Information Theory and Networks

Lecture 2: A Brief History of Networks

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Part I

A Brief History of Telecommunications

You know what they say. Those of us who fail history, are doomed to repeat it in summer school.

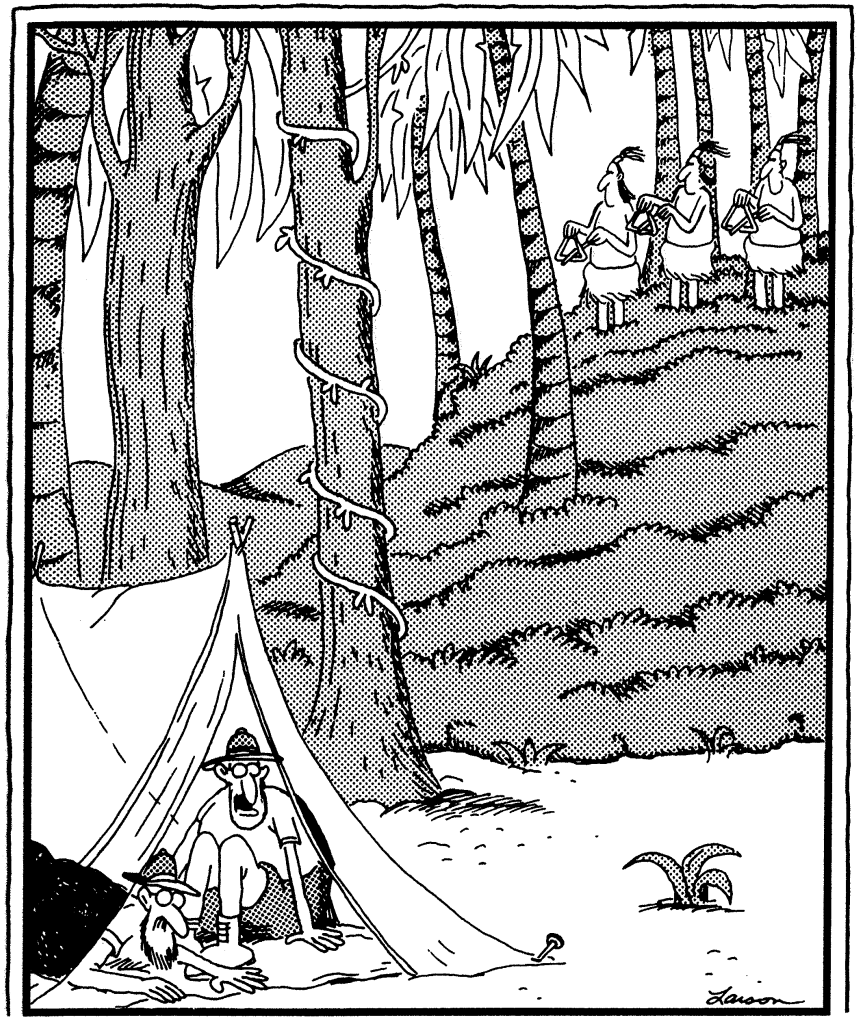
Buffy (the Vampire Slayer), "After Life" (Season 6, Ep. 3), 2001

An outline

1. pre-industrial
2. 19th century
3. early 20th century
4. computer networks
5. early 21st century (now)

Pre-industrial

- Jungle drums
- Signal fires
  1184 BC, fall of Troy [AesCE]
  1588 AD, Arrival of Spanish Armada
- Carrier pigeons
  700 BC, Olympic games
- Smoke signals
  150 AD, Romans
- Semaphore
  1791 AD, Chappe brothers
  later used by Napoleon



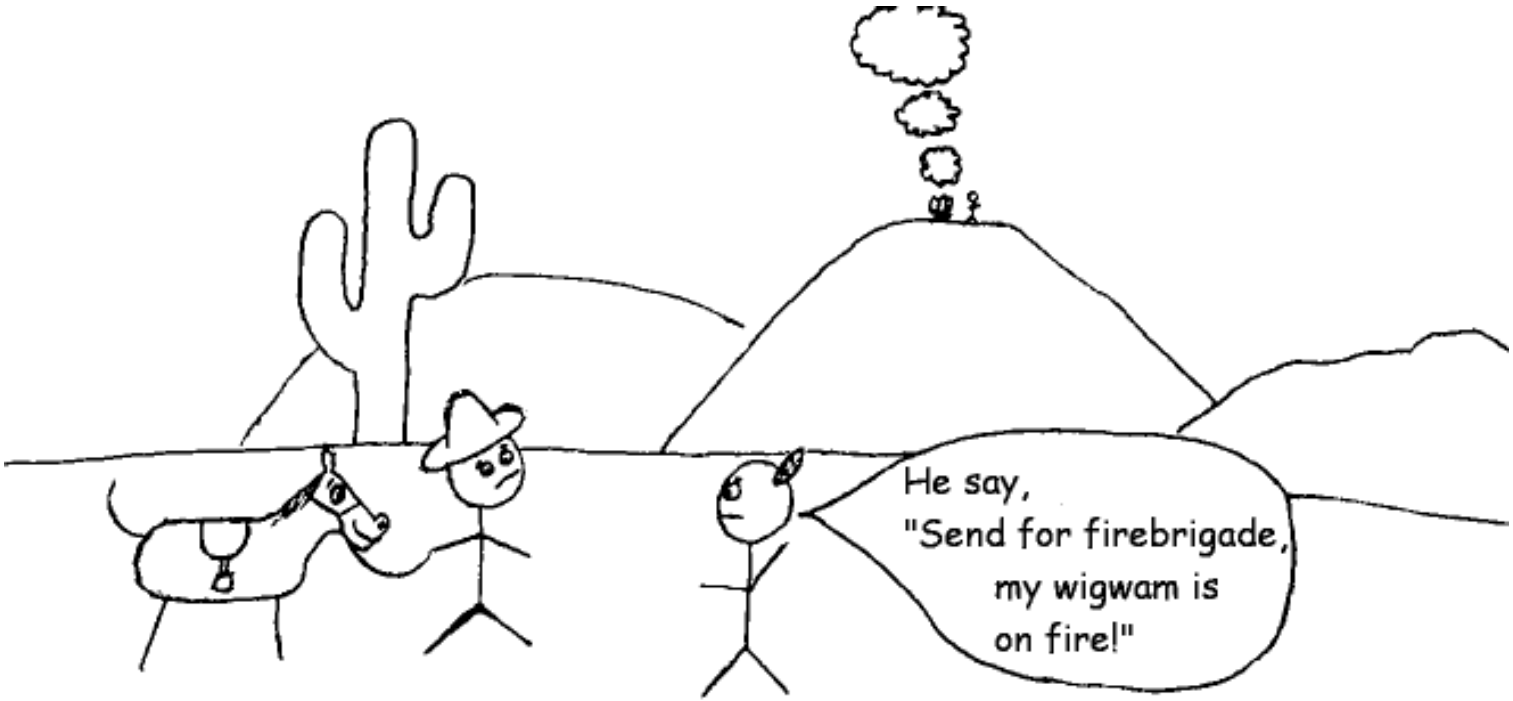
"Wait, Morrison! ... It's OK—those are jungle *triangles*!"

Gary Larson, 1993

Pre-industrial

These had limitations

- Carrier pigeons: `1 short message per pigeon`
- Signal fires: `one bit per fire`
- Semaphore: `15 characters per minute.`



19th century

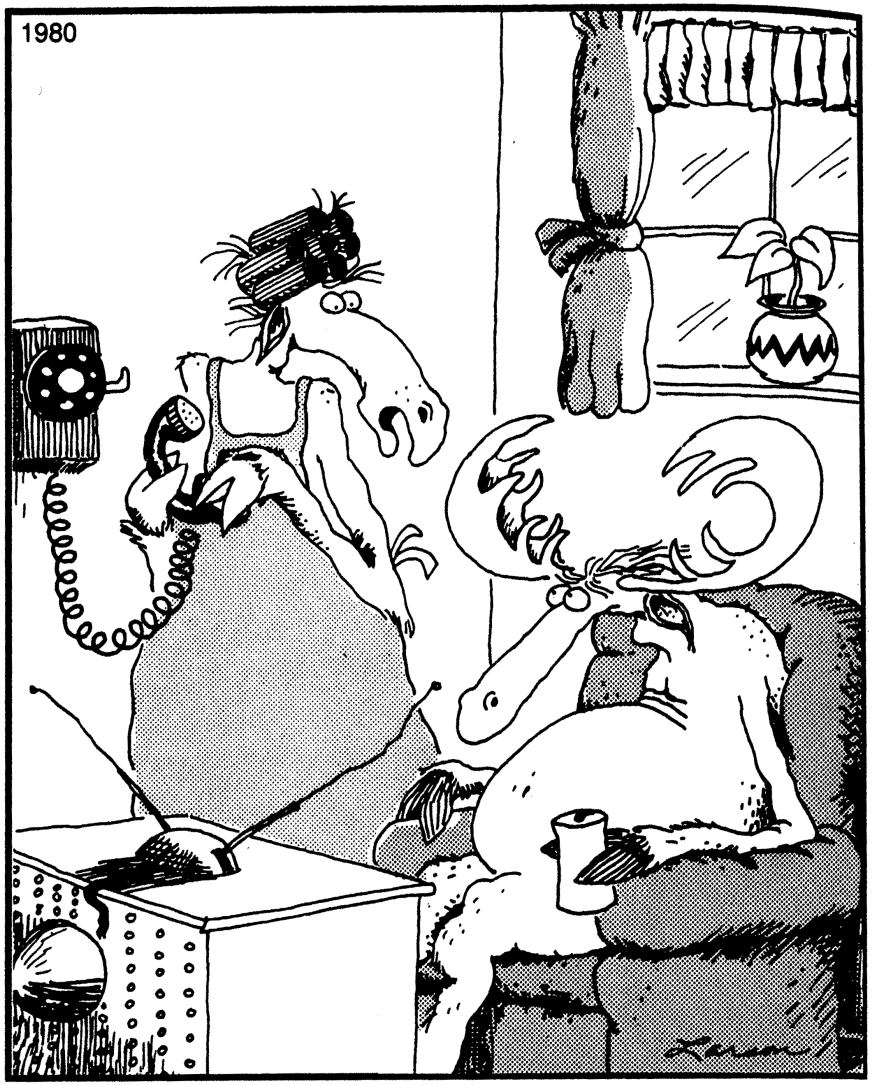
Post office:

- British post office founded 1635.
- modern postoffice 1840 (1st "penny black" in UK)
- send **content** as letter or parcel
- encapsulate package with address on the front
- send to local postoffice
- each postoffice determines next postoffice
- final postoffice delivers to the address

19th century

Electronic communication:

- telegraph
  - invented 1753
  - Morse code 1835
  - take off 1838
  - 1st transatlantic line 1866
- radio (Marconi, 1896)
- telephone
  - A.G. Bell
  - filed patent Feb. 14, 1876, 3 hours before Elisha Gray

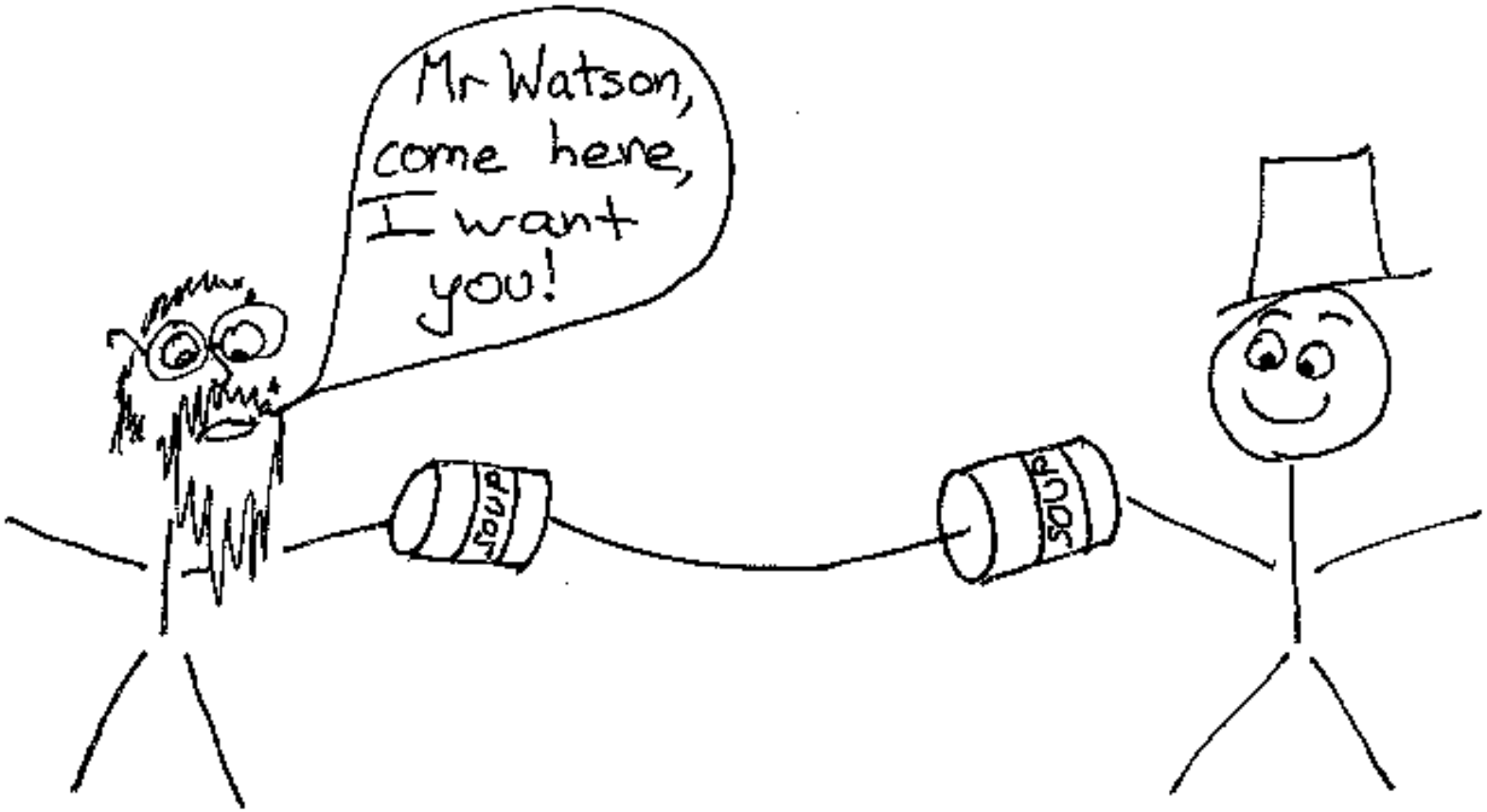


"It's the call of the wild."

Gary Larson, 1980

19th century

Simple telephone: connects two points with a wire



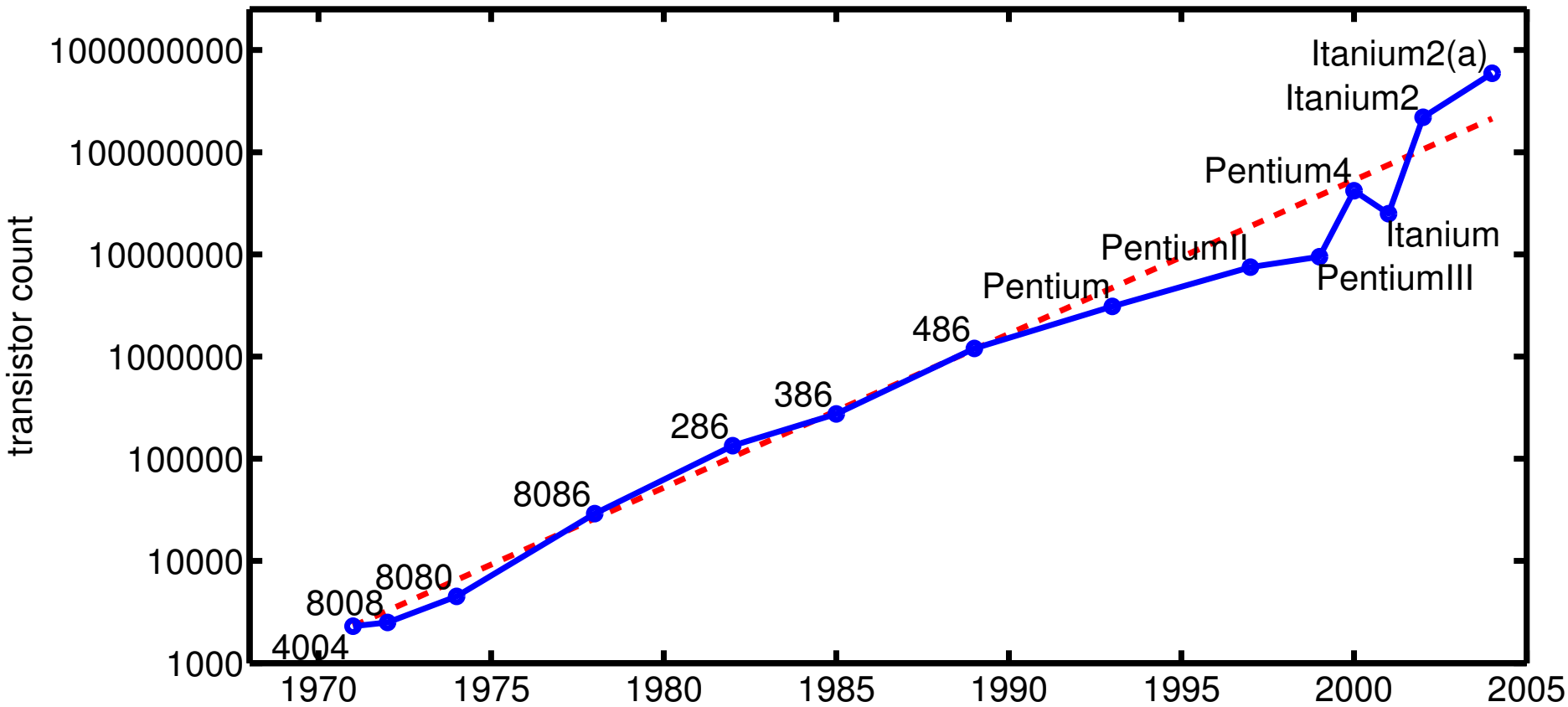
Reportedly, the first words over the telephone came when Bell spilled some acid on his pants, whereupon he call "Mr. Watson, come here, I want you!"

Towards modern telephony

- switching
  - electronic switch (instead of electromechanical)
  - 4ESS (like a building)
    http://www.att.com/history/nethistory/switching.html
- networks become hierarchical
  - long distance versus local
- reliability and redundancy become important
  - alternate routing
- billing systems
  - harder than you think!
- massive capacity increases
  - fibre optics
  - better transmission techniques (e.g., DSL)

Moore's Law

Moore's law: the speed of digital hardware increases by a factor of two every 18 months, or the number of transistors on a chip doubles, or the cost halves [Moo65].



Actually looks more like a factor of 2 every 2 years.

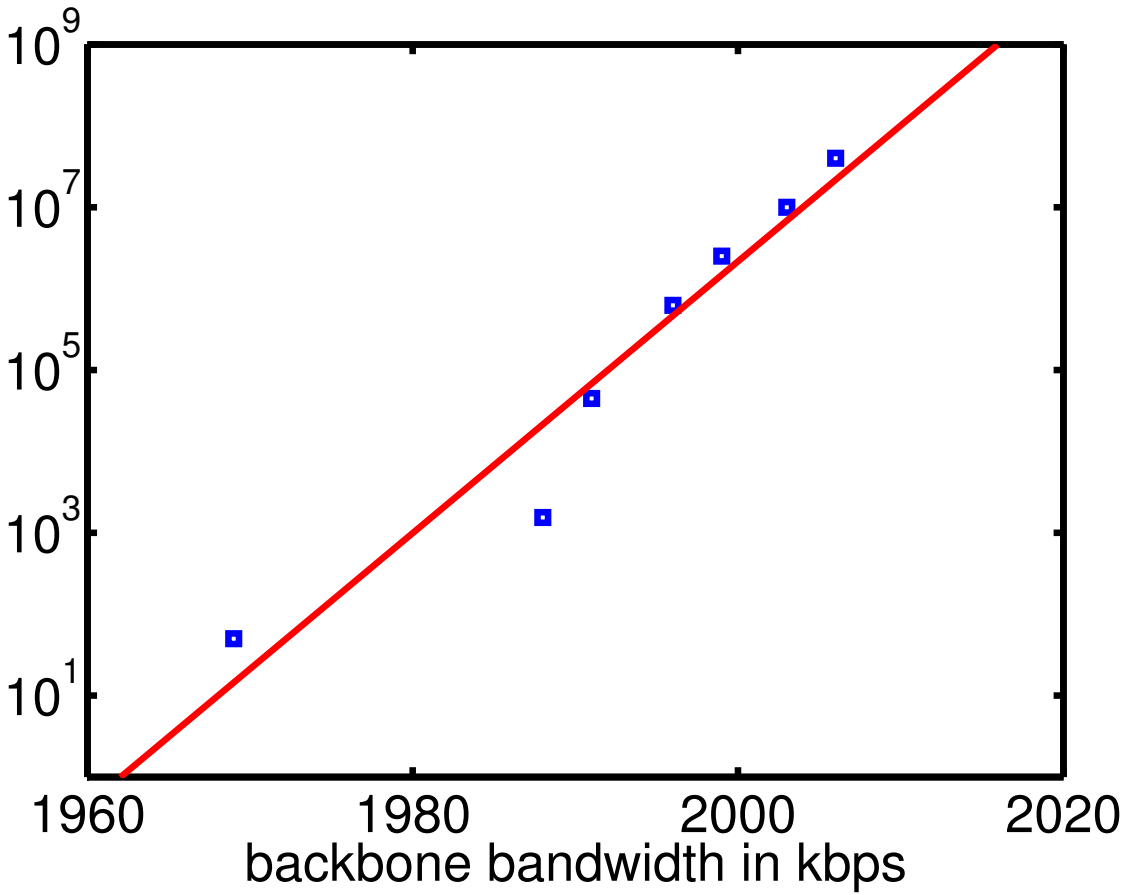
Gilder's Law

Gilder's law: theoretical transmission capacity of a link increases by a factor of two every 12 months.

- http://www.seas.upenn.edu/~gaj1/promise.html
- http://www.dtc.umn.edu/~odlyzko/doc/tv.internet.txt
- http://telecomvisions.com/articles/beyondip/
- transmission capacity is still behind storage
  - 2000, backbones in US carried 144 PB/year, total disk capacity 3000 PB
    - ★ it would take 20 years to carry all the data
  - 2005, 100 GB disk is common, 1.5 Mbps
    - ★ it would take 6 days to carry all the data
  - network is catching up?

Actual backbone link speed growth

Roughly doubles every two years (45% per year)

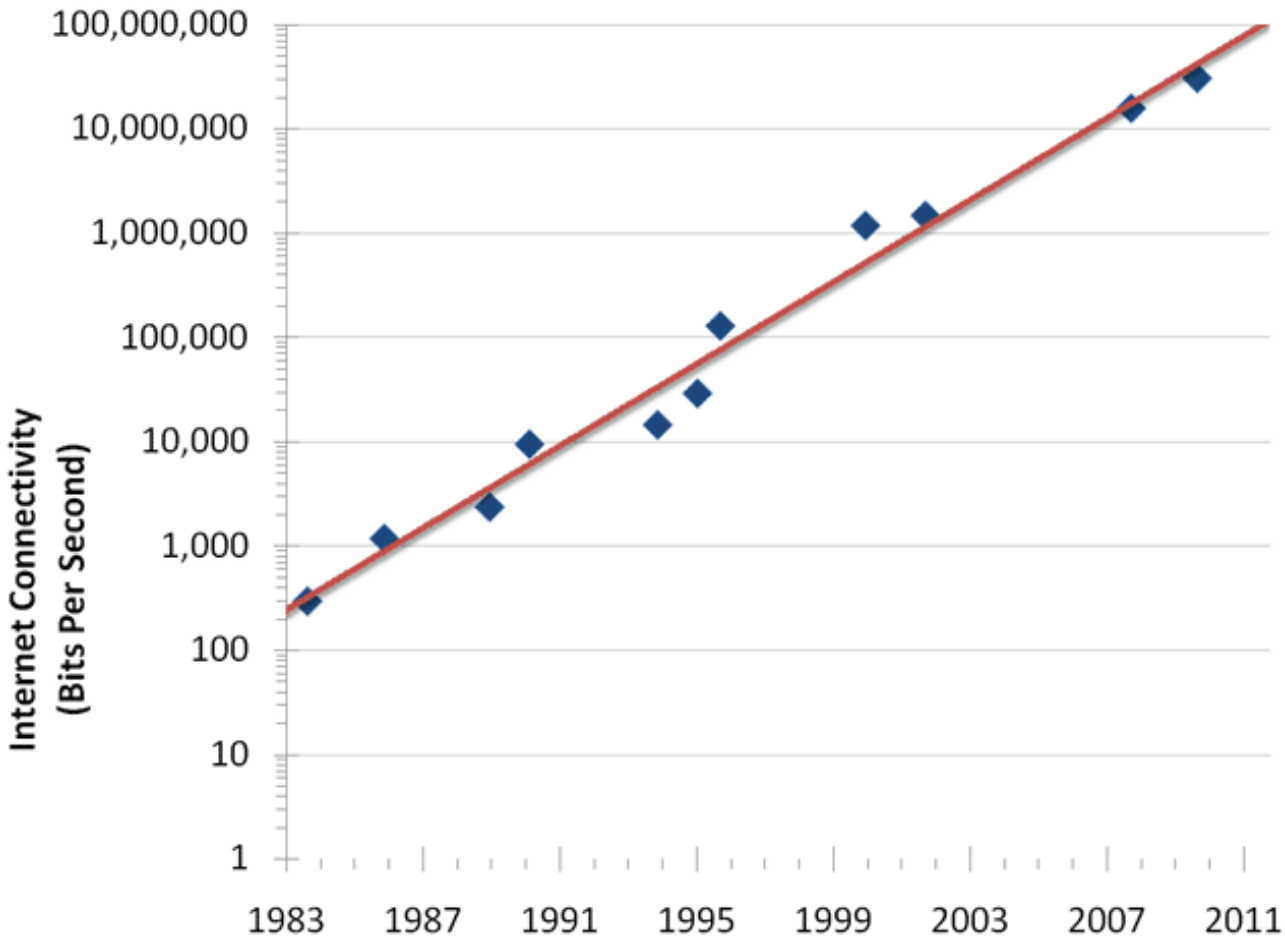


Note that extra links are added every year as well, so the actual bandwidth available to use grows faster.

Access-link speeds

Nielsen's Law of Internet (Access) Bandwidth

- a high-end user's connection speed grows by 50% per year



http://www.useit.com/alertbox/980405.html

Further reading I

Aeschylus, *Agamemnon*, http://classics.mit.edu/Aeschylus/agamemnon.html, 458 B.C.E.

Gordon E. Moore, *Cramming more components into integrated circuits*, Electronics **38** (1965), no. 8.