Industry’s evolutionary path
Moore’s Law: ¿Que sera sera

Gordon Bell
Microsoft Research
Outline

• Theory of Computer Industry formation
• Interesting new & converging classes
  – Large stores: PC rebirth; capture all corp. data
  – Small form factor everything; phone, PC, camera...
  – Wireless sensor nets
  – Convergence: Computers & Consumer Electronics
• Game changers
  – GPU
  – Speech – the technology of the future
  – New user interfaces & apps… life beyond WIMP?
Moore’s First Law

- Transistor density doubles every 18 months
  - 60% increase per year
  - Chip density transistors/die
  - Micro processor speeds
- Exponential growth:
  - The past does not matter
  - 10x here, 10x there … means REAL change
- PC costs decline faster than any other platform
  - Volume and learning curves
  - PCs are the building bricks of all future systems

Computing Laws
Computer components must all evolve at the same rate

- Amdahl’s law: one instruction per second requires one byte of memory and one bit per second of I/O
- Storage evolved at 60%; after 1995: 100%
- Processor performance evolved at 60%.
  - Performance flat >1995.
  - Multi processors.
  - GPU
- Wide Area Network speed evolved at >60%
- Local Area Network speed evolved 26-60%
- Grove’s Law: Plain Old Telephone Service (POTS) thwarts speed, evolving at 14%!
Everything cyberizable will be in Cyberspace! Goal? Quest? or Fate?

Continent

Region/Intranet

World

Campus, including SANs

In Body

On Body

Car

Home

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Cyberspace: one, two or three networks? in 2005, 2010, 2020
Computer Classes...
Every Decade a new one emerges to cover Cyberspace

• Every decade a new, lower cost class of computers emerge defined by
  – Computing platform
  – Interface to humans or other parts of world
  – New networking and/or interconnect structure

• The classes… a decade in price every decade
  – 60s  $millions  mainframes
  – 70s  $10K-100K  minis
  – 80s  $10K  workstations and PCs
  – 90s  $1K  PCs
  – 00s  $100s  PDAs & cellphones
  – 10s  $10  wireless sensor nets, motes, etc.
Bell’s Evolution Of Computer Classes

Technology enables two evolutionary paths:
1. constant performance, decreasing cost
2. constant price, increasing performance

1.26 = 2x/3 yrs  
10x/decade; 1/1.26 = .8

1.6 = 4x/3 yrs  
100x/decade; 1/1.6 = .62
### Platform, Interface, & Network

#### Computer Class Enablers

- **Platform**
  - "The Computer"
  - Mainframe
  - Tube, core, drum, tape, batch O/S

- **Interface**
  - Mini & Timesharing
  - SSI-MSI, disk, timeshare O/S
  - Micro, floppy, PC, scalable servers, disk, bit-map display, mouse, dist’d O/S
  - Terminals via commands

- **Network**
  - POTS
  - LAN
  - Internet

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- **PC/WS**
- Web browser, telecomputer, tv computer

- **WIMP**
- Web, HTML
# Bell’s Nine Computer Price Tiers

<table>
<thead>
<tr>
<th>Tier</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1$</td>
<td>embeddables (e.g., greeting card)</td>
</tr>
<tr>
<td>10$</td>
<td>wrist watch &amp; wallet computers</td>
</tr>
<tr>
<td>100$</td>
<td>pocket/palm computers</td>
</tr>
<tr>
<td>1,000$</td>
<td>portable computers</td>
</tr>
<tr>
<td>10,000$</td>
<td>personal computers (desktop)</td>
</tr>
<tr>
<td>100,000$</td>
<td>departmental computers (closet)</td>
</tr>
<tr>
<td>1,000,000$</td>
<td>site computers (glass house)</td>
</tr>
<tr>
<td>10,000,000$</td>
<td>regional computers (glass castle)</td>
</tr>
<tr>
<td>100,000,000$</td>
<td>national centers</td>
</tr>
</tbody>
</table>

**Super server**: costs more than $100,000

**“Mainframe”**: costs more than $1 million

an array of processors, disks, tapes, comm ports
A New Computer Class Emerging

Scalable computers
Interconnected via IP

year

log (people per computer)

David Culler UC/Berkeley
Software Economics: Bill’s Law

Price = \frac{Fixed\_cost}{Units} + Marginal\_cost

- Bill Joy’s law (Sun): don’t write software for <100,000 platforms @$10 million engineering expense, $1,000 price
- Bill Gate’s law: don’t write software for <1,000,000 platforms @$10M engineering expense, $100 price
- Examples:
  - UNIX versus Windows NT: $3,500 versus $500
  - Oracle versus SQL-Server: $100,000 versus $6,000
  - No spreadsheet or presentation pack on UNIX/VMS/...
- Commoditization of base software and hardware
The Virtuous Economic Cycle that drives the PC industry

- Standards
- Competition
- Innovation
- Utility/value
- Volume
The Hz, Bits, Bytes, Pixels
CACM 1997 Predictions

Secondary Memory

Primary Memory

Processing

Processing

10^{18} (exa)

10^{12} (peta)

10^{12} (tera)

10^{9} (giga)

10^{6} (mega)

10^{3} (kilo)

1 1947 1967 1987 2007 2027 2047
Computing Laws

National Storage Roadmap

100x/decade = 100%/year

~10x/decade = 60%/year

Areal Density (Gbits per square inch)

Date

Jan-90 Jan-92 Jan-94 Jan-96 Jan-98 Jan-00 Jan-02 Jan-04 Jan-06

New NSIC Target
Molecular mechanics accelerator

- Pharmix has developed the first system to implement an entire molecular mechanics calculation on a single chip
- **1000x speedup** (vs. 1GHz PIII) supercomputer → one chip
  year 2020 → year 2002
- Enables complex simulations of drug-receptor interactions for unprecedented accuracy
Product and Industry Implications
Prediction, c 1995

• —in a 1995 Computerworld article headlined “The View from Here: Gordon Bell Previews a Future in Which Plugging in to a Worldwide Network Is as Easy as Getting a Dial Tone”

• **Mainframes, Minicomputers, Servers, and Workstations**

  Individual low-cost, high-powered PCs, such as Compaq Computer Corp.’s ProLiant, combined with Windows NT, SQL-based databases and a single communications network will form the heart of the scalable computer. You can say good-bye to mainframes, proprietary minicomputers, servers and workstations.
Very large disks … are the driver
Old world vs. New World

- Mainframe: a few TB
- Cents/transaction
- Cost: $85/GB
- Sparse transactions

- Scaled out PCs
- Zero cost/transaction
- Cost: $1M/year/petabyte
- Capture Everything!!!
  - Track every item e.g. sheet rock…serial no.
  - Phone call
  - Track every person x ad
Debit/Credit Benchmark – Jim Gray

1988: Tandem 10M 208 tps
IBM 2M 70 tps
2005: Toshiba PC 8350 tps
14M BofA accounts = 4 GBytes

Figure 1: A $10M Tandem 208 tps system (1, 2) and a 2M$ IBM 70 tps system (3) circa 1988. A $0.002M Toshiba 8,350 tps system circa 2005 (4); the desktop equivalent of this machine costs ~$400 in 2005 (5).
Archive.org

• Founded in 1996 to archive the internet
• Includes books, movies, music, and programs
• Copies: San Francisco, Alexandria, and Amsterdam
Brewster Kahle
Archive.org
1 petabyte store

$2K/terabyte/year

$0.0004/page/year
SAN FRANCISCO -- Marketers are testing new techniques to measure whether advertisers' messages are getting across, and they are prepared to spend vast sums and deploy astonishingly complex technologies to do so.

At the Ad:Tech conference in San Francisco last week, advertising experts contemplated a variety of approaches, ranging from round-the-clock automated ad tracking to simply reducing the number of ads per show, that could make it easier for advertisers to reach an increasingly fragmented viewing public.

To measure the impact of ad campaigns, VNU, the parent company of television-audience measurement firm Nielsen Media Research, and Arbitron, the media research firm, are developing an experimental program called Project Apollo that takes the concept of viewer tracking to a level of unprecedented detail.
I am data.
Re-discovery of Memex
As We May Think, Vannevar Bush, 1945

“A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility”

- Full-text search, text & audio annotations, and hyperlinks
The 1 TB Life

- 40 MB/day = 1 TB for 65+ years of:
  - 100 email messages a day (5KB each)
  - 100 web pages day (50KB each)
  - 5 scanned pages a day (100KB each)
  - 1 book every 10 days (1 MB each)
  - 10 photos per day (400 KB JPEG each)
  - 8 hours per day of sound - e.g. telephone, voice annotations, and meeting recordings (8 Kb/s)
  - 1 new music CD every 10 days (45 min each at 128 Kb/s)

- It will take you 5 years to fill up your 80 GB drive
- Want video? Buy more cheap drives (1 TB/year lets you record 4 hours/day of 1.5 Mb/s video)
Capturing what you see or hear
Wearable & interactive jewellery  LEDs flash according to sensor type triggered

Prototype V1

Fish Eye lens captures 180 degree view
LED for audio trigger
USB to PC
LED for motion trigger via accelerometer
Internal Digital camera 800 images/day
Sensory trigger

SenseCam 17 Oct 2003
Lyn
MSR Cambridge

A device for “personal video recall” of the days, weeks events.
“Where did I leave my keys? Where have I been? Who have I met?”
Potentially useful trivia – but not normally photographed
Convergence: Computers & Consumer Electronics
Cables/links
Speaker 5+1
Plasma 2 or 3
Cable/Enet 2
IR 8
Stereo 4
5.1 digital 2
Comp./S-video 3
Plasma panel 1
Power 10
Kbd/mse 2
Monitor II (opt.) 4
Camera 2
Total 42 – 46
Things 18+remote

*Video = composite or S-video
Microsoft Seeks Antitrust Dismissals

Joe Wilcox, Staff Writer, CNET News.com, News.com

Microsoft on Friday hopes to reverse a series of legal setbacks before a Baltimore judge, whom it will ask to dismiss three private antitrust cases pending against the software giant.

During a hearing before U.S. District Judge J. Frederick Motz, Microsoft will argue that cases brought by Be Inc., Burst.com and Sun Microsystems are without merit. Lawyers for the plaintiffs are expected to explain why the cases should be allowed to continue.

The cases largely draw on Microsoft's lengthy antitrust case, which effectively ended in November, with U.S. District Judge Colleen Kollar-Kotelly approving a settlement agreed to by Microsoft, the Justice Department and nine states.
Convergence: Computers, Phones & Consumer Electronics...
Personal devices

• Will the notebooks we all know and love to carry, take on a much smaller and or disintegrated form factor?
  – Phone+ camera, GPS, personal store, “PC”, body area gateway

• Tablet or book?

• General purpose or n special appliances?
OQO & Tiquit
Chameleon: PC/XP & CE phone c2001
20-40 MB; 400 x 800 pixels
SPOT Overview

Services
- MSN Operations Center
- Small Footprint CLR & Applications
- OEM Modules
- ARM720
  - 512K ROM
  - 384K SRAM
  - FM SCA Radio

Network
- Dedicated Ku-band Satellite Feed
- 12 kbps/radio station FM subcarrier broadcast
- Frame Relay
- WAN
- MSN Operations Center
- Components:
  - LCD
  - Battery
  - Module
  - Case & Strap

Watches
- Frame Relay WAN
- US:
  - All 50 states
  - Top 100 MTAs
  - 219 FM stations
  - 177M reach
- Canada:
  - Top 12 cities
  - 24 FM stations
  - 12.5M reach

And more...
What Are Smart Personal Objects?

**Smart Personal Objects**

- Everyday devices whose core functionality is amplified and improved with the addition of software
- Devices that provide people the personalized information they want, when they want it
- A new computing space that compliments existing technology and provides a new method for people to remain connected to their world

**SPOT**

**Smart Personal Objects Technology**

- Makes Smart Personal Objects smarter, connected and essential information tools for people
- Incubated in Microsoft Research for the past three years
  - Developed a new hardware platform to enable low power, low cost, connected devices
  - Extends the reach of .NET architecture into a smaller and broader class of devices
Dust Networks

• Incorporated July 2002
• Goals:
  – Turnkey networks
  – No embedded software development
  – Highest performance
• SmartMesh shipped Aug 2004
Conclusion

• **Wired** sensor networks are everywhere today
  – HVAC, security, power, lighting, process control, …
• Installation is dominated by wiring costs
• Commercial adoption of **wireless** sensor networks is gated by reliability and power consumption, and virtually nothing else
Flashback: 2002, UC/Berkeley

Intel Developers Forum, live demo
800 motes, 8 level dynamic network,

Seismic testing demo: real-time
data acquisition, $200 vs. $5,000 per node

Motes dropped from UAV, detect vehicles, log and report direction and velocity

50 temperature sensors for HVAC deployed in 3 hours. $100 vs. $800 per node.

vs.

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vs.

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Example uses

• Env. Monitoring, Conservation biology
  • Precision agriculture, land conservation, ...
  • built environment comfort & efficiency ...
  • alarms, security, surveillance, treaty verification ...

• Civil Engineering: structures response
  • condition-based maintenance
  • disaster management
  • urban terrain mapping & monitoring

• Interactive Environments
  • context aware computing, non-verbal communication
  • handicap assistance
    » home/elder care
    » asset tracking

• Integrated robotics
Energy Monitoring Pilot

• Honeywell Service: monitor, analyze and reduce power consumption
• Problem: >> $100/sensor wiring cost
• Solution: Dust SmartMesh
  – Entire SmartMesh™ network installed in 3 hours (vs. 3-4 days)
  – 9 min/sensor
  – Software developed in 2 weeks (XML interface)
  – 5 months, 99.97%
In a decade, the evolution:

**We can count on:**

- Moore’s Law provides ≈50-100x performance, const. $20\%$ decrease/year => ½ per 5 years
- Paper quality screens on watch, tablets… walls
- Terabyte personal stores => personal db managers
- Murphy’s Law continues with larger and more complex systems, requiring better fundamental understanding
- Astronomical sized, by current standards, databases!
- DSL wired, 3-4G/802.11j nets (>10 Mbps) access
- Personal authentication to access anything of value
- Ubiquity rivaling the telephone.
  - Challenge: An instrument to supplant the phone?
  - Challenge: Affordability for everyone <$1500/year
- Network Services: Finally computers can use/access the web. “It’s the Internet, Stupid.”
  - Enabler of intra-, extra-, inter-net commerce
  - Finally EDI/Exchanges/Markets
Decade out (cont’d)

We are likely to “get”:

- CaA/VS (Computer aided A/V sensing aka surveillance) aided by a new level of radio-linked networks
- Personal location tracking in many environments
- Sensing and non-sensing rooms with “total recall” of everything it saw and heard

Several platform/net classes form:

- Wireless, sensor-effector nets enable a variety of apps
  - On body monitoring/stimulation/x-delivery
  - Building sensing of everything (cf. CaA/VS)
  - Outdoor sensing/surveillance of everything
  - (Sensors/effectors/platforms are the apps!)
  - Serendipity: new platform/net/interface
The End