination point, independent agents

Telegraph: *Electronic* communication

In US, telegraph invented in 1837 by Samuel Morse

- 10 miles at 10 words/minute

Simple circuit

- Send signals by making/breaking the connection

Could (almost) instantly transmit information

Telegraph in-use until 1985!

Engineering the telegraph

How to

- encode information?
- feed in/output information?
- improve distance?
- improve speed (bandwidth)?

Issues faced by all communication systems

Example: Encoding information

How to convert messages to electrical signals?

A E B I C S D H E 5 ...

Can we do better?

Hint: Use dashes (—)

A A B B C C D D E E F F G G H H I I
J J K K L L M M N N O O P P Q Q
R R S S T T U U V V W W X X Y Y Z Z

Morse code

Telephony

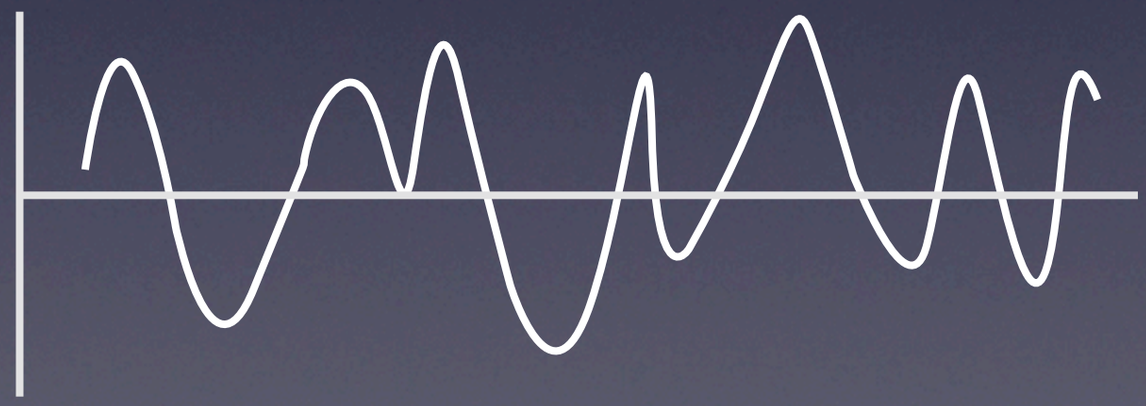
Provides auditory telecommunication

- Didn't require trained operator

Uses microphone/speaker and electric circuit

- Old school: Actual electrical connection end-to-end
- New school: Voice-over-IP (over the Internet)

Continuous analog signal



Example military telephone (EE-8)

Would run a wire between a pair

Effective range: 100s of miles

Scaling telephony

1876: Each pair directly connected

Did not scale

1878: Instead, use a *switch*

Allowed any two lines to be connected

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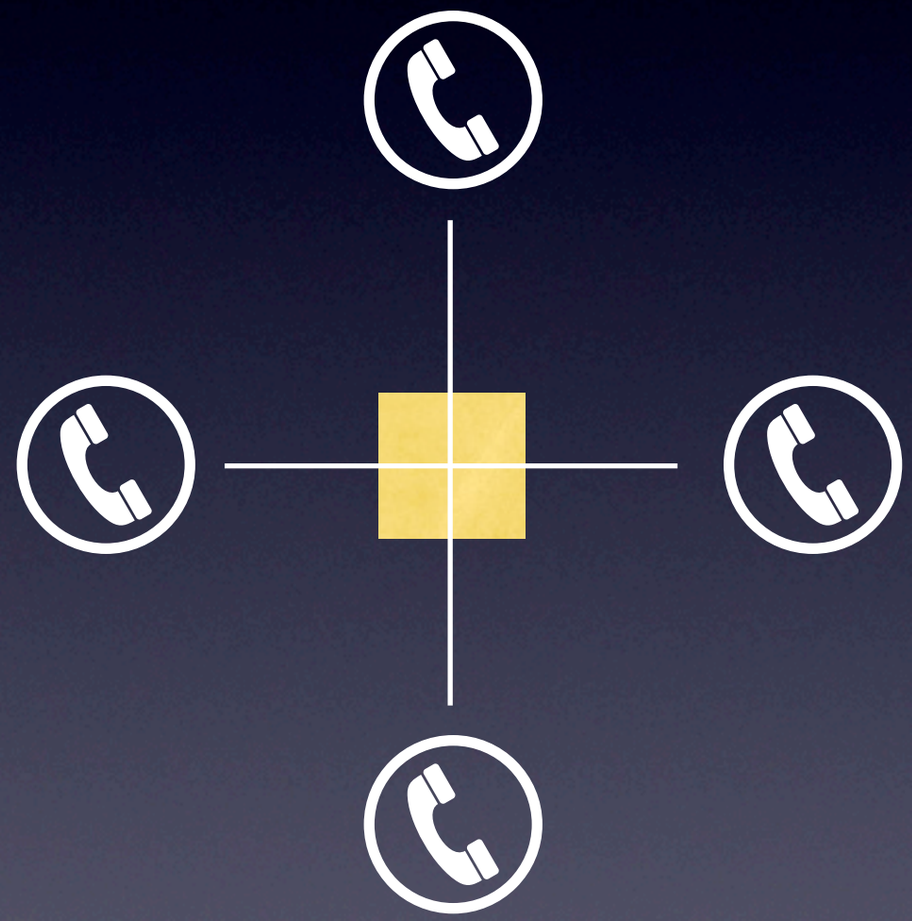
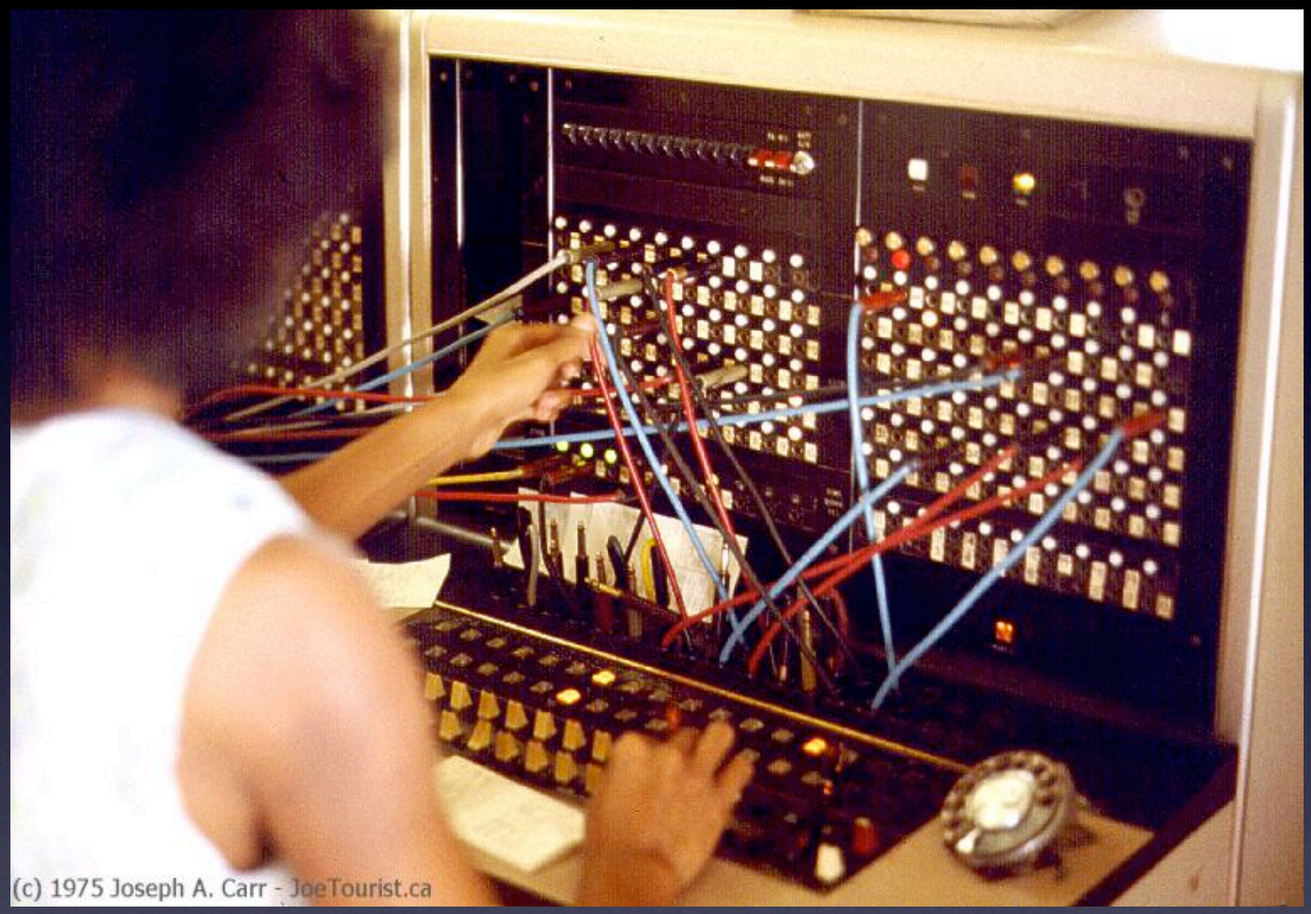


Telephone switch

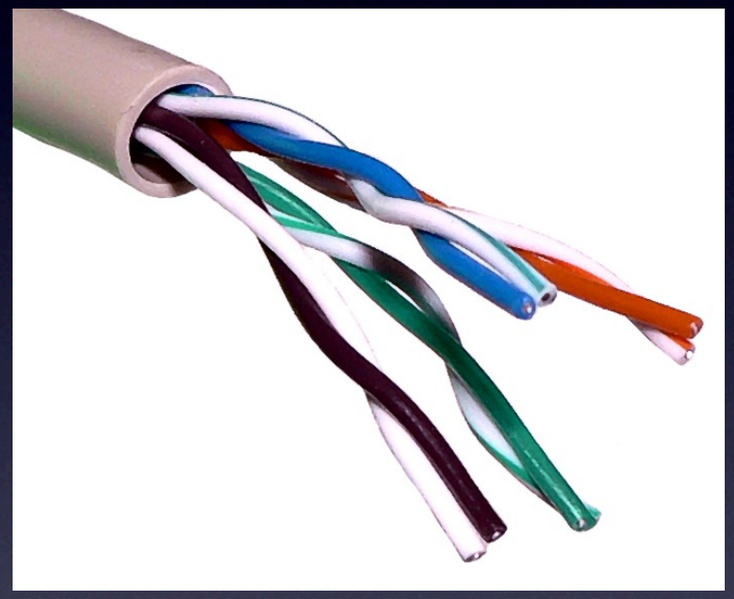


Would tell operator who to connect to

In 1918, cross-country call took 15 minutes *to set up*

Telephony milestones

1881: Using *twisted pair* for local loops
1885: AT&T formed
1892: Automatic telephone switch
1903: Three million telephones in US
1915: First transcontinental cable
1927: First transatlantic telephone service



at&t
Your world. Delivered.

Scaling telephony (again)

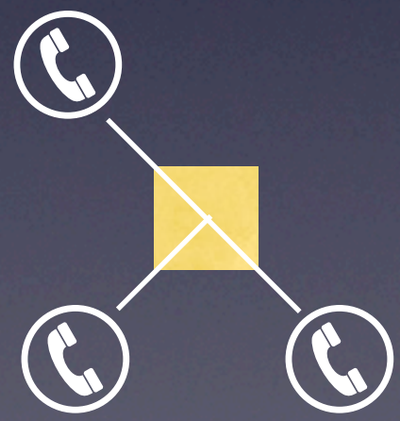
Connections between switches required wires

- One wire = one call

Not scalable

1937: Multiplexing

- Multiple calls over single wire
- Called trunk lines



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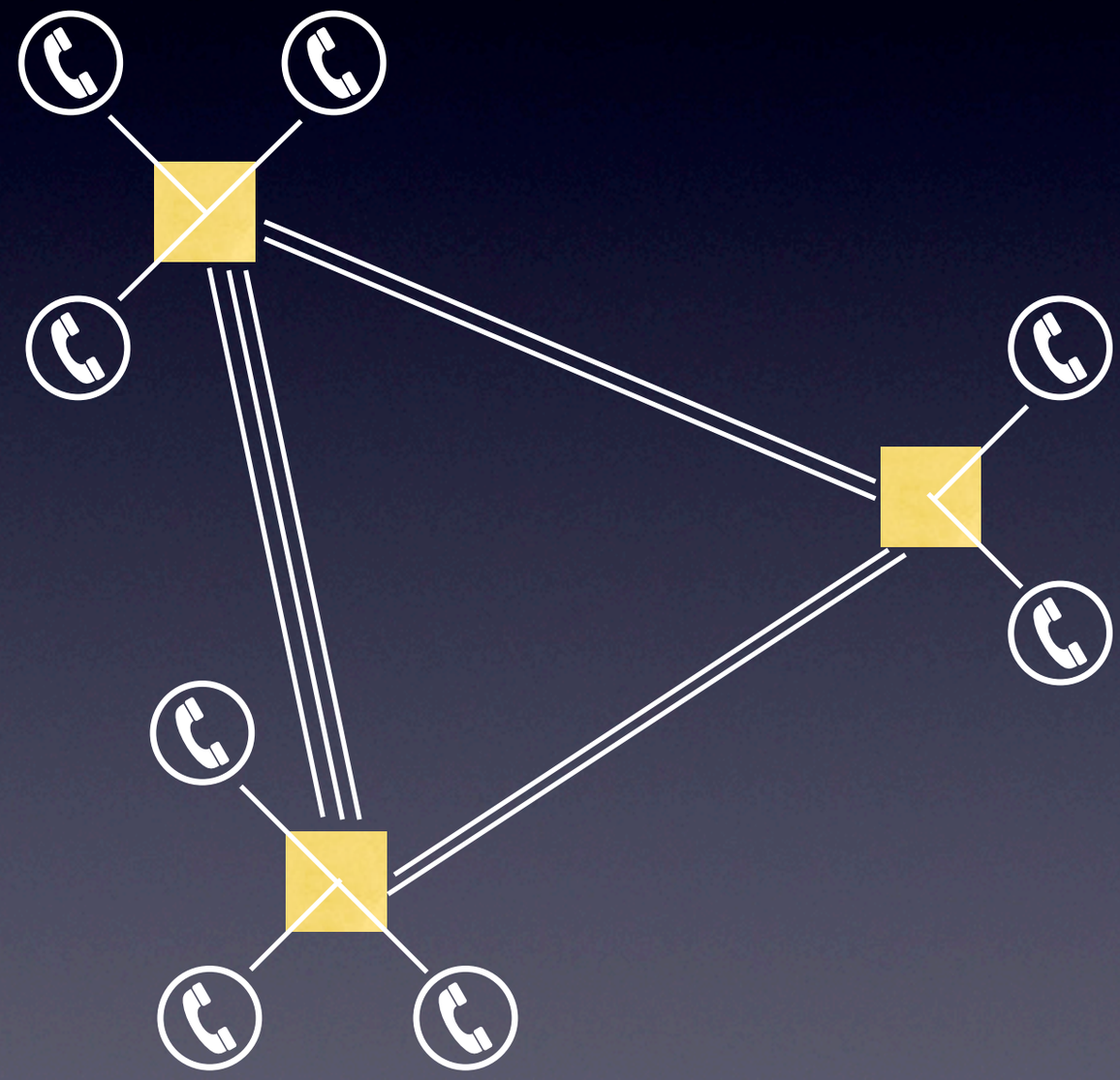

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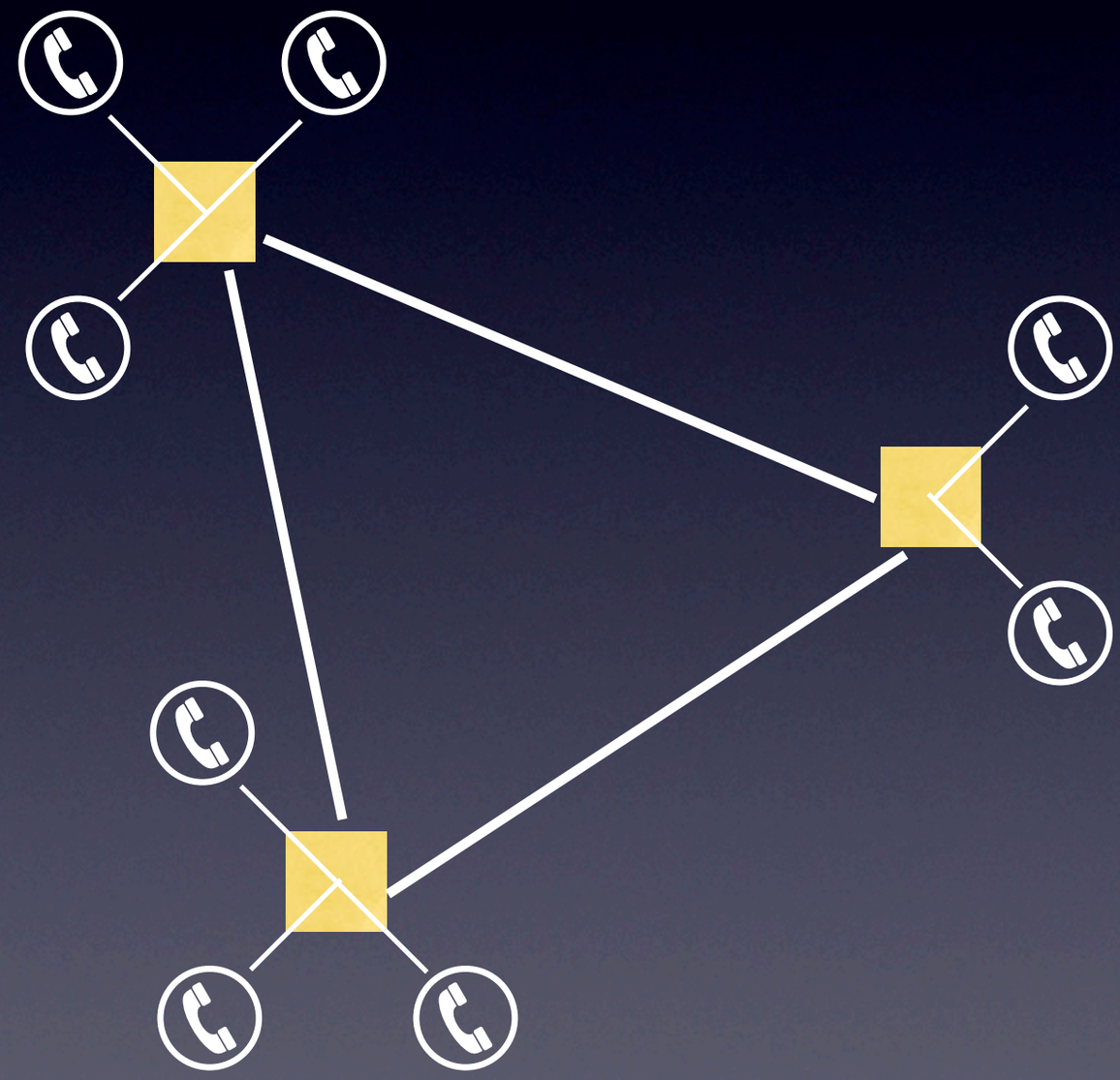


Summary of telephony

Communication a problem before computers

Will see similar challenges in computer networks

- Switching
- Multiplexing
- Analog vs. digital
- Bandwidth
- Latency

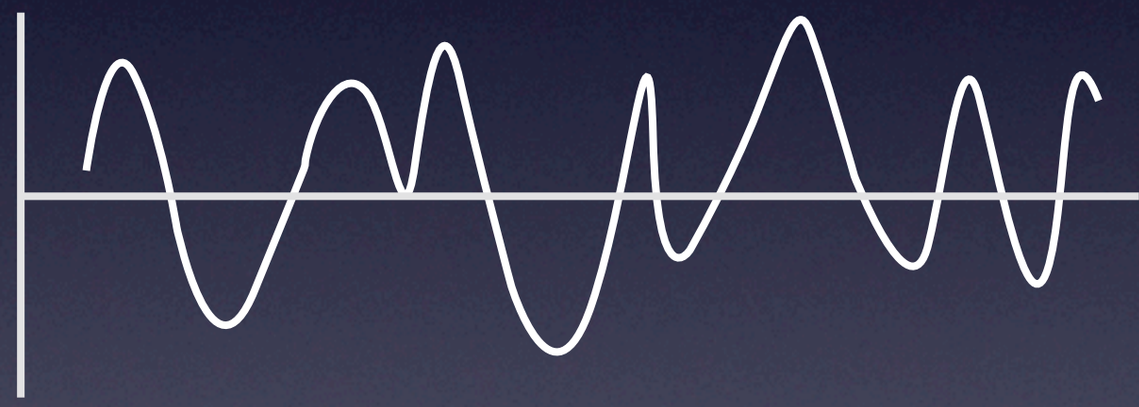
On to computer networks

Networks designed for computer communication

- As opposed to (direct) human communication

Digital messages

- Binary



101100001010101001110101

What are the components?

Links

Copper, fiber, wireless, satellite

Interfaces

10-base-T, wireless, fiber

Switches/routers/NATs/firewalls

Route (or drop) messages

Architecture

Packet vs. circuit switched

Protocols/standards

TCP, IP, Ethernet

Applications

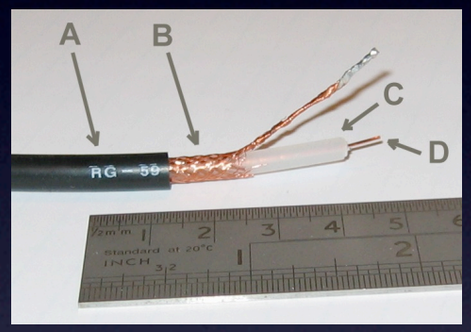
HTTP, FTP, SSH

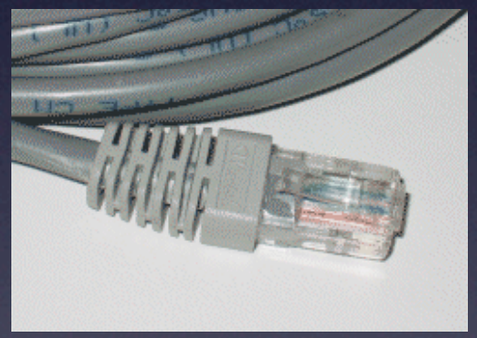
End hosts

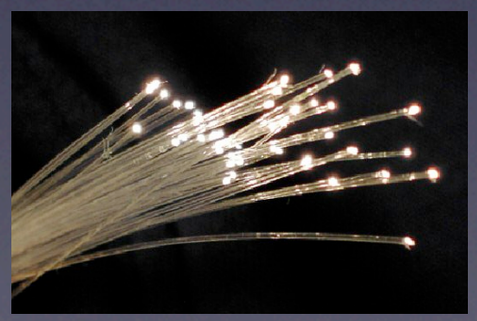
Mac, Windows, Linux

Example components

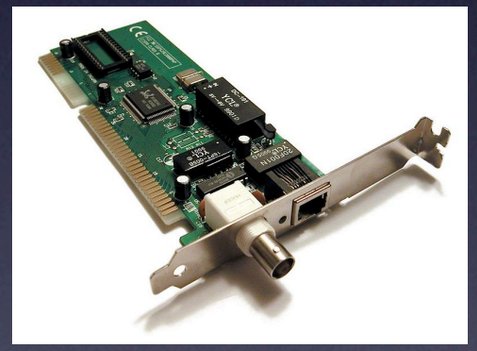
Links







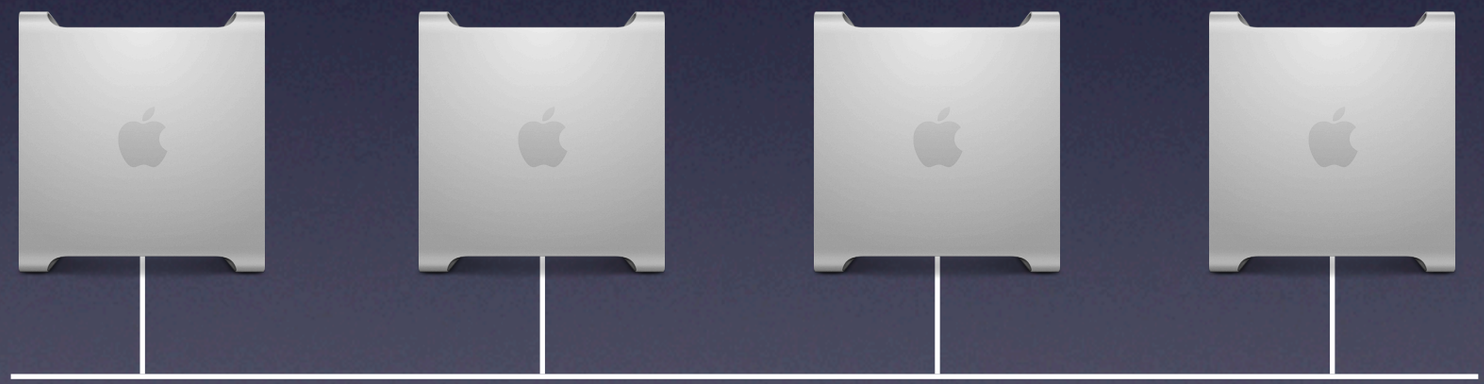
Interfaces



Routers

Example links

Point-to-point



Multiple access

Networks differentiated by

Geographical area
- PAN, LAN, MAN, WAN

Architecture
- Dumb terminals vs. dumb switches

Intended applications
- Special purpose: Airline reservations, banking, credit cards
- General purpose: Internet, telecommunications

Networks differentiated by

continued

Right to use

- Private: enterprise networks, airline reservations
- Public: telephony, Internet

Ownership of protocols

- Open: IP (Internet)
- Private: SNA (IBM)

Technologies

- Terrestrial vs. satellite, wired vs. wireless

The Internet

What distinguishes it from other networks?

- Open, public, decentralized, heterogeneous

Based on Internet Protocol (IP)

- Governed by Internet Engineering Task Force (IETF)

Developed by research community

- Super computer research centers needed remote access

History of the Internet

1970s: Research project, funded by DoD

56 Kbps, tens of computers

1980s: ARPANET and MILNET split

1985: NSF builds NSFNET backbone linking 6 centers

1987: Multiple networks linked together (NSFNET, ESNet, ...)

1992: NSFnet at 45 Mbps

1994: NSF backbone dismantled, private backbones

Today, backbones run at many Gbps, millions of end hosts

Internet structure

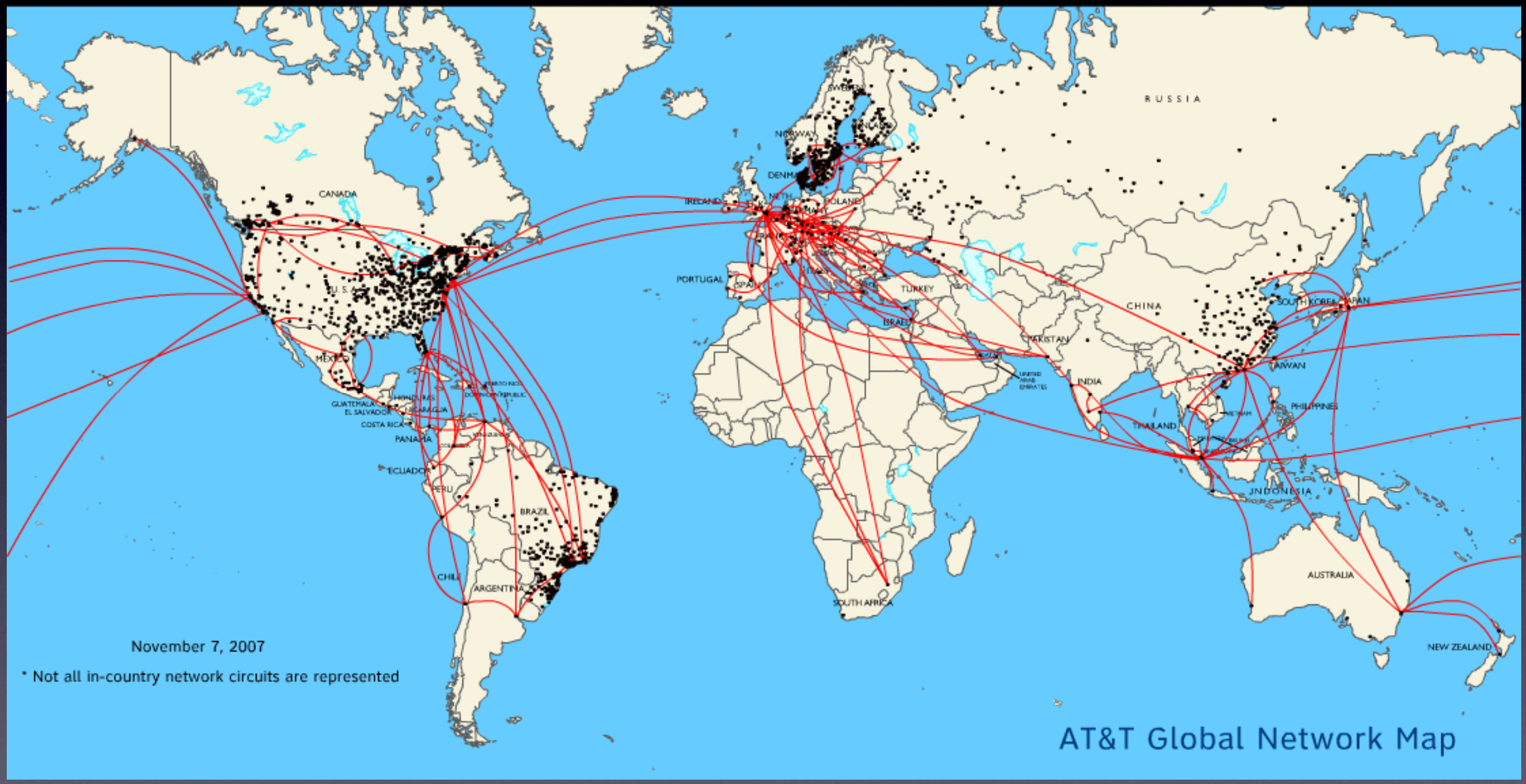
Divided into *tiers*

- Tier 1: AT&T, Level 3, NTT, etc...
- Tier 2: Deustche Telekom, France Télécom, British Telecom, etc...
- Tier 3: Your local ISP (likely)
- ...

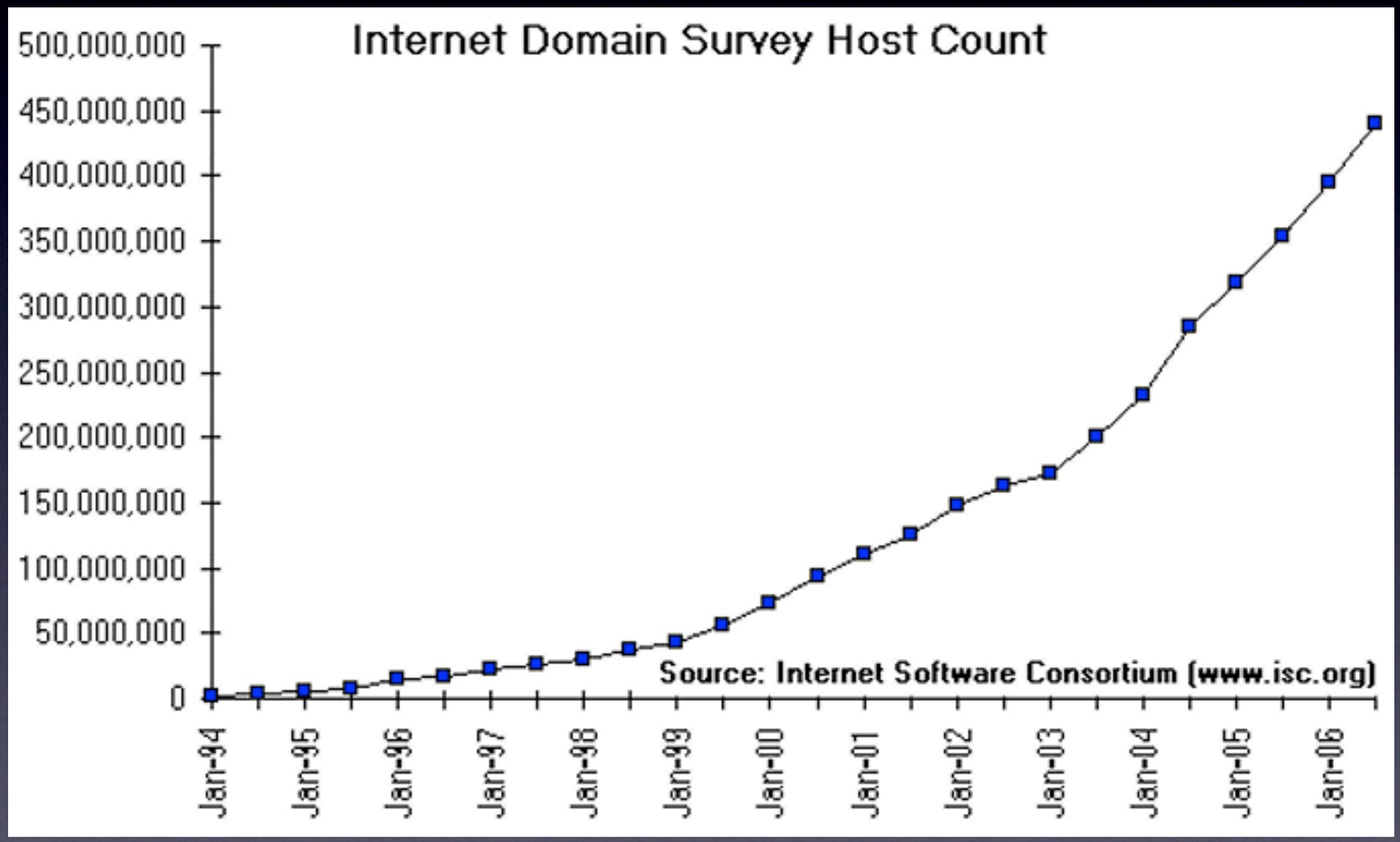
What defines tier 1?

- Do not pay *transit fees*

Example: AT&T's network



Internet growth



Final words

It's all about communication

Internet has made communication (essentially) free

- Can communication with millions of others

Networking is at the center of it

- How to enable communication?