March 14, 1969

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This draft is being distributed to give an indication of what kind of prices one might expect for Multics at M. I. T. Comment or discussion about either the assumptions or the policy is welcome.

(Note: Due to a mishap in distribution, this is just getting out, 3/27/69.)

Draft

March 14, 1969

A Proposed Pricing Policy for Multics at M. I. T.

By F. J. Corbató and J. H. Saltzer

The following notes are an attempt to outline a framework for a suitable pricing policy for Multics operated with a GE645 computer system. The present proposal, however, cannot be considered definitive since all M. I. T. computer prices must be approved by Richard G. Mills, Director of Information Processing Services. Rather, the intent is to expose the appropriate pricing issues as well as to give an indication of what services it is feasible technically to monitor for charging purposes.

Assumptions

The expression "pricing policy" is, of course, redundant since all prices contain within them a policy of usage encouragement. The policy which is considered of interest in the present case contains the following assumptions:

1. Prices will be such that at a load of 2/3 of the effective machine capacity for services, the revenue collected will equal costs. The 2/3 figure allows one to operate the system at some loss while usage is building up and at some gain while one is arranging for an expansion of capacity; it represents an attempt to operate the computer system on a "non-profit" basis in a university environment.

2. Prices of functionally distinct system services are determined by the "direct cost pools" of the equipment required to support these services exclusively. Prices are set such that the income from a particular service will just support the

cost of providing the service. Under these circumstances, prices of given services will change only slightly as the equipment configuration is enlarged (or contracted) to meet long-term change of usage needs. In this way, the management of the system will be in a position to be responsive to whatever direction user needs develop, and the users of the system will be given a correct set of incentives for making efficient utilization of the system.

3. To arrive at prices, all costs are divided into two categories: direct and indirect. Direct costs for a particular system service are those which are directly related to the service capacity; Indirect costs are defined to be those which are not direct. Prices for a given service are then obtained from the expression:

$$\text{service price} = (\text{service direct cost}) \times \frac{(\text{sum of all costs})}{(\text{sum of all direct costs})}$$

4. Prices given below are averages. Normally one would set price schedules for a given service which would vary according to the time of use and which would thereby encourage load balancing and more complete utilization of the system. For example, in CTSS the central processor prices vary from \$150/hour to \$330/hour with an effective average of about \$250/hour.

5. For our pricing example, the configuration of equipment which is assumed consists of:

1 - processor

2 - memory controllers with 128K words of core memory each

1 - 4M word paging drum

1 - GIOC

2 - disc units of 17M words each

6 - 120kc magnetic tape units (150"/sec, 800 bpi)

1 - each of card reader, card punch, line printer, system clock

This configuration, which is more than the minimum possible to support Multics, should allow a CTSS-like (or better) class of service. In addition, some benefits of scale in minimizing the cost/performance ratio are realized. The overall equipment rent and costs are comparable to that required for CTSS.

6. Abbreviations used are:

a. $K = $1,000

b. K words = 1024 words = page

c. M words = (1024) x (1024) words

Cost Pools

The following cost pools are proposed:

1. Central processor (1)
2. Core memory available for paging (128K words)
3. Secondary (disc) memories (34M words)
4. Teletypewriter communication equipment
5. ARDS terminal communication equipment
6. Indirect costs (includes core memory which contains the wired down supervisor, system clock, paging drum, magnetic tape drives, card reader, card punch, line printer, basic GIOC, operations cost)

The first five pools are of direct costs. The core memory available for paging is considered somewhat arbitrarily to be a single controller with 128K words; the other controller with 128K words is considered dedicated to the wired-down supervisor. (The 128K words wired-down figure is probably too high and will shrink with system programming refinement; it is unlikely, however, that it will ever go below 32K words for systems operated in the style of CTSS.)

The mechanism for charging for pageable core memory usage is an important one to understand since it allows charging correctly those users that minimize resource usage by sharing programs and data. The basic technique is for the supervisor program to periodically (e.g., every 10 seconds) remove access to all pageable blocks of program and data by changing each page table word to a particular kind of directed fault. Then as system operation proceeds, the first user process that attempts to access each page is momentarily delayed while the supervisor charges that user for the rent of the page during the next period of use. In addition, the normal page table entry is restored for subsequent immediate access.

The consequences of this technique are several:

1. No user is charged for the use of idle pages.

2. Users are charged for shared pages only if they are actively using them. Statistically averaged over time, the charge to a user for a shared page is inversely proportional to the number of other users actively sharing the page.

3. The period of usage sampling should be kept large enough so that the overhead of monitoring is less than, say, 1 percent of the CPU usage; conversely the period of usage sampling must be small enough so that round-off and statistical effects are of insignificant value relative to normal resource usage. It would appear that these constraints can be easily met.

4. Users have a direct economic incentive when designing programs to manage core memory requirements effectively since they will be charged for that core memory that they will actively use.

The indirect cost pool mentioned above includes items such as the unit record equipment and magnetic tapes which could easily be split off as separate direct cost pools. The effect of such splitting off will be to reduce slightly the other prices. Splitting off a service into a direct cost pool becomes important when usage of the service begins to grow and not all users of the system benefit equally from the service.

Overall Cost Summary

The basic cost figures given below are for monthly rental and represent normal commercial rates. In the case of the GE equipment the actual costs are arrived at by adjusting by a factor of 0.80 for an educational discount and by an additional factor of 1.05 for full maintenance service during 5-day second-shift operation. (Additional maintenance for third shift and weekends can either be obtained by individual service calls or by getting continuous maintenance coverage; in the latter case the factor of 1.05 becomes 1.12). Dataset equipment from the telephone company has neither educational allowances nor extra charges for maintenance.

Direct Costs:		
GE equipment (\$52K) (.80) (1.05)	\$43.7K	
Datasets	1.7K	
Subtotal		45.4K
Indirect Costs:		
GE equipment (\$51K) (.80) (1.05)	\$42.8K	
Operations (includes operator salaries with overhead but not floor space, etc.)	20.0K	
Subtotal		62.8K
Total Cost:		108.2K

Ratio of total cost to direct cost $= \frac{108.2K}{45.4K} = 2.38$

Prices

Direct costs are adjusted by the ratio of total cost to direct cost to yield prices.

1. Central Processor

equipment: 1 - CP 9031B \$15K

$$\text{price} = \frac{(\$15K)\ (.80)\ (1.05)\ (2.38)}{300\ \text{Hours}} = \$100/\text{hr.}$$

Note: 300 hours is conservatively assumed to be about 2/3 maximum usage.

2. Pageable Core Memory

equipment: 1 - CM 8030 (with 128K) \$21K

$$\text{price} = \frac{(\$21K)\ (.80)\ (1.05)\ (2.38)}{(100\ \text{pages})\ (300\ \text{hours})} = \$1.40/\text{page-hour}$$

Note: 100 pages for 300 hours is estimated to be the amount of core rent actually charged out during CPU usage since some pages will be idle.

3. Secondary Storage

equipment:	1 - DDA600 (adapter channel)	$ 680
	1 - DSC 11F (controller)	3360
	2 - DSU 10F (17M words each)	8200
		12,240 ~ $12K

$$\text{price} = \frac{(\$12K)\ (.80)\ (1.05)\ (2.38)}{(22M\ \text{word})\ \ (1\ \text{month})} = (\$1.09)/\text{page-month}$$

Notes: 1) assumes only 22M word rented out of 34M word capacity.

2) price does not include cost of disc maintenance, backup and retrieval procedures

4. Teletypewriter Communication Equipment

equipment:	3 - TTA600	$1260
	8 - TTC600	1000
	8 - TTL600	520
		2780
	48 datasets	$1200

computation: $2780 (.80) (1.05) = 2340

$$\text{price} = \frac{(\$2340+\$1200)\ (2.38)}{(11\ \text{consoles})\ \ (450\ \text{hours})} = \$1.70/\text{TTY console-hour}$$

Note:

a) Only 11 out of a capacity of 32 users are assumed to be logged in on the average during 450 hours of system operation.

b) There are 48 hardware ports to accomodate different classes of terminals and to respond to dial-ups even when the system is fully loaded.

5. ARDS Terminal Communication Equipment

equipment	2 - CAA600	$290
	2 - CAC600	570
		800

6 datasets $480

computation: $800 (.80) (1.05) = 670

$$\text{price} = \frac{(\$480+\$670)\ (2.38)}{(2\ \text{consoles})\ (450)} = \$3.04/\text{ARDS console-hour}$$

Note: only 2 ports out of a capacity of 6 ports are assumed to be dialed in on the average during 450 hours of system operation.

Comparison with CTSS

The prices given above are consistent with the improved cost performance of the GE645 system over earlier equipment. If one were to use Multics in a CTSS-like way and need 32K words of core memory, the effective price would be:

effective price = $100 + 32 ($1.40) + 30 (1.70) =

= 100 + 45 + 51 = $196/CPU-hour

where it is assumed 30 hours of console time are required to use one CPU-hour. This figure, which should be compared with the approximate $250/CPU-hour charge of CTSS, also allows more computation since the average instruction execution time of the 645 is faster than the IBM 7094 although not quite as much as the ratio of memory cycle times, (one microsecond to two microseconds), would indicate.

Summary

The present proposal has tried to show that it is possible with this structure to price Multics in a realistic and competitive way. Perhaps most significantly it is possible to design special text editors, and other sub-systems which are extremely economic to operate. (For example, a desk calculator program might be written allowing 10 interactions for 4 cents if each interaction required only 100ms of CPU time and 10 pages of core.) Such low-cost computing is particularly attractive since it opens up the possibility of developing new classes of computer applications on a mass scale while at the same time offering the subsystem designer the full range of the sophisticated Multics environment.