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* table modified

STANDALONE COMPUTERS AND THEIR INTERACTION WITH NETWORKS

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The evolving computing environment is fundamentally a network structure permitting shared and standalone systems to communicate with one another. The introduction of both standalone and small, shared-computers will cause continued network evolution.

Figure GS shows the evolving network structure, with the constituent parts:

Switching--a nearly memory-less communications network that transmits messages (of varying length) among the other parts ushly along the lines of evolving value-added packet switched networks (e.g. Telenet Corp.).

Terminals with little or no programmability.

Remote job entry stations to handle various card, magtape input and to accept printed output and plotted output. Clearly high quality, and/or high speed printed output will continue to be required, although these stations will be relatively less in demand.

Standalone systems--require occasional access to other systems for data base updating (e.g. new programs and data), maintenance diagnosis, transmission of mail, communicating with users of similar systems, and overflow of work to more general, large stems.

Real Time computation--on an interconnected basis.

Multi-terminal Special Purpose computers for fixed functions programs. Various systems which trade off generality for size (and lower cost) must exist. A highly specialized system for Transaction Processing would resemble a general purpose timesharing system except that only a single language, single fixed program, fixed database would exist for a single function.

Multi-terminal General Purpose Shared Computers--these systems are becoming relatively more expensive, but must exist to handle tasks beyond the capability of other components, when required. As they are needed less by removing work from them, their cost increases. For the very large systems (e.g. ILLIAC IV, STAR), though uneconomical by current standards, will exist for highly specialized tasks.

Although all forms of current systems will clearly be less costly, they will continue to exist, but in a highly interconnected fashion because:

0. Human costs, relative to computer costs, is increasing at about 40%/year, making it uneconomical to not transmit machine readable information by persons.

1. The small, standalone (and shared) systems will successfully off-load the large shared (timesharing and batch) systems. This will require more terminal interaction; also these small systems require occasional assistance from their larger, more general counterparts.

2. Databases (lower cost disks) associated with small shared and standalone systems will be more distributed and some interaction will be required to both larger and other databases.

3. A plethora of highly specialized, cost-effective systems requiring terminal switching.

In the next section, the cost for people, terminals, and the amount available for computing are given. The cost and performance for the very large, shared computers and the very small computer are then compared historically. While looking at the very small computers is necessary, the purpose here is to examine the more ideal, standalone computer as it evolves from: terminals, hand-held and desk calculators, and the small computers. This section presents an ideal together with some of the uses. It also argues that use must be high in order to get the necessary low costs.

While the economic comparison is a factor, it is important to look qualitatively at the functions, and the pro's and con's of the large, highly shared system and compare it with the standalone. (Generally, this shows that while off loading occurs by the latter, there is a need for the former...and better networks.)

Finally, a table of currently available systems is given to illustrate the tradeoffs among price, performance, storage size, and program generality (use).

Relative and Available Costs for Computing

Table C shows the cost of a person (Human) in an environment together with some of the relevant computing costs, especially terminals. It is important to know the value of a computer to a user in order to know when various applications are feasible. Here we make the assumption that a computer must improve productivity by at least 10%; and that the additional 10% is available for computing. For a professional (e.g. lawyer, engineer, educator, businessman), we assume that the cost/year for these people would be about $40,000; hence, $4K is available for computing, and a 5 year amortization, this would equal a purchase cost of about $16,000. This is clearly a rough guideline and depends both on utilization and the value of the information processing (e.g. very high cost of errors in structural engineering tasks).

Table C OPERATING COSTS FOR COMPUTING

($1K)	Cost/Year	Cost/Hr.@2400Hr.
Human	0,5,10,20,40	0,2,4,8,16
Computer	1.2 to 2.5	.5 to 1.
Terminal	.25 to .75	.1 to .4
Service	.05	.02
Power	.005 to .01	.002 to .004
Line	0 to 2.4	0 to 2.
Paper	0 to .1	1/3 cents to 3 cents
Space	.05 to .1	.02 to .04
Amt Avail. at 10% human	,.5,1,2,4	0,.2,.4,.8,1.60

Cost and Performance Characteristics and Trends of Large and Small Computers

It is useful to look at how the relative cost of large and small computers have changed over the last few years. Table LS compares the PDP-8, and CDC 6600 (for 1967) with a hypothetical large computer and the LSI-11 (for 1975).

First, note a large increase in price differential over time, reflecting production learning for small computers, and more expensive design costs for large computers. While there may be economies of scale for larger machines, there is a fundamental economy of scale for small computers through production; this reflects an elastic demand. In the case of the primary memory, Mp price, there was barely a factor of 2 difference in 1967, whereas, in 1975, the price for the large machine had come down a factor of 2, and the price of the small machine had come down about a factor of 12.

For performance, two things should be noted about small machines: the basic speed is about the same for simple operations; but the performance for complex (real) operations is drastically improved reflecting better use of microprogramming to give large machine programming characteristics. In the case of the large machine, its performance/cost has gone up by a factor of 30. The performance differential between small and large is about 1000 in 1967; whereas this year, the performance differential is only about 5000, assuming a reasonable mix of floating point arithmetic. The better performance for this year's small machine acts to take work from the large machine. The large machine must find new, very large problems in order to be effective, since the best match for computers is to run on the smallest, least general that will do the job. (Running small problems on large machines generally implies idle resources, hence poor cost/performance.) Under these assumptions, the performance/cost characteristics are improving more for small machines, although the performance gap is wider. In neither year would we suggest that Grosch's law holds.

An Ideal, Standalone Personal Computer

There are several attributes a personal computer system would (might) have in order to achieve a high degree of use. Unless it's used, a shared system where a large fraction of the terminals are dormant will be more cost effective. Some of the attributes and their value ranges are given below:

Size	Fits in briefcase ≤ typewriter
Portability	Notebook → typewriter
Input	Voice, script, typewriter
Output	Voice, picture (2-3D), letter-perfect hard copy.
File Memory	Several 1000 pages (personal, database) ≤ 100 pages
Processor & Primary Mem.	Fast enough and large enough for applications
Program interface	Understands natural language for database > programming languages we know (e.g. APL, BASIC, COBOL, FORTRAN

Use	Text (with figs) preparation; plus in to send/receive mail; access to large database; pre-programmed functions (e.g. sketchpad, statistical analysis and data-plots);
programmable	

The degree of use depends on portability, size, convenience and our ability to communicate with it. The hand-held calculators have achieved high use by being portable (so they're always available), but have traded off human performance by having small, relatively hard to use keyboards. A typewriter keyboard is much more of the scale of the current finger sizes, although with genetic engineering, finger size could probably be decreased.

The personal computer in many respects is an active notebook and provides a convenient way of communicating with it through various channels (and ultimately voice), a substantial file memory that can be activated to search out information, and a programmable device to carry out algorithms. Assuming such a device existed for a programmer, it would contain his design notes, papers relevant to the design, any programs he was working on and the ability to check whether the program had valid syntax (assuming a large program which could not be run at the standalone site).

Qualitative Characteristics of Small (decentralized/personalized) Computers and Large, Shared Computers

Table Q gives this comparison. A large system is attractive because of the peak capability to handle any problem, whereas the small system is a private, bounded, simple system with independence of computing bureaucracy. A study by Seldwyn (1970) indicated a significant economy of scale with computer size according to the following relationship:

Total Cost = 8 X rental **.8

Advocates of personal computers predict an overhead cost of 0, but this is somewhat misleading, since the management, maintenance, programming, system programming, consulting, etc. of a computer center is now distributed with the user. For users of hand-held and programmable desk calculators, it should be clear that the programming cost is quite high...in fact many of these are programmed in octal and the user (programmer) has no backing store to retain a program, and it must be written down and then keyed-in each time used.

Again, we know that the best cost/performance characteristics are obtained when run on the smallest system that will do the task (assuming there is no idle capacity).

Table S gives the characteristics, prices and price/user for various scale computer systems from programmable desk calculators, standalone personal computers, through small shared computers to larger timeshared computers. In general, this comparison is for users who are doing text preparation and editing (as in a programming environment), accessing a database, running a pre-defined program, or program writing. The cost per user is highly variable over the range. The very large system is predicated on being able to run very large programs and provides a large virtual machine and/or memory environment; hence, the cost is high to provide this capability. By trading off some of this generality, the price is smaller for a DECsystem 10 (versus the 370). A large mini provides a similar environment to the very large systems, but it does so at the expense of generality, maximum program size, virtual memory, and speed. That is, when a large number of users are attached to a mini, we assume they are doing relatively small, well defined tasks (e.g. transaction processing, database accessing).

As we get down to the very small, single user standalone systems, the IBM 5100 and the DEC 11V03, the cost per user is relatively low even comparable to the timeshared systems. Here a user trades off program size, on line storage and associated database capability...although with the 11V03 system, about 200 pages of text can be on line with random access. The small calculator is of course very low cost, and nearly comparable in cost to a terminal for a shared system.

This indicates the very low cost of converting any mechanism (i.e. a keyboard and display) to a computer by the addition of a small amount of memory. This general trend will force dumb terminals to become programmed in some way.

A key aspect of the cost per terminal is the actual number of terminals in use (or dormant) at a given time. In some environments, if the utilization is quite low on a per terminal basis, it is clearly better to have a shared system because the cost for a dormant terminal is only about $1,000, whereas the dormant standalone system is much more expensive. Most timeshared systems are predicated on only 5% to 10% of the population available actually being connected. This phenomenon clearly argues for shared systems for some time. However, by providing standalone capability for editing text, utilization as a typewriter, and a data base increases the terminal utilization and forces usage away from a shared system.

Conclusions

We have tried to argue on historical grounds that small machines will continue to increase rapidly as prices decline. This creates more use and requires better intercommunication with all other computers. Better, personal computers, although they off load large, shared facilities still require interconnection for a variety of tasks. Thus, a rapid decline of large machines won't exist, but rather a relative decline compared to small machines.

Seldwyn, Lee L., ECONOMIES OF SCALE IN COMPUTER USE: INITIAL TESTS AND IMPLICATIONS FOR THE COMPUTER UTILITY, MIT Project MAC TR-68, June 1970.

FIGURE GS GENERAL NETWORK STRUCTURE OF EVOLVING COMPUTATION ENVIRONMENT

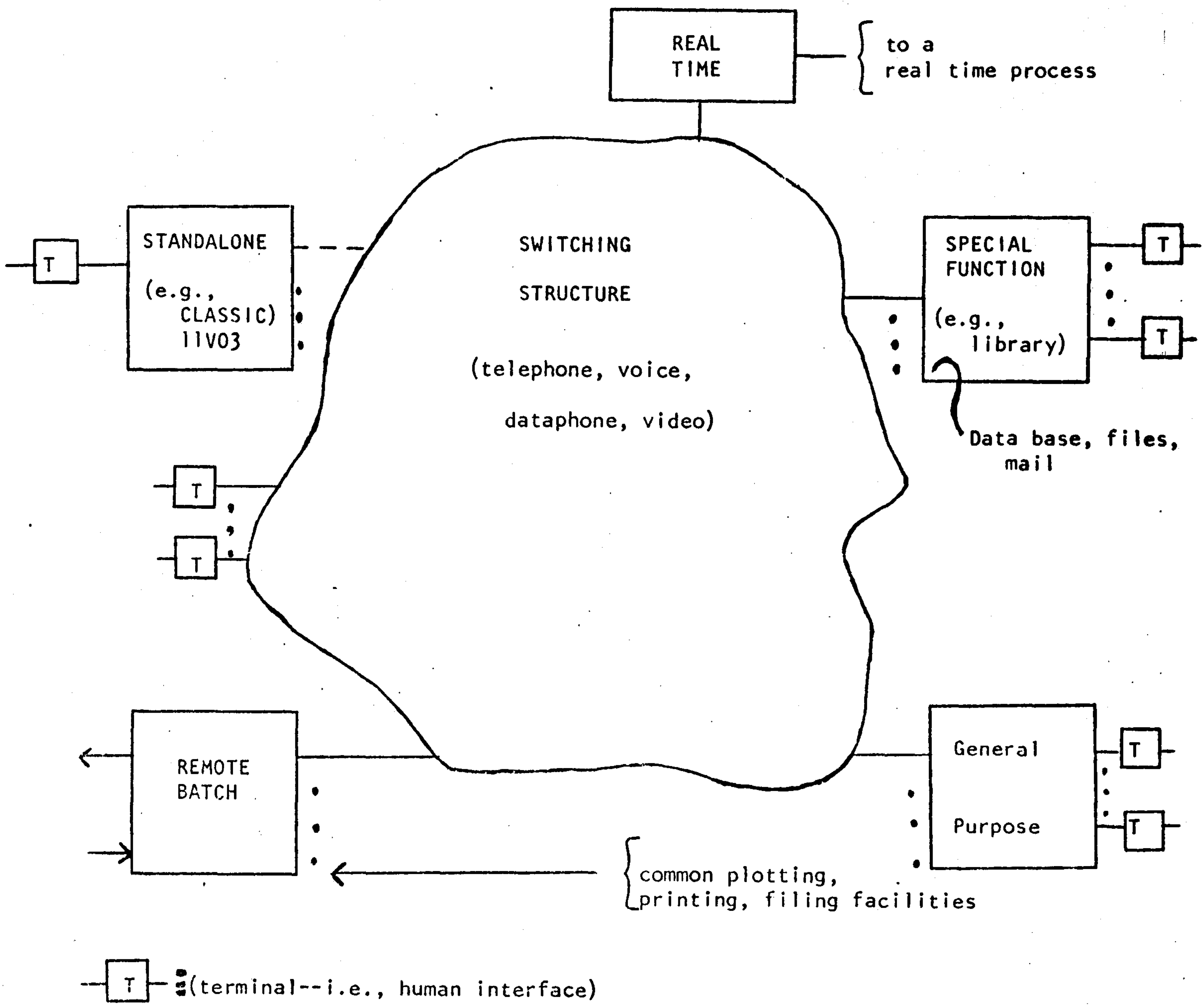

TABLE 5 CHARACTERISTICS OF VARIOUS SCALE SYSTEMS

	User Prog. Size (K bytes)	Mass Storage	Use	I/O	# Users	Purch. K$	Yrly Cost	Cost Yr(K$)	Cost User/yr($K)
Small Desk Calculator		Cassette	Algebraic Problems	Kybd (Special) Printer	1	5	1	1.3	1.3
IBM 5100 (Standalone)	16 (65 max)	Cassette	APL BASIC	Kybd. 5"CRT Printer	1	17	3.4	4.4	4.4
DEC 11V03 (Standalone)	16 (65 max)	Floppy	BASIC, Fortran, Text Prep. Data Base	Typewriter or (CRT)	1	10	2	3	3
Small, Shared System	16 – 65+ Virtual Arrays	On-Line Disk (Floppy backup)/take-away	BASIC, Text Prep., Data Base	Typewriter or (CRT)	8	50	10	22	2.8
Mid-Mini (e.q., 11/45)	16 – 65[redacted]	On-Line Disk (+ take away)	BASIC, Text Prep., Data Bases	Typewriter or (CRT)	32	100	20	44	1.4
Large-Mini (e.q., 11/70)	65[redacted]	On-Line Disk (+ take away)	BASIC, Fortran Cobol Data Base	Typewriter or (CRT)	20 50	250	50 50	110	5.5 2.2
Mid - G. P. (DECsystem 10)	1000*[redacted]	On-Line Disk	Lots	Typewriter or (CRT)	50+	750	150	300	6
Large, G. P. (System 370/158)	[redacted] 16,000[redacted] *	On-Line Disk	Lots	Typewriter or (CRT)	50+	3,000	600	1,000	20

*Virtual Memory organized

TABLE LS PARAMETERS OF LARGE AND SMALL COMPUTERS 1967 AND 1975

ACTUAL AND (RELATIVE)

1967	COST (K$)	WL	Mp.Size	$/bitx100	MIPs	MIPS X WL	REAL (MIPS)	PERF/COST (MIPS/MS)
8	10(1)	12 (1)	.05Mb(1)	20	.3 (1)	(1)	.002 (1)	30
6600	3K(300)	60 (5)	8Mb(160)	38	3(10)	(50)	3 (1500)	1
1975								
LSI-11	1(1)	16 (1)	4Kw(1)	1.6	.3 (1)	(1)	.04 (1)	300
Large	$10K(10^4)$	64 (4)	$1Mw(10^3)$	16	100 (10K)	(40K)	100(2500)	10

TABLE Q CHARACTERISTIC DIFFERENCES OF SMALL (decentralized)

VERSUS LARGE (central) FOR COMPUTATION

Attribute	Small (Decentral)	Large (Central)
Performance	Greater average	Greater peak Large memory (programs)
Cost	Economies through production f(COMM line, terminal, memory costs, and utilization)	Economy of scale for disk Cheaper when user utilization is low
	Production limited	Design limited
	Overhead of maintenance on individual (hidden)	Explicit, central maintenance costs
Use	Small (or 0) data bases	Large, shared data base; and/or general (undefined) large computational tasks
	Fixed, (well-defined) computation; or small computational (e.g., text publishing, program preparation, CAI, statistical)	
Security	Private	Public (but easy to share programs, data, etc.)
Reliability	Distributed	Central + Comm. System