Abstract

This paper is concerned with the traffic evaluation of the central processing system controlled by the operational program for the DEX-2 electronic switching system which was designed by the Electrical Communication Laboratory in NTT.

In order to evaluate the traffic performance of the DEX-2 system, a traffic simulator to simulate seriously the DEX-2 operational program was programmed to run on the CDC 3600 computer. The following results were obtained: the occupancy of the Central Control, various service delays and the waiting time in serving the various types of work. From these results, the traffic handling capacity is estimated.

The simulator was used to compare the executive control plan of DEX-2 system with another executive control plan.

Finally, an automatic overload control for the DEX-2 system is described and its effectiveness under heavy load condition is showed from the simulation results.

1. Introduction

The DEX-2 Electronic Switching System designed to serve in large local offices has been in field trial at Ushigome Central Office in Tokyo, since December, 1969 and is to be placed in service in April, 1970. The traffic characteristics of the DEX-2 switching network made up with eight stage link system has already been reported. This paper is mainly concerned with the traffic evaluation of the central processing system.

The traffic engineering problems, which occur in the central processing system controlled by a stored program are too intricate to build a mathematical model representing in and to analyze it theoretically in detail. Therefore, a traffic simulator to simulate fully the DEX-2 operational program was programmed to run on the CDC 3600 computer. Results of the simulation were used to estimate the occupancy of the Central Control, various service delays, traffic handling capacity, as well as the waiting time in serving the various types of work and to study executive control plans, automatic overload control strategies and traffic measurement methods.

2. Executive Control Plan of DEX-2

The DEX-200 operational program which is the first software version for the DEX-2 system, has been described in the published paper. However, for convenience, an outline of the executive control plan of the DEX-200 is explained in the following.

Executive levels of the DEX-200 are normally divided into H (High), L (Low) and B (Base) in order of priority.

Both H and L levels are clock interrupt levels which is executed every 4 milliseconds. The L level always follows the H level and permits the next clock interruption. Every input and output job belongs to either the H or the L level and is cyclically executed in batch. The jobs to be performed at each interrupt level are specified by a prepared time table.

The other jobs are executed steadily in the B level which is interrupted by 4 milliseconds clock and restarts after the end of the L level. Most of the jobs performed in the B level are detected by either input or output program which runs during the interrupt level. As each program finds work, corresponding information is stored in special areas of the memory block called "transaction". Sometimes the input program is discontinued for lack of transaction. Then the next program is executed.

Jobs of the B level are divided into three classes: the 1st Q (Queue), the 2nd Q and 3rd Q in order of priority. The number of classes and the control method for this level are quite different from those in the No. 1 ESS. The
transactions are usually attached to the 1st Q when the output jobs such as speech path control, magnetic drum control were performed and to the 2nd Q when the input or output jobs, such as trunk scan, digit store, DP and MF digit sending, MF code receiving are performed. The 3rd Q is used for routine maintenance and administrative jobs.

Fig.1 shows the flow of the B level control program. As the class of the queue is decided, the program takes the first transaction from the queue. The order of service is "first-in, first-out". Control is then passed to the internal processing. The task analysis program analyzes the information in the transaction. As the task is designated, the task execution program performs it.

For example, the program hunts the trunk required, selects the idle links in the network by matching, edits the output order on a transaction block and attaches it to the output queue. When the above task is completed, the next transaction is taken from that queue, and processed. When the queue becomes empty, the control program goes to the queue of the next class and serves it in the same way. It goes without saying that the clock interruption occurs every 4 milliseconds during the processing of these works.

The traffic simulator consists of three parts; the input program, the simulation program and the output program. These programs were coded in FORTRAN but the simulation program has a few subroutines coded in COMPASS, the assembly language for the CDC 3600. The simulation program has about 37,000 words in amount, use memory areas of about 57,000 words. The run time of the simulation takes about 20 times to the real time.

(1) Input Program

The input data described by the traffic conditions and equipments of the office to be simulated, are read by this program. Then these data are edited as data of the simulation program and written on a magnetic tape.

(2) Simulation Program

The simulation is carried out by this program as reading the above magnetic tape. The program generates random numbers to simulate origination time, dial digit number, dial pause, ringing time, and conversation time which describe the behavior of customers. And the program simulates seriously the DEX-200. Then the times which the real DEX-2 takes to perform call processing are counted by an appropriate processing unit. These times are expressed by sum of instruction execution times to process the unit. The internal blocking in the network and busy of subscriber's line are assigned by generating random numbers. The program measures various aspects of the call processing performance, i.e., various service delays, waiting times for various kinds of equipments, queuing times in the queues, revisit time of each level, holding times of various kinds of equipments and so on. These measurements are written on a magnetic tape at appropriate interval.

(3) Output Program

The traffic measurements recorded on the above magnetic tape are classified, computed and printed output tables with the form of distribution by this program.

4. Traffic Characteristic of DEX-2

The simulations were performed under the standard traffic condition of large local offices in our country. The required numbers of trunks and equipments for the office to be simulated were assigned in conformity with telephone traffic engineering standard in NTT.

The simulations were carried out for 6 minutes in real time. Fig.2 illustrates the variations of the total calling rate (originating and incoming) and the occupancy of the Central Control obtained from the simulations. It can be seen that the system is in stationary state when the simulation run elapses more than 30 seconds. Therefore, the simulation results during last 5 minutes were analyzed.

4.1 Occupancy of Central Control

The occupancy of the Central Control (CC) is the defined by the proportion of CC time spent in call processing. The occupancy is composed of execution control part, input and output processing part and internal processing part. Some of the above occupancies depend on traffic condition and office size. However, if the traffic condition is fixed, the occupancy \( \psi \) is given by the following expression on an average.

\[
\psi = K + K_s C + K_s S + K_t T
\]

where \( K \) is constant occupancy, \( K_s, K_s \) and \( K_t \) are the proportional occupancies per call, per scanning of one subscriber line, per scanning of one subscriber line.
per scanning of one trunk row respectively. $C$, $S$ and $T$ are the number of calls, the number of subscriber lines and the number of trunk rows respectively. $K_1, K_2, K_3$ and $K_4$ can be obtained from the calculation of the call processing dynamic steps and the average execution time per instruction. The calculation results of the occupancy for the DBX-2 are shown by a broken line in Fig.3. It is seen that the calculated $\%$ values reach about 105 percent in the office with 30,000 subscribers. For comparison, the simulation results are shown by solid lines in the same figure where the occupancy is divided into the occupancies of the executive control, the $H$ level, the $L$ level, the $1st$ $Q$ and the $2nd$ $Q$ for reference. It can be seen that the simulated $\%$ values increase linearly according to the increase of office size as the calculated $\%$ values do so and the agreement between them is good if $\%$ is less than 95 percent. Therefore, the Equation (1) has sufficient accuracy for most practical uses.

In the case of higher occupancy, the time to revisit the $L$ level will lengthen. Hence the effective dynamic steps to process in the $L$ level will decrease. The fact that $\%$ in simulation becomes less than that in calculation is considered to be due to the above effect. This effect was evaluated from simulation results and good agreement was found.

4.2 Dial Tone Delay

Fig.4 shows the distributions of the dial tone delay in the offices with total calling rate of 0.1 erl. Since the occupancy of $CC$ in the office with 30,000 subscribers equals to about 99 percent from Fig.3, Fig.4 illustrates that the dial tone is returned to 99 percent of originating calls in less than 750 milliseconds even at 99 percent occupancy and good service to customers is sufficiently kept. It is because of the fact that average execution speed per instruction in the $CC$ is high (the speed of the DBX-2 is 3.4 microseconds) and the number of the Originating Register Trunk (ORT) are engineered to keep the efficiency within 70 percent. The latter results in fact that the waiting probability of ORT will usually be less than 0.02, and the average waiting time less than 2 milliseconds.

The dial tone delay is composed of the following time in processing order:

- Time to detect the origination of call by the line scan program.
- Time spent in the MD (Magnetic Drum) queue to execute the MD channel control program and to look into MD in order to translate the line equipment number.
- Time spent in the last queue to perform the internal processing.
- Internal processing time.
- Waiting time for ORT.
- Waiting time for the switch controllers.

Fig.5 shows the average dial tone delay...
divided into the above items. In the figure the fixed time expresses the sum of the internal processing time and the time spent in the SP queue. As the office size becomes more than 28,000 subscribers, the dial tone delay noticeably increases. A great part of the increase is occupied by the increase of the line scan delay which is caused by the delay of B level revisit. Therefore, the dial tone delay will be affected sensitively by small traffic fluctuation when the CC is operating at more than 95 percent occupancy.

**Fig. 5 Average Dial Tone Delay**

4.3 Talking Connection Delay

The talking connection delay is the time to switch from the ringing connection to the talking connection when a customer answers the telephone call. Fig. 6 shows the distribution of the talking connection delay for various office size. Assuming office size to be less than 28,000 subscribers, the delay to 99 percent of the customers will be set up in less than 500 milliseconds. Therefore, the talking connection service is kept good up to the above office size.

The talking connection delay consists of the following time in processing order:

- Time to detect the answer by the trunk scan program.
- Time spent in the 2nd queue to perform the internal processings.
- Internal processing time.
- Time spent in the SP queue to execute the SP control program.
- Waiting time for the switch controllers.

Fig. 7 shows the average talking connection divided into the above items. In the figure the fixed time is sum of the internal processing time and the time spent in SP queue. It should be noted that increase of the delay is due to that of the queueing time in the 2nd queue. As office size exceeds 28,000 subscribers (95 percent occupancy), the delays become
so long that they are noticeable and trouble to customers in many cases. Therefore, in order to make the CC operate at higher occupancy, we must study the means for eliminating the delays.

4.4 Traffic Handling Capacity

In addition to the simulations which make office size vary with the total calling rate fixed at 0.1 erl, we have carried out the simulations under several traffic conditions, i.e., variations of the total calling rate with the office size fixed, variations of the proportion of Push-Button station, variations of the proportion of multifrequency pulsing and so on.

From these simulation results, it has been estimated that the DEX-2 call processing system is able to process traffic of about 2,800 erl on the peaked busy hour of the year, although it was designed for the objective of 3,000 erl.

5. Another Executive Control Plan

One might think that the queueing time in 2nd Q is too long under the executive control plan of DEX-2. Hence the control method shortening the queueing time in the 2nd Q was investigated. As such an alternative we considered a base level control plan that unifies the 1st Q and the 2nd Q into one queue without priority, where the clock level control remains unchanged. In this control plan, it is evident that the queueing time to the 2nd Q is surely shortened at the expense of the one to 1st Q. Various connection delays affected by the above queueing time were studied by the traffic simulator.

It will be easily supposed that the difference between the queueing time in the 1st Q and that in the 2nd Q is negligibly small in the heavy traffic condition. Therefore, simulations are performed under the heavy traffic condition.

Fig. 8 illustrates a comparison between the distribution of the dial tone delay in the case of one queue and that in the case of two queues.

The dial tone delay is improved as expected, on the contrary the dial tone delay grew noticeably worse. The decrease of the dial tone delay is on an average about 70 milliseconds, which consists of the increases of the queueing time and the waiting time for the SP transaction. The increase of the waiting time is due to the increase of the holding time of the SP transaction when the queueing time is increased.

By the above mentioned reasons, the DEX-2 system has adopted the executive control plan using two queues with priority.

6. Automatic Overload Control

In order to use the CC at very high occupancy, it is necessary to apply efficient overload control. The simulations were used to study how to detect the overload and to limit the originations.

The means to detect overload of the CC are roughly divided into two categories. One is to measure directly the occupancy of the CC; effective or non-effective operating time of the CC, and the other to measure indirectly the occupancy; the 3rd Q revisit time, the
After 2 seconds, as the control logic finds that both states have been recovered and the cumulative idle time for 10 seconds exceeds \( T_2 \), the acceptable number of calls is increased by \( n_3 \). As such states continue for some cycle, the acceptable number of calls reaches the maximum allowed, then the system returns to normal state.

The above mentioned parameters, \( T_r, T_1, T_2, n_1, n_3 \) and \( n_2 \) are preassigned according to the traffic condition of the office.

The control logic is illustrated in Fig.9 and Fig.10.

6.2 Simulation Results

The simulations were performed under various types of heavy load condition. Two simulation results under the condition which is normal load with total calling rate (C.R.) 0.1 erl for the first 1 minute, heavy load for the next 2 minutes and normal load for the last 1 minute, are illustrated here. One of them has heavy load; both originating C.R. and incoming C.R. are equal to 0.065 erl (correspond to 100 percent occupancy of the CC). And the other has heavy load; originating C.R. 0.08 erl and incoming C.R. 0.05 erl.

And in the simulations control parameters are given as follows.

\[ T_r = T_1 = 0.5 \text{ seconds}, \quad T_2 = 1 \text{ second} \]

\[ n_1 = n_3 = 1, \quad n_2 = 2 \text{ seconds} \]

Fig.11 shows the variations of the total calling rate and the occupancy of the CC under a heavy load condition. Fig.12 shows the distribution of dial tone delay and Fig.13 the distribution of talking connection delay. In these figures, the same distribution in the case of no-control are showed for comparison. The present overload control acts efficiently and the service delays are sufficiently improved.

7. Conclusion

By using a traffic simulator to simulate seriously the DEX-2 operational program, the traffic performance of the DEX-2 system and an automatic overload control method for the system were evaluated.

Consequently, it has been estimated that the traffic handling capacity of the DEX-2 call processing system has about 2,800 erl.
Fig. 11 Variations of Calling Rate and Occupancy of CC, Overload Control Used

Fig. 12 Comparison of Distribution of Dial Tone Delay between Overload Control Used and No-Control

Fig. 13 Comparison of Talking Connection Delay between Overload Control Used and No-Control

on the peaked busy hour of the year and the overload control method is sufficiently effective and keeps good service even when the Central Control operates at 100 percent occupancy.

Comparison between mathematical analysis of the queueing in the base level and simulation results is remained.

References


(2) S. Takamura, H. Ogata and F. Ishino: An Electronic Switching System Program for the DEX-2, Rev. of ECL, 17, No. 11, pp 1346, 1969.