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MEASUREMENT OF LAWRENCE LIVERMORE LABORATORY CDC-7600 SYSTEM PERFORMANCE

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MEASUREMENT OF LAWRENCE LIVERMORE LABORATORY
CDC-7600 SYSTEM PERFORMANCE *

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ABSTRACT

Performance measures of machine utilization is done on a continuing basis at Livermore. A brief description of the sampling and presentation techniques are given. The impact of timesharing and heavy I/O loading is shown graphically.

* This work was performed under the auspices of the U.S. Atomic Energy Commission.

When the Lawrence Livermore Laboratory (LLL) acquired the first Control Data Corporation 6600 computer, it was decided to include time sharing in the system software and to connect all worker computers to a common data base. The result is an operational network called Octopus (Fig. 1). Users are permitted to log on to any of the CDC 6600 or 7600 machines. Machine identification is alphabetic. Card decks and printouts can be processed remotely. In the near future, additional user services will include keyboard display units and high-speed printers with graphic capability. The IBM trillion-bit photostore provides the data base for the worker computers. The data cell and disk packs are used for directory storage for the photostore and to provide medium lifetime storage for the user. A television monitor display system is available for interactive graphics.

One technique for gathering data about performance of the network is for the system software to tally events. At the present time, the CDC 7600 is the major computer and as such is the subject of most data gathering attention. The LLL configuration of the CDC 7600 is shown in Fig. 2. Only minor hardware differences, transparent to the user, are found on the three 7600's. Almost 200 software and hardware items are monitored on a regular basis and recorded in a table in the large core memory of the 7600. Once every 0.5 hr or on the occurrence of a system crash, the table is written to a disk file and the memory is cleared for subsequent entries. The disk file is 32,000 sixty-bit words in length. The records from each 0.5-hr interval are formatted in an end-around fashion; the most recent record replaces the oldest.

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About three 24-hr periods can be accommodated in this way. The disk file is accessible to all programs run in user mode on the CDC 7600.

The results of editing the disk file when output to hard copy run to about 40 pages for each machine. This count does not include errors concerning the file transport system and disk file units. Table 1 is a typical page of one edit of a typical run. One of the items of interest is the column labeled USER CPU. The INTERVAL shown to the left is given in hours. Most administrators choose CPU utilization to measure efficiency. If one were to review these edits regularly, he could quickly develop a feeling about the operation of the CDC 7600 at LLL. Unfortunately, the typical administrator does not have the time to devote to this kind of study so alternate techniques must be provided.

One means is to display the data graphically. The hard copy graph of time vs user CPU is shown in Fig. 3. At approximately 10 hr, there was a period of preventive maintenance and thereafter the beginning of the timesharing day. The large dip to the left of 20 hr is the result of very high timesharing activity during which the computer was 67% I/O idle. That means the queue of programs ready to compute was empty most of the time and the number of programs waiting for I/O to complete was unusually large.

A disadvantage of the graphing procedure is that it requires 24 hr for hard copy. To overcome this, the results are displayed on a CRT device that is connected to the television monitor display system (TMDS) on the PDP-10. An interpretive program was written to process the output of the edit program and to convert the columns of numbers into vector form. Once in vector form, the data can be displayed,

sent to hard copy, or manipulated further. The interpretive program permits arithmetic on the vectors, individual elements, or groups of elements within a vector. One of the more useful options in the program is the ability to receive commands from a disk file. The program is usually run in an interactive mode from teletype. By predefining all vectors on cards, the user can save considerable typing. He simply displays each graph frame by frame. If the results are of permanent interest, the user can activate another program, which causes hard copy pictures of the graphs to be made. Plans are being made to keep a continuous history of the edits in the photostore. This will be done automatically by system software and could be used to measure long term trends such as workload.

Figures 4 through 13 are taken from the same run as Fig. 3. Figure 4 shows I/O idle. The three periods where I/O idle dominates are characteristic of the timesharing activity, which presents an unfavorable I/O load. In the past, LLL experienced very little of this I/O idle. However, as more users take advantage of timesharing and as better conversational programs become available, the I/O capacity has been severely taxed. Figure 5 shows the percentage of memory occupied by programs waiting for I/O to complete. The number of jobs started is shown in Fig. 6. The dramatic dips during timesharing are system crashes. LLL has an open operation and as such the users present work to the computers without regard to schedule. Service is offered on a bidding system. Each user has a daily time allotment to bid with as he chooses and service is awarded

to the highest bidder, sometimes at the expense of overall system efficiency and to the detriment of other users.

Figure 7 shows the ratio of loads from disk to the number of jobs started. In the LLL timesharing system, jobs are rolled out from memory to disk when waiting for a reply from the teletype. The graph indicates a rough average of 5 to 6 messages per job. One measure, which is not plotted, reveals that between 60 and 70% of the time users will respond within 3 sec. One must assume that many of the responses are by rote.

The traffic that results from swapping programs between the two cores for execution is shown in Fig. 8. Although the numbers appear high, one does not find much of the CPU devoted to this task. Figure 9 shows the percentage of the CPU required to do the core to core transfers. The spikes of 6 and 8% are the result of user looping on a system call.

The total disk traffic in words is shown in Fig. 10. Once again, one sees the effect of timesharing. The last spike near 80 hr is above 250 million words in the 0.5-hr interval. This represents a highly buffered user program that received 80% of the CPU while moving this vast amount of data to and from disk.

One of the primary reasons for I/O idle during heavy timesharing is the time required to complete an I/O request. Figure 11 shows peaks of better than 1 sec for severe cases. Head motion or disk seek time is the culprit. Figure 12 shows spikes of 5000 moves per interval. The average worst case access time is 102 msec for these disk units. This contributes to a high degree of channel utilization, as shown in Fig. 13. Another problem is that the disk seeks are unevenly distributed across the available units. This is due to the fact that the utility files reside

on the same unit for ease of maintenance. The utility files, which receive high user attention during timesharing, include compilers, assemblers, and diagnostic routines.

Figures 14 through 17 indicate traffic on the file transport.

Figure 14 indicates words read with the major portion coming from the IBM photostore. Peaks of 20 million words near 10 hr and 25 million words near 60 hr are unusual. Figure 15, shows the number of words written. Note that the scale on this graph has a factor of 10 less than the previous Figure.

Message traffic is shown in Fig. 16. Messages from processes or programs to the users average about 2500 per 0.5 hr during the timesharing day. Messages or responses from the user to the process are somewhat less, averaging 1500 per 0.5 hr, as shown in Fig. 17.

As mentioned, a user can bid for computer time. When a user waiting for memory outbids users already in memory, those in memory will be rolled out and the high bidder rolled in. This bumping is measured and plotted in Fig. 18. Between 350 and 450 jobs were successful in bumping during the first timesharing interval. In Fig. 19, one finds the number of codes rolled out to make room in memory for the high bidders. An average of 2 or 3 jobs are rolled out for each successful bump.

We have presented only a portion of the graphs available. More edits are added as the need dictates. On the basis of these data, LLL is considering modifying the CDC 7600 by adding disk packs to give overlapped seeks, and to reduce head move and latency time. The edits also provide a measure of system operating efficiency. If there are large deviations in known measures, causes can be quickly pinpointed and corrective action

taken. The programming effort to gather and edit the data has paid for itself many times over. Evaluation of the present system and of future acquisitions would be difficult at best without it.

ACKNOWLEDGMENT

The author gratefully acknowledges the work of Henry Moll who wrote the interpretive program and Jeffrey Rowe who wrote the display program.

Table 1. Typical performance edit.

S 12/03/72 20.45152															
TIME	INTERVAL	USER CPU	IDLE CPU	IDLE IO	SWAP TIME	SYS CHG	SYS NCHG	IO CPU	*****C*****	*****A*****	*****V*****	*****N*****	*****E*****	ACTV MEM	I/O MEM
									DRUM	DISK	DISK	TAPE1	TAPE2	POPS	NEW MEM
12/03/72															
20.45	0.500	0.942	0.	0.048	0.005	0.000	0.002	0.000	0.002	0.007	0.039	0.014	0.009	0.	97.4 5.5 6.8
21.16	0.500	0.943	0.	0.048	0.004	0.000	0.001	0.000	0.002	0.039	0.036	0.	0.005	0.	98.3 5.9 7.8
21.45	0.500	0.942	0.	0.048	0.006	0.000	0.001	0.001	0.002	0.059	0.076	0.	0.	0.001	96.2 3.4 10.4
22.16	0.500	0.937	0.	0.053	0.004	0.000	0.001	0.000	0.003	0.030	0.035	0.	0.005	0.	98.0 4.3 7.7
22.45	0.500	0.933	0.	0.085	0.008	0.000	0.001	0.001	0.002	0.038	0.034	0.	0.005	0.000	97.4 5.4 13.2
23.15	0.500	0.782	0.	0.169	0.032	0.000	0.003	0.001	0.002	0.331	0.232	0.141	0.187	0.001	47.3 14.0 48.7
23.46	0.500	0.831	0.	0.116	0.033	0.000	0.004	0.000	0.002	0.195	0.231	0.185	0.171	0.001	59.1 9.8 21.1
12/04/72															
00.07	0.336	0.703	0.	0.102	0.025	0.000	0.004	0.000	0.004	0.109	0.204	0.130	0.212	0.000	59.8 10.5 19.7
00.37	0.500	0.872	0.	0.088	0.020	0.001	0.003	0.001	0.003	0.112	0.226	0.194	0.162	0.001	76.3 7.6 16.1
01.07	0.500	0.847	0.	0.124	0.037	0.002	0.003	0.001	0.003	0.164	0.148	0.272	0.228	0.001	90.2 10.3 9.2
01.37	0.500	0.845	0.	0.126	0.020	0.000	0.002	0.001	0.003	0.171	0.134	0.016	0.080	0.001	79.1 12.5 8.3
02.07	0.500	0.807	0.	0.167	0.018	0.000	0.002	0.001	0.004	0.229	0.133	0.053	0.059	0.000	72.1 17.0 10.8
02.37	0.500	0.783	0.	0.177	0.024	0.004	0.003	0.000	0.002	0.228	0.109	0.102	0.068	0.000	63.9 18.0 18.0
03.07	0.500	0.897	0.	0.072	0.017	0.002	0.002	0.000	0.003	0.134	0.105	0.117	0.001	0.000	41.3 3.7 55.0
03.37	0.500	0.933	0.	0.009	0.044	0.002	0.001	0.000	0.002	0.031	0.034	0.009	0.	0.	90.8 3.3 5.7
04.07	0.500	0.936	0.	0.005	0.044	0.002	0.001	0.000	0.003	0.044	0.034	0.005	0.	0.	91.5 3.2 5.3
04.37	0.500	0.804	0.	0.179	0.069	0.001	0.002	0.001	0.002	0.178	0.121	0.121	0.035	0.	73.0 10.9 16.2
05.07	0.500	0.183	0.362	0.433	0.010	0.000	0.000	0.000	0.003	0.240	0.091	0.101	0.149	0.	15.4 9.3 76.3
05.13	0.081	0.029	0.874	0.046	0.000	0.000	0.000	0.000	0.016	0.041	0.031	0.	0.001	0.	0.1 0.1 99.8
06.21	0.322	0.184	0.715	0.074	0.003	0.004	0.003	0.000	0.005	0.049	0.113	0.003	0.012	0.002	1.3 1.4 97.3
08.52	0.501	0.659	0.031	0.280	0.033	0.005	0.011	0.002	0.001	0.373	0.458	0.048	0.173	0.039	22.5 11.5 65.9
09.22	0.500	0.562	0.071	0.298	0.027	0.005	0.013	0.001	0.004	0.020	0.404	0.080	0.093	0.013	11.9 12.6 75.5
09.52	0.501	0.589	0.	0.498	0.036	0.009	0.030	0.002	0.005	0.897	0.781	0.154	0.132	0.017	34.9 34.9 30.2
10.22	0.501	0.618	0.	0.156	0.061	0.008	0.044	0.003	0.007	0.036	0.940	0.279	0.164	0.016	49.7 33.3 12.0
10.52	0.500	0.714	0.	0.120	0.038	0.004	0.027	0.002	0.004	0.304	0.711	0.057	0.06	0.014	57.6 20.2 12.2
11.22	0.501	0.434	0.	0.239	0.048	0.006	0.036	0.002	0.004	0.394	0.948	0.073	0.086	0.004	55.3 32.0 12.7
11.52	0.501	0.524	0.	0.359	0.027	0.008	0.044	0.002	0.004	0.697	0.951	0.288	0.164	0.005	49.3 39.3 11.5
12.22	0.501	0.741	0.	0.147	0.037	0.004	0.042	0.003	0.008	0.685	0.939	0.287	0.164	0.022	55.5 34.4 10.2
12.52	0.501	0.752	0.	0.149	0.032	0.004	0.040	0.003	0.004	0.628	0.948	0.254	0.040	0.016	36.3 33.9 9.9
13.22	0.501	0.435	0.	0.450	0.029	0.008	0.046	0.002	0.004	0.712	0.932	0.195	0.039	0.019	42.0 47.3 10.1
13.52	0.501	0.179	0.	0.674	0.013	0.011	0.063	0.002	0.006	0.798	0.985	0.214	0.165	0.019	32.3 55.9 11.9
14.22	0.501	0.309	0.	0.506	0.047	0.007	0.079	0.002	0.012	0.704	0.978	0.050	0.092	0.007	31.0 59.4 9.6
14.39	0.177	0.433	0.	0.423	0.033	0.009	0.053	0.002	0.005	0.620	0.975	0.057	0.132	0.005	22.2 66.5 11.2
15.09	0.502	0.552	0.	0.351	0.021	0.007	0.040	0.002	0.007	0.588	0.958	0.117	0.126	0.019	41.0 47.3 11.7
15.39	0.501	0.619	0.	0.283	0.021	0.008	0.044	0.003	0.007	0.580	0.922	0.036	0.045	0.017	47.5 41.8 10.7
16.09	0.501	0.575	0.	0.327	0.023	0.007	0.040	0.003	0.016	0.662	0.847	0.093	0.086	0.014	30.0 37.3 12.8
17.00	0.500	0.982	0.	0.019	0.038	0.005	0.028	0.002	0.008	0.568	0.708	0.090	0.236	0.010	56.5 20.5 13.1
17.09	0.500	0.994	0.	0.020	0.043	0.007	0.016	0.002	0.005	0.431	0.629	0.034	0.003	0.016	72.9 14.7 12.4
17.39	0.501	0.986	0.	0.028	0.041	0.004	0.016	0.001	0.004	0.434	0.510	0.165	0.006	0.016	73.1 10.7 16.2
18.09	0.500	0.943	0.	0.061	0.043	0.005	0.019	0.001	0.013	0.385	0.672	0.249	0.161	0.007	56.1 12.4 16.5
18.19	0.126	0.719	0.	0.150	0.045	0.004	0.019	0.001	0.003	0.467	0.693	0.371	0.143	0.000	49.7 35.1 15.2
18.49	0.501	0.711	0.	0.164	0.042	0.004	0.011	0.001	0.003	0.633	0.557	0.275	0.212	0.002	50.5 24.1 15.6
19.19	0.500	0.822	0.	0.112	0.039	0.003	0.008	0.001	0.003	0.381	0.406	0.201	0.058	0.003	70.7 14.5 14.7
19.49	0.500	0.873	0.	0.088	0.020	0.001	0.006	0.001	0.003	0.223	0.172	0.141	0.055	0.002	77.2 7.0 15.8
20.19	0.500	0.694	0.	0.219	0.052	0.004	0.012	0.001	0.017	0.726	0.336	0.187	0.393	0.001	30.1 35.2 14.8
20.50	0.500	0.837	0.	0.126	0.022	0.001	0.006	0.001	0.003	0.314	0.136	0.050	0.285	0.009	72.4 15.7 10.8
21.20	0.500	0.945	0.	0.011	0.030	0.002	0.004	0.001	0.003	0.132	0.119	0.064	0.025	0.003	94.5 3.2 12.3
21.50	0.500	0.882	0.	0.076	0.022	0.003	0.006	0.001	0.003	0.271	0.139	0.138	0.017	0.005	78.8 7.7 11.5
22.20	0.500	0.899	0.	0.374	0.010	0.003	0.007	0.001	0.014	0.250	0.206	0.079	0.021	0.003	92.2 7.1 10.6
22.50	0.500	0.913	0.	0.060	0.008	0.002	0.004	0.001	0.003	0.178	0.142	0.041	0.004	0.002	53.4 3.0 11.7
23.20	0.500	0.904	0.	0.070	0.013	0.002	0.004	0.001	0.003	0.194	0.195	0.059	0.004	0.003	92.8 7.3 9.9
23.50	0.500	0.932	0.	0.037	0.026	0.001	0.003	0.001	0.003	0.154	0.083	0.032	0.000	0.000	92.3 5.4 11.3
12/05/72															
00.20	0.500	0.723	0.	0.039	0.021	0.002	0.004	0.001	0.013	0.188	0.137	0.077	0.012	0.001	50.3 5.1 13.5
00.50	0.500	0.734	0.	0.036	0.020	0.001	0.003	0.000	0.003	0.190	0.037	0.069	0.030	0.007	94.5 7.0 4.5

FIGURE CAPTIONS

- Fig. 1. OCTOPUS network.
- Fig. 2. CDC-7600 LLL configuration.
- Fig. 3. User CPU utilization.
- Fig. 4. CPU idle for I/O.
- Fig. 5. Memory idle for I/O
- Fig. 6. Number of processes run.
- Fig. 7. Number of processes load-to-run ratio.
- Fig. 8. Number of core swaps per process run.
- Fig. 9. CPU time for swapping.
- Fig. 10. Total disk traffic.
- Fig. 11. I/O request completion time.
- Fig. 12. Disk seeks.
- Fig. 13. Disk channel utilization.
- Fig. 14. File transport read traffic.
- Fig. 15. File transport write traffic.
- Fig. 16. Output message traffic.
- Fig. 17. Input message traffic.
- Fig. 18. Number of successful priority bumps.
- Fig. 19. Number of programs dumped to accommodate priority bumps.

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Sutherland - Fig. 14

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Sutherland - Fig. 17

Sutherland - Fig. 18

Sutherland - Fig. 19