

The telephone company

Bell's patent in 1876

Bell system started in 1878

Within 10 years assumed form of 20th century "Bell System"

Originally point-to-point

Then manual switchboard with operators to connect

Then long distance switchboards

1882 Western Electric acquired to make all equipment

1925 Bell Laboratories organized to do research for Bell System

Government ran telephone system in most countries

Wires were strung overhead on large telephone poles with many arms

Original amplifiers were a microphone connected to an earphone

Signal quality became an issue on long circuits

"Loading" coils

Decreased dispersion

Placed a cutoff on frequency

Switching techniques

Need to connect any subscriber to any other

Labor intensive for operators

Automatic switching systems installed to increase speed and decrease costs

Call setup sequence

Request service

connect to operator

determine other number

select a path

test if not busy

if busy tell originator else ring destination

stop ringing when answered

determine when call is completed

tear down connection

(bill call)

drops replaced with lights

switchboards designed with multiple jacks and plugs for "trunks"

Automatic switching designs

1889, Strowger designed a mechanical switch that allowed fully automatic call connections

Difficulty was that equipment was committed to call as successive digits dialed

No global planning of route

Panel systems were designed that moved contacts over hundreds of contacts

Mechanical monstrosity

Noisy and poor quality connections

Crossbar relays could connect any of 10 (or 20) inputs to any of 10 outputs simultaneously

Crossbar offices would determine the destination without committing any resources and then globally plan a route through office

Common control circuits were called "markers"

Multiple markers could operate simultaneously in an office

Electronic offices developed to use computer technology

Largest problems were to count dial pulses ("touch tone" receivers were simpler)

Generate ringing voltages with low-voltage electronic components

Electronic offices (SS6, SS7 etc.) carried common control across the country

Routes are planned across the country

Changes in strategy can be implemented at a single point

"Mother's day"

Design

progression

cord boards

step by step

crossbar

ess

electronic

digital voice

Digital network

Was the largest distributed relay computer

originally mechanical replacement for operators

originally call committed equipment as it was dialed

common control developed

now a digital network of computers

Reliability

Spec for phone office is 1/2 hour outage in 40 years

redundant circuits and alternate paths a way of living

Many telephone offices combined many different technologies

#5 crossbar used special card punch to record error conditions

#4A tandem crossbar used edge punched metallic cards to store routing information

read photoelectrically

Many trunk circuits used radio / microwave links, vacuum tube amplifiers, transistor amplifiers

Traveling wave tubes used to amplify wide band signals

Disruptive Technologies

The Telephone Company assumed data was sent on dedicated links

Cost of setting up connection high so short connection times discouraged

Blindsided by data communication needs

Telephone company view

Dumb terminals, smart connection network

Value add in services provided by (and controlled by) network

New features controlled by the network

Charges for network features on use basis

three-way calling, call forwarding, call interrupt etc.

Internet view

Dumb network, no surprises, no value add

Smart terminals, all features controlled by terminals

New features deployed at terminals with no network changes

Value add is outside of network (google, amazon.com, ebay etc.)

Only value of network is forwarding packets

Charging model very different (and not sorted out yet, e.g., spam mail)

Feynman

Los Almos - How the bomb calculations were done
propagation of errors

Early Electronic Calculators

edvac

edsac

apexc

whirlwind

seac

Manchester machine

maniac

sage***

LGP-30

Serial

Magnetic drum

101 vacuum tubes

optimizing by placing data and instructions around the drum

DEC

pdp8

pdp6/10

IBM

650

701

704***

FORTRAN

709/7094

1401

1620

stretch/7030***

360/370

Univac

1101

GE

multics

burroughs

220

5500

6500

illiac IV

CDC 1604

CDC 6600/7600

Amdahl

minicomputers

nova

microcomputers

national SC, motorola, signetics, Texas instruments

intel 4004 - pentium

Computer Logic

mechanical

relays

vacuum tubes

diodes

cores (magnetic logic)

transistors

integrated circuits

bipolar

FET

Computer Memory

card punch equipment

hollerith

census

code

keypunch

verifiers

plug board programming

IBM

sorters

407 accounting machines

workflow by moving decks of cards

cards in mail for subscriptions, billing

relays

mercury delay lines

Williamson tubes

drums

core

mag tape

disks

RAMAC 305

integrated circuits

Mag tape

IBM 7-track - 9-track - high-density

linc tapes / dec tapes

cartridge tapes (gigabytes)

Themes in History of Computers

Many lessons from the history of computers and technology

Some of these lessons need to be learned many times

It is difficult to predict the future and future lessons

The past can be a guide to the future

"Those who do not know history are doomed to repeat it"

Cost and Size of

Logic

Originally very expensive - now virtually free

Memory

Originally very expensive - now virtually free

Speed

Mechanical - seconds

Relay - tenths of seconds

Drums - milliseconds

Tubes/core - microseconds

Today - nanoseconds

Speed of light is now an issue

1 foot per nanosecond (10^{-9} second)

Connections

Originally not an issue

Now connections dominate area in computers

Communications

Expensive vs Free

Memory

Bandwidth

Cycles

Computers

Communication

Digital vs analog

Digital is indistinguishable from analog if fine enough quantization

Quantitize space and time

Packets are now fast enough to be considered a continuous stream

Xerox call center volume of calls so big that was controlled like a pipeline

Serial vs Parallel

Serial simpler but slower

Parallel more complicated but faster

Serial will win if high enough speed

Control vs Individuality

Who is in charge?

Computer

Company

Government

Individual

Peripherals

Originally for convenience of computer

Now designed for humans or application

Example - Displays

Terminals

Teletypes

2741

IO Devices

Vector Graphics

24 X 80

Bit-Mapped Graphics

Hardware vs Software

Last century products were designed in hardware

Now features, interfaces etc. designed in software

Turn Around Time

Do it myself vs using tools vs special "coders"

Electrical engineering vs mathematicians

Assembly

Compilers

Libraries lapack linpack

Leveraging work of others always wins over "ego of doing it myself"

Fixed vs Floating-Point Computations

Early computers generally fixed-point

Decision was which one - too expensive for both

Floating-point looked down on because of harder error analysis

IEEE standard and previous implementations

Precision vs Speed

Some early computers had short word lengths

Cost of memory

Round-off errors accumulate depending on the length and stability of the computation

Faster, bigger machines did more floating-point operations so needed more precision to have any significance in the final answer

Early computer users knew numerical analysis (from calculator days)

Modern user puts in data and assumes computer is mathematically right

Exponent fields also growing increasing range of floating-point numbers

Change In Computer Applications

Originally, computers solved engineering problems about real numbers and continuous curves

Then commercial problems were the driver

Banks

Insurance

Inventory control

Linear programming

Gradually, discrete problems were attacked

List processing

Compilers

Networking

Communications

Arpanet

Internet

"The Web"

"Point-In-Time" Optimizations

Good at the time

Not generalizable

Not flexible

Eventually more general methods displace

Optimization no longer important

Other considerations become more important