Computer Systems Research and the Transformation of Practically Everything

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http://lazowska.cs.washington.edu/MIT150.pdf



MIT150 SYMPOSIA

Computation and the Transformation of Practically Everything

Forty years ago ...















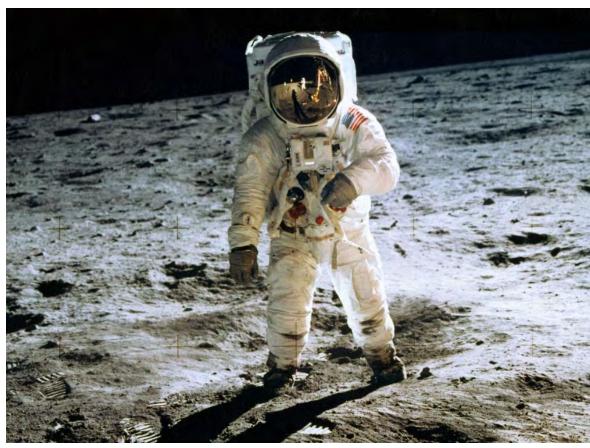


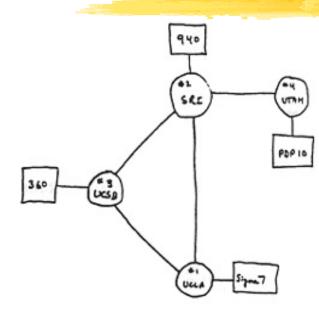


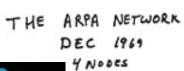


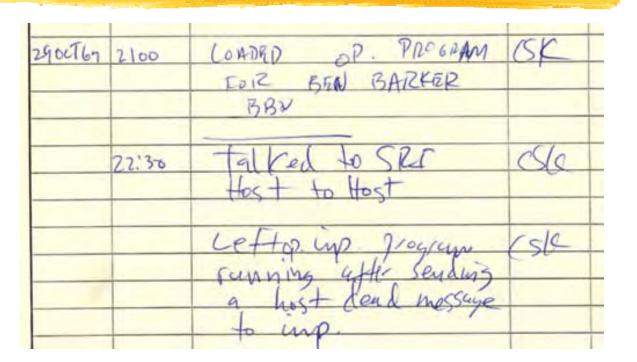














With forty years hindsight, which had the greatest impact?

Unless you're big into Tang and Velcro (or sex and drugs), the answer is clear ...



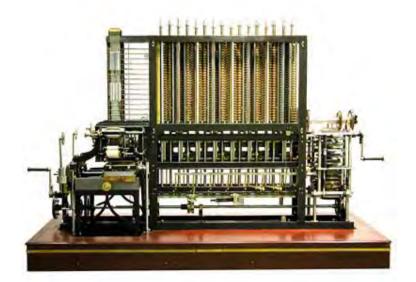


And so is the reason ...

EXPONENTIALS STUS



Mechanical



Babbage's Difference Engine No. 2 (designed 1847-1849, constructed 1989-2000) [11'x7', 8000 parts, 5 tons]

Vannevar Bush's Differential Analyzer (1931)

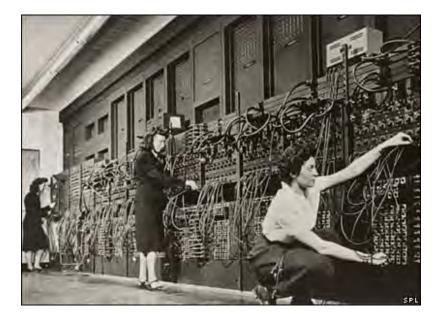




Vacuum tube electronic



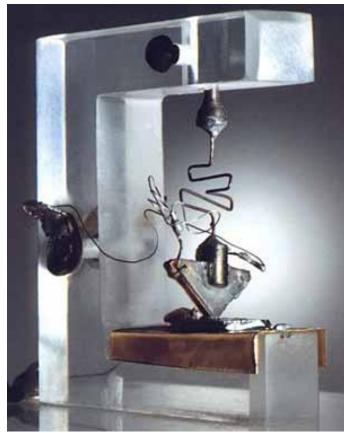
ENIAC (constructed 1943-1946) [8.5' (h) × 3' (d) × 80' (linear), 30 tons, 17,468 vacuum tubes, 150 kW of power, 5,000 additions/second]



The transistor (1947)

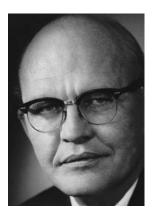
William Shockley, Walter Brattain and John Bardeen, Bell Labs



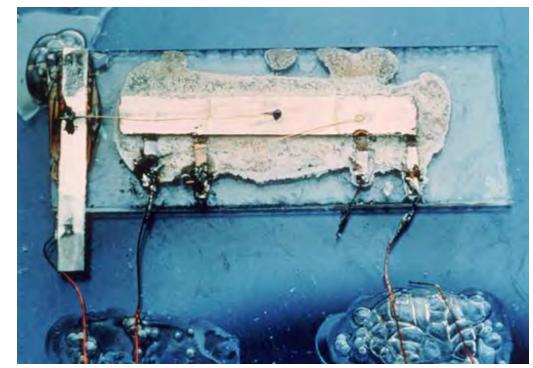


The integrated circuit (1958)

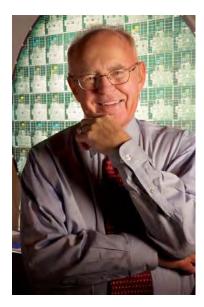
Jack Kilby, Texas Instruments, and Bob Noyce, Fairchild Semiconductor Corporation

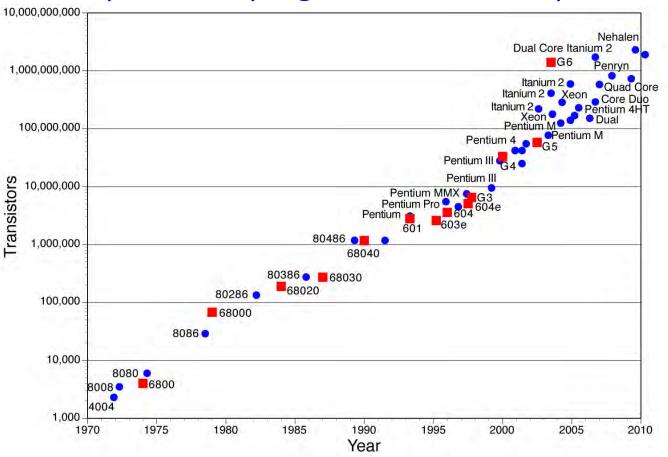






Moore's Law and exponential progress (1965-today)



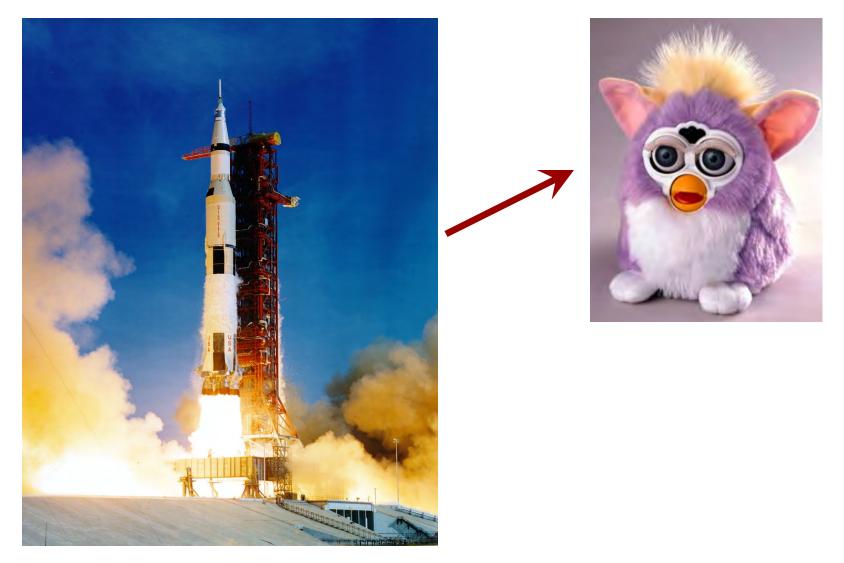






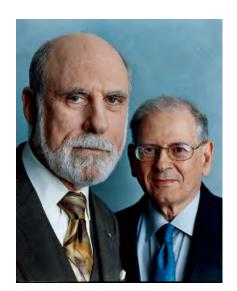








Ditto the Internet



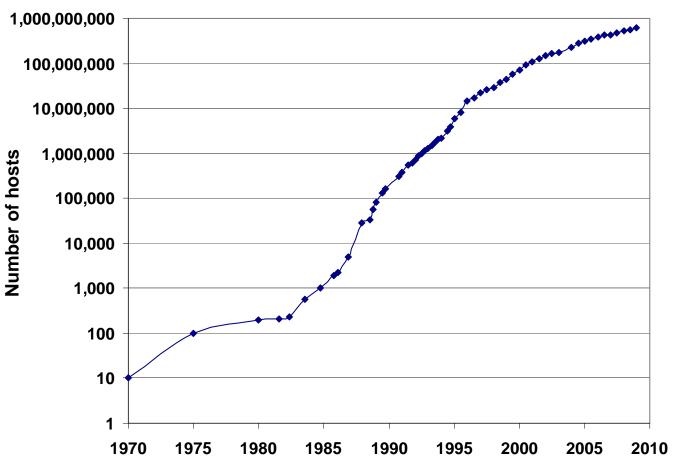


Table 1

BRIEF DESCRIPTIONS OF POTENTIAL HOME INFORMATION SERVICES

- CASHLESS-SOCIETY TRANSACTIONS. Recording of any financial transactions with a hard copy output to buyer and seller, a permanent record and updating of balance in computer memory.
- DEDICATED HEWSPAPER. A set of pages with printed and graphic information, possibly including photographs, the organization of which has been predetermined by the user to suit his preferences.
- 3. COMPUTER-AIDED SCHOOL INSTRUCTION. At the very minimum, the computer determines the day's assignment for each pupil and, at the end of the day, receives the day's progress report. At its most complex, such a service would use a real-time, interactive video color display with voice input and output and an appropriate program suited to each pupil's progress and temperament.
- SHOPPING TRANSACTIONS (STORE CATALOGS). Interactive programs, perhaps video-assisted, which describe or show goods at request of the buyer, advise him of the price, location, delivery time, etc.
- 5. PERSON-TO-PERSON (PAID WORK AT HOME). Switched video and facsimile service substituting for normal day's contacts of a middle-class managerial personnel where daily contacts are of mostly routine nature. May also apply to contacts with the public of the receptionist, doctor, or his assistant.
- PLAYS AND MOVIES FROM A VIDEO LIBRARY. Selection of all plays and movies. Color and good sound are required.
- COMPUTER TUTOR. From a library of self-help programs available, a computer, in an interactive mode, will coach the pupil (typically adult) in the chosen subject.
- MESSAGE RECORDING. Probably of currently available type but may include video memory (a patient showing doctor the rash he has developed).
- SECRETARIAL ASSISTANCE. Written or dictated letters can be typed by a remotely situated secretary.
- HOUSEHOLD MAIL AND MESSAGES. Letters and notes transmitted directly to or from the house by means of home facsimile machines.



 MASS MAIL AND DIRECT ADVERTISING MAIL. Higher output, larger-sized pages, color output may be necessary to attract the attention of the recipient-otherwise similar to item 10 above.

- ANSWERING SERVICES. Stored incoming messages or notes whom to call-possibly computer logic recognizing emergency situation and diverting the call.
- GROCERY PRICE LIST, INFORMATION, AND ORDERING. Grocery price list is used as an example of up-to-the-minute, updated information about perishable foodstuffs. Video color display may be needed to examine selected merchandise. Ordering follows.
- 14. ACCESS TO COMPANY FILES. Information in files is coded for security; regularly updated files are available with cross-references indicating the code where more detailed information is stored. Synthesis also may be available.

- FARES AND TICKET RESERVATION. As provided by travel more comprehensive and faster. Cheapest rates, info the differences between carriers with respect to see may be available.
- PAST AND FORTHCOMING EVENTS. Events, dates of event description; short previews of future theater plays past events.
- CORRESPONDENCE SCHOOL. Taped or live high school, a tional courses available on request with an option of graduate. Course on TV, paper support on facsimile.
- DAILY CALENDAR AND REMINDER ABOUT APPOINTMENTS. Propointments and regularly occurring appointments stor reminder.
- COMPUTER-ASSISTED MEETINGS. The computer participat meeting, answering questions of fact, deriving correolating trends.

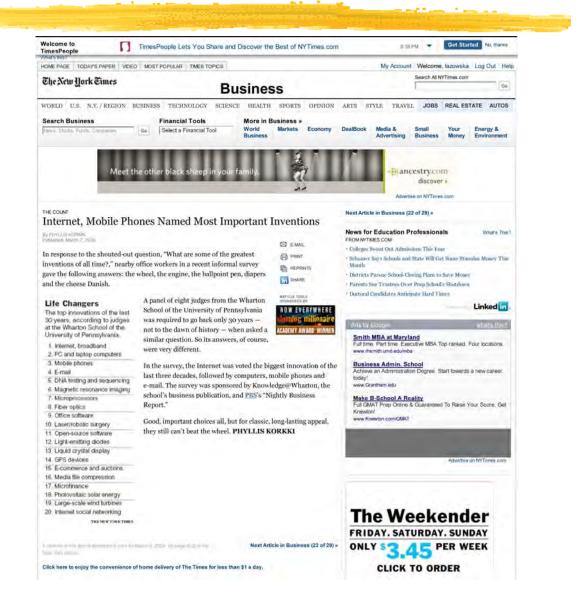


- NEWSPAPER, ELECTRONIC, GENERAL. Daily newspaper, possibly printed during the night, available in time for breakfast. Special editions following major news breaks.
- ADULT EVENING COURSES ON TV. Noninteractive, broadcast mode, live courses on TV--wider choice of subjects than at present.
- 22. BANKING SERVICES. Money orders, transfers, advice.
- LEGAL INFORMATION. Directory of lawyers, computerized legal counseling giving precedents, rulings in similar cases, describing jurisdiction of various courts and changes of successful suits in a particular area of litigation.
- SPECIAL SALES INFORMATION. Any sales within the distance specified by the user and for items specified by him will be "flashed" onto the home display unit.
- CONSUMERS' ADVISORY SERVICE. Equivalent of Consumer Reports, giving best buy, products rated "acceptable", etc.
- 26. WEATHER BUREAU. Country-wide, regional forecasts or special forecasts (farmers, fishermen), hurricane and tornado warnings similar to current special forecast sorvices.
- BUS, TRAIN, AND AIR SCHEDULING. Centrally available information with one number to call.
- RESTAURANTS. Following a query for a type of restaurant (Japanese, for instance), reservations, menu, prices are shown. Displays of dishes, location of tables, may be included.
- 29. LIBRARY ACCESS. After an interactive "browsing" with a "librarian computer" and a quotation for the cost of hard copy facsimile or a slow-scan video transmission, a book or a magazine is transmitted to the home.
- INDEX, ALL SERVICES SERVED BY THE HOME TERMINAL. Includes prices or charges of the above, or available communications services.



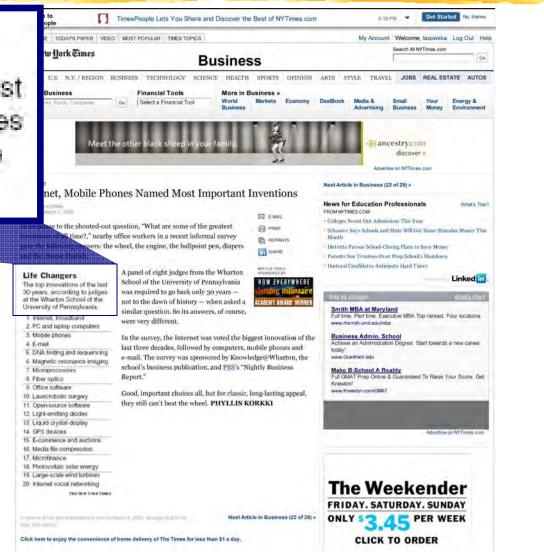
© 1971 SR-71-21 | Toward a Study of Future Urban High-Capacity Telecommunication Systems | Paul Baran | December 1971





Life Changers

The top innovations of the last 30 years, according to judges at the Wharton School of the University of Pennsylvania.

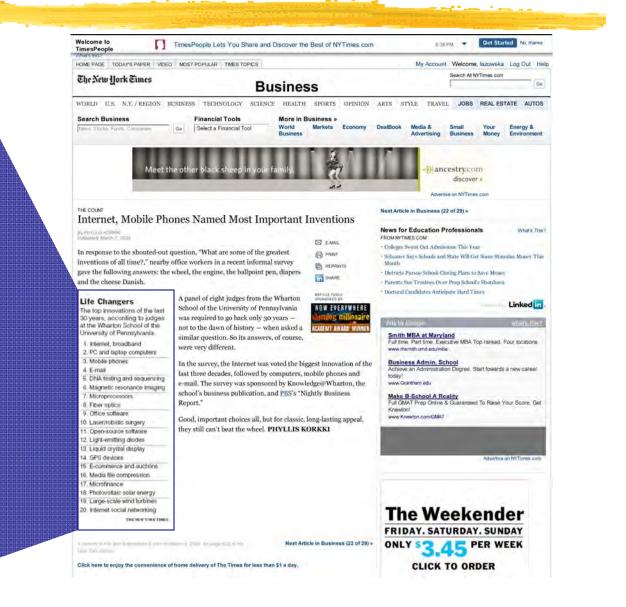


Life Changers

The top innovations of the last 30 years, according to judges at the Wharton School of the University of Pennsylvania.

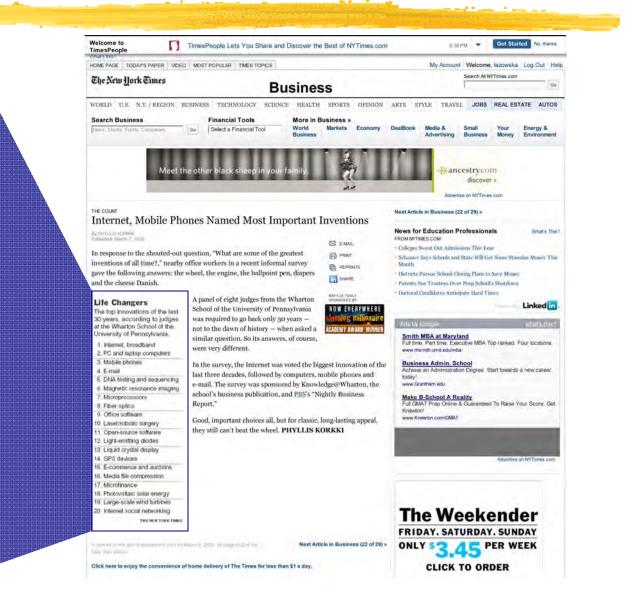
- 1. Internet, broadband
- 2. PC and laptop computers
- 3. Mobile phones
- 4. E-mail
- 5, DNA testing and sequencing
- 6. Magnetic resonance imaging
- 7. Microprocessors
- 8. Fiber optics
- 9. Office software
- 10. Laser/robotic surgery
- 11. Open-source software
- 12. Light-emitting diodes
- 13, Liquid crystal display
- 14. GPS devices
- 15. E-commerce and auctions
- 16. Media file compression
- 17, Microfinance
- 18. Photovoltaic solar energy
- 19. Large-scale wind turbines
- 20, Internet social networking





Life Changers





The most recent ten years ...

- Search
- Scalability
- Digital media
- Mobility
- eCommerce
- The Cloud
- Social networking and crowd-sourcing





Scalability



AlphaServer 1200 product brief

Leadership

"To support our rapid growth, we had to find a highly upgradable and scaleable Internet server. The AlphaServer platform provides the upgrade path we need."

Jeff Bezos CEO and Founder Amazon.com





"(The) AlphaServer series knows no rival."

Jeff Bezos CEO and Founder Amazon.com

> COMPAC Better answers

Compaq AlphaServer Series

OTHER STATES

Need a solution that can grow with you?

"(The) AlphaServer series knows no rival."

Jeff Bezos CEO and Founder Amazon.com

A decade later ...

- Vastly greater scale
- The cheapest imaginable components
- Failures occur all the time
 - You couldn't afford to prevent or mask them in hardware
- Software makes it
 - Fault-Tolerant
 - Highly Available
 - Recoverable
 - Consistent
 - Scalable
 - Predictable
 - Secure





Operational efficiency is part of scalability

- An IBM System/360 came with a full-time on-site support person
- Web services of the middle 2000's typically required 1 support staff for every 250 servers
- Microsoft Azure today requires only 12 support staff for 35,000
 2 x quad-core servers
 - 6 support staff in the US, 6 on the other side of the globe, to provide 24-hour support



Digital media







Simulation -> Communication -> Embodiment











In the next ten years, advances in computer systems will put the "smarts" in ...

- Smart homes
- Smart cars
- Smart health
- Smart robots
- Smart science (confronting the data deluge)
- Smart crowds and humancomputer systems
- Smart interaction (virtual and augmented reality)





Smart cars

DARPA Grand Challenge





DARPA Urban Challenge





Google autonomous car on US 101 near Mountain View CA

Autonomous Driving

Google's modified Toyota Prius uses an array of sensors to navigate public roads without a human driver. Other components, not shown, include a GPS receiver and an inertial motion sensor.



Smart crowds and human-computer systems







Smart interaction



Speech recognition (MSR Redmond)

- No push-to-talk
- 4-meter distance, no headset
- 80db ambient noise
- Microphone array costs 30 cents

Identity recognition (MSR Asia)

- VGA camera
- 4-meter distance
- Varying ambient light
- Sibling differentiation
- Tracking (MSR Cambridge)
 - Real-time
 - 100% on deal with compounding errors
 - All body types, all numbers of bodies
 - People are jumping like monkeys
- System performance (MSR Silicon Valley)
 - Machine learning training utilized massive parallelism
 - Xbox GPU implementation of key functions yielded several-thousand-fold performance gains



Watson, 2011

Ken Jennings, Watson, Brad Rutter





Watson, 2011

Bill Cassidy, Watson, Rush Holt



Trends

Everyone is building systems - complete systems

- You no longer do speech recognition, or identity recognition, or tracking, or system performance – you collaborate to create Kinect, or an autonomous vehicle
- AI and systems are converging
 - All systems must be "smart"
 - All systems must deal with <u>uncertainty</u>
- Ubiquity, embodiment, invisibility
 - Digital systems are part of the fabric of our lives: they are everywhere, they interface to the physical world, they are not thought of as computers - you don't have to think about them at all

Increasingly, "best efforts" is good enough (and that's good news, because it's all you can afford)

- Facebook, Amazon.com, Google don't have to get it totally right – it's more important to be there, to be fast, to be cool and innovative
- Reusable components are finally catching on
 - Watson integrated a huge number of independentlydeveloped components
 - Kinect will be a component in countless amazing systems

A left coast view of MIT's role



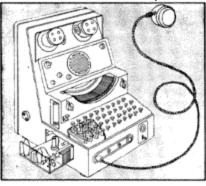
1931: Vannevar Bush, Differential Analyzer



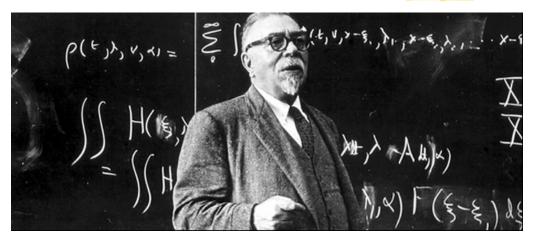


Video capture

Voice capture

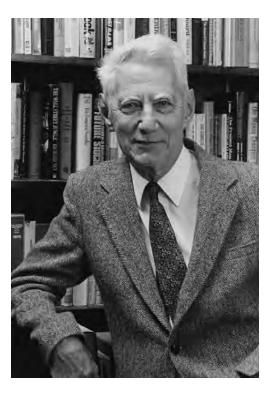


1945: Vannevar Bush, "As We May Think"



1948: Norbert Wiener, "Cybernetics"

1948: Claude Shannon, "The Mathematical Theory of Communication"



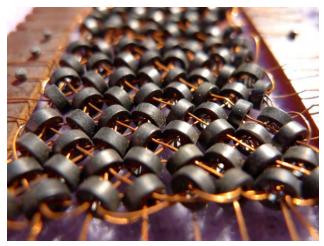




1951: Whirlwind



1953: Jay Forrester, core memory







1960: DEC PDP-1

1956: TX-0 (first transistor machine)



1962: Spacewar





1958: TX-2

1956: TX-0 (first transistor machine)



1963: Sketchpad (Ivan Sutherland)





1961: CTSS: time sharing, virtualization, text processing (RUNOFF), user messaging

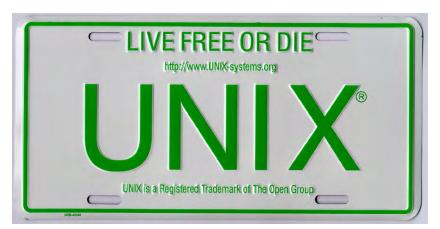


1963: Project MAC



1969: Multics

1969: Unix



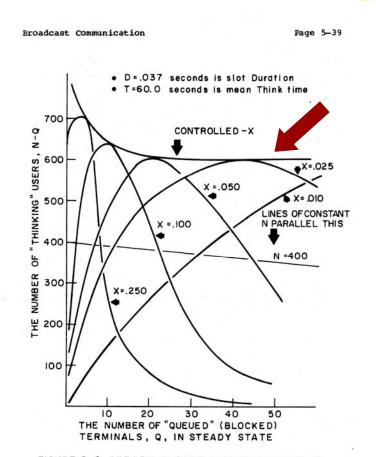


FIGURE 5-2 STEADY STATES OF A CONTROLLED-X SLOTTED ALOHA SYSTEM



1973: Bob Metcalfe and the genesis of Ethernet



1976: Emacs (Richard Stallman)

1978: RSA

A Method for Obtaining Digital Signatures and Public-Key Cryptosystems

R.L. Rivest, A. Shamir, and L. Adleman*

Abstract

An encryption method is presented with the novel property that publicly revealing an encryption key does not thereby reveal the corresponding decryption key. This has two important consequences:

- 1. Couriers or other secure means are not needed to transmit keys, since a message can be enciphered using an encryption key publicly revealed by the intended recipient. Only he can decipher the message, since only he knows the corresponding decryption key.
- 2. A message can be "signed" using a privately held decryption key. Anyone can verify this signature using the corresponding publicly revealed encryption key. Signatures cannot be forged, and a signer cannot later deny the validity of his signature. This has obvious applications in "electronic mail" and "electronic funds transfer" systems.

A message is encrypted by representing it as a number M, raising M to a publicly specified power e, and then taking the remainder when the result is divided by the publicly specified product, n, of two large secret prime numbers p and q. Decryption is similar; only a different, secret, power d is used, where $e \cdot d \equiv 1 \pmod{(p-1) \cdot (q-1)}$. The security of the system rests in part on the difficulty of factoring the published divisor, n.

1986: Thinking Machines CM-1 (Danny Hillis)





1983: GNU (Richard Stallman)







1994: World Wide Web Consortium (Tim Berners-Lee)

President's Council of Advisors on Science and Technology, December 2010



REPORT TO THE PRESIDENT AND CONGRESS DESIGNING A DIGITAL FUTURE: FEDERALLY FUNDED RESEARCH AND DEVELOPMENT IN NETWORKING AND INFORMATION TECHNOLOGY

Executive Office of the President

President's Council of Advisors on Science and Technology

DECEMBER 2010



"NIT [Computer Science] is arguably unique among all fields of science and engineering in the breadth of its impact ...

"Recent technological and societal trends place the further advancement and application of [Computer Science] squarely at the center of our Nation's ability to achieve essentially all of our priorities and to address essentially all of our challenges"



Is this a great time, or what?!?!

HAVING A GREAT TTME !!!! http://lazowska.cs.washington.edu/MIT150.pdf (Z) ZOZZIE