Future of the Internet

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Notes on this version

This version of the slides differs in two respects from the original version that was presented. First, a number minor errors have been correctly and text elaborated to make the presentation easier to read and follow rather than simply as an aid to an oral presentation. Second, a few notes and references have been added to aid those who are interested in further reading about some of the historical assertions in the text. Those notes appear in the smaller type size used on this page.

Many possible futures

- Economic and social pressures/ constraints
- Policy issues
- Unpredictability of innovation
- So, rather than predicting, will muse on history, mythology, prediction
- And then discuss "convergence" a bit

Rapid innovation in underlying technology

- Packet papers to ARPANET
- Modem speeds
  - 300 baud and 1200/75 impressive in 1960s
  - 2400 the theoretical limit?
  - Compression, packets, error correction, and back to asymmetry

More rapid low-layer technology innovation –dedicated

- Current loop at 19.2
- ARPANET backbone at 56Kbps
- DWDM and other illuminating ideas

But....

- Who cares, really?
- Pipes and what flows through them
- Graphics a counterexample?
  - Vector technology in place by 1970
  - 2000x2000 dynamic displays by 1975
  - Raster gear in production about the same time
  - *S-l-o-w* at that time

so maybe not

Applications innovation

- Some stories
  - Web
  - Digital libraries
  - Email and instant messaging
- Major developments implemented very slowly

Hypertext and the web

- Bush specified almost all important principles in 1930s, published in 1945
  - 50 years?
  - We still haven't quite gotten to all of his ideas

Vannevar Bush, "As We May Think", *The Atlantic Monthly*, **176**, 1 (July 1945), pp 101-108.

Digital Libraries

- Licklider outlined automated, anticipatory, retrieval systems and anticipated interconnected digital libraries in early 60s.
  - 40 years?
  - Still haven't figured out
    - stable identifiers
    - variant form identity/ matching
    - ...

See, e.g.,J.C.R. Licklider, *Libraries of the Future*, MIT Press, Cambridge, Mass, USA, 1965.

Email and Instant Messages

- de Sola Pool predicted evolution of email to international
  - two-way or multiway
  - optionally real-time
  - multimedia system

  in about 1968
- So we "invented", we are told
  - email in 1971 (or 1964 (!))
  - IM in 1966, 1979, ~1985, ~1999,...

The predictions were made in several private conversations and seminars at that

time, but were apparently not written down until much later. There is some discussion in Ithiel de Sola Pool, *Technologies of Freedom*, Harvard University Press, Cambridge: 1983, and, more importantly, in his posthumously published *Technologies without Boundaries*, Harvard University Press, Cambridge: 1990.

While there have been several claims and celebrations of the "invention" of electronic mail in around 1971 or 1972, both electronic mail and facilities that would be recognizable as instant messaging today were in active use at a number of institutions in the mid-1960s. For example, a MAIL command is described in section AH.9.05 (February 1966) and "interconsole communications" (essentially indistinguishable from instant messaging, including per-sender control over which users can use it to communicate) in section AH.2.19 of P.A. Crisman, ed., *The Compatible Time-Sharing System: A Programmer's Guide*, 2nd Ed., MIT Press, Cambridge: 1965 (with sections updated incrementally). The innovations of the early 80s were the transport and delivery of electronic mail over wide-area networks (rather than single, or closely-coupled, machines) and the introduction of the "@" symbol.

Strange hypothesis

- Network technology does not drive "killer apps" but
- The innovative applications come along years in advance and wait for the network to catch up

On today's horizon -- Some nightmares

- 500 channels of mindless entertainment
- Fantastic opportunities for surveillance, database integration, complete privacy loss
- Return to
  - charge-by-packet
  - charge-by-minute
- Fragmentation of various types
  - Tower of Babel as a warm-up exercise
  - How many years to do that one really well? ☹.

Convergence in communication at a distance: not always progress

- Signal fires
- Light on mountain
- Good range, poor bandwidth
- Weather sensitive

- Messengers on horseback with letters
- Better bandwidth, lower speed, more robust
- *?? Rider carries torch to destination, lights fires in front of recipient ??*

Messengers on horses to trains

- Messenger has more flexible start times
- But slower and limited bandwidth
- Adaptive routing

- Faster
- Eventually more reliable
- More bandwidth

??Just load the horse on the train, and continue with it carrying the message??

Train to telegraph

Train
- High bandwidth

Telegraph
- High speed
- Flexible scheduling (like the horse)
- *??Messages in little capsules, pulled along wires??* `(... did try a variation on that one)`

Telegraph to telephone

Telegraph
- Digital medium
- High speed, poor bandwidth

Telephone
- Back to analog
- More bandwidth, but lower accuracy
- The CO switch did bring us telex but...

??Convergence??

Remembering the design of the phone system

- Stupid terminal requires smart center
  - Intelligence of center may have peaked with plug boards and human operators
  - Been trying to catch up ever since

Symptoms of a dumb terminal network

- Terminal stays dumb ? more and more cleverness at middle
- Complexity takes over
  - Feature interactions
  - Very slow diffusion of innovation
  - Requirement for central planning
- Is "intelligent network" a dumb idea?

The Internet is designed the other way

- Stupid network, smart end devices, hence
- Easy and rapid innovation
  - Once we have the power and figure out what we are doing
- Low complexity
- Different communications models ?

Two other nightmares

- Loss of end to end model to clever ideas
  - Design errors create business opportunities
- "Converging" on a
  - Smart, over-complex network with
  - Smart edge devices that try to outsmart it
  - Complexity multiplies

Interpersonal Communication with Smart Terminals

- Do not
  - Want to talk with a legacy identifier of a trunk or instrument
  - To be at the mercy of anyone who wants to reach you
- Do
  - Want to turn communication modes back into a negotiated relationship

Making a Call

- Destination is
  - A person or group
  - With a set of attributes/requests
    - How important
    - How quickly
    - How much disruption
    - Preferred medium

Receiving one

- Recipients apply rules
  - Medium
  - Interruptability
  - Range of search choices
  - Potentially, priors on sender and preferences.

The "phone call"

- A special case:
  - Two party
  - No advance schedule
  - Known receiver location/ device
  - Audio only
- ENUM?
  - May be a waste of time
  - Too much legacy "telephone" baggage ?

The Future?

- Hard to predict
- Might want to look at the good, but unrealizable, ideas of years ago
- And we should avoid constraining the future to yesterday's ideas.