Design of the Data Switching System of the Japanese National Railways

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1. *Introduction*

It was in Nov., 1968 when the design of the data switching system was made a start in order to apply the system mainly to the freight information processing system of the Japanese National Railways (henceforward abbreviated as JNR). And the system was put into operation in May, 1970. In this paper, the procedure of designing the system is described, and the contents of the system are briefly presented.

2. *Aims of the System*

The system has two aims. One of them is to enlarge the freight information processing system in which the applications to transport freights on the inter-block express freight trains are handled on the on-line real time basis. The other is to have an enough experience to construct the central data switching system needed in the future data communication networks of JNR.

JNR already has the large seat reservation system handling about 500,000 seats a day. In the future, not only the passenger and the freight system but also the train operation system and the systems concerning accounting, purchases and stores, equipment maintenance, workshops, construction, etc. will be built up as the large on-line systems. Then a large number of the terminal devices will be used in common, and therefore the use of large scale data switching systems will be necessary. (see Fig. 1).

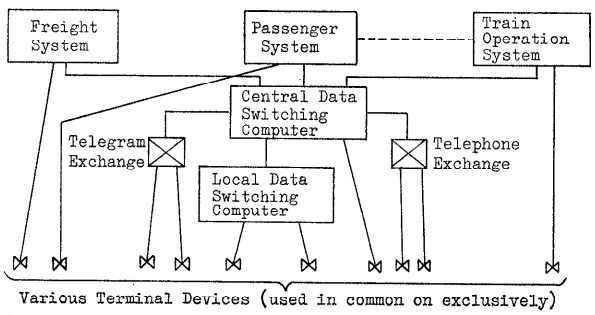

Fig. 1. JNR Data Communication Network Envisioned.

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3. *Data Types and the Flow*

Types of the data handled had to be made clear. In the system there are two types of the data, except the one used for the system operation. One is the type of the data used for the freight information system, and the other used for the JNR official multi-address telegrams. The data flow should also be considered as the next step.

4. *Communication Network*

The communication network of the system was considered to be the one shown in Fig. 2. In the figure, the terminals directly connected to the data switching computer are mainly for the handling of the freight information, and the ones connected to the cross-bar telegram exchanges, primarily, for the JNR telegram transmission.

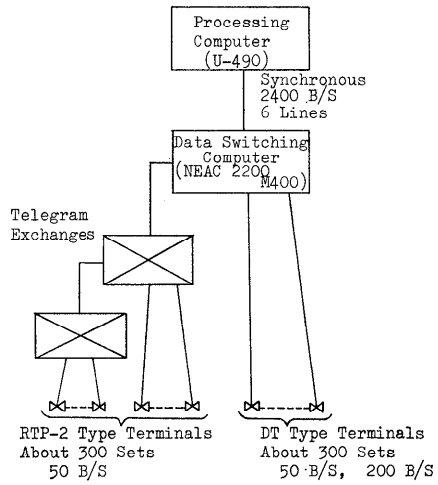

Fig. 2. Communication Network.

5. *System Requirements*

The system requirements should be made clear before the processing techniques are to be discussed. They are as in the following.

(1) 32KC cores are allocated to the background area for the concurrent batch processing to run the computer efficiently.

(2) 90% of the transactions in the busiest hour should be responded from the computer within 3 seconds.

(3) The number of the terminals directly connected to the computer is about 300, and among the terminals connected to the cross-bar exchanges, about 300 devices can communicate with the computer.

(4) The terminal devices, typewriter type, directly connected to the computer

are to be designed newly by JNR based on the ISO communication procedure standard. They will be named DT-type devices.

The terminals belonging to the cross-bar exchanges are the conventional JNR standard typewriter type devices (named RTP-2).

(5) The synchronous telecommunication lines having the transmission speed of 2,400 B/S are used between the computers.

(6) The recovery process of the system should be completed within 30 minutes.

6. *Composition of the Software*

The operating system, MOD 1 EXTENDED, was taken up to deal with the one real time job, and the one batch job concurrently. The structure of the resident programs and the flow of the data and control are shown in Fig. 3.

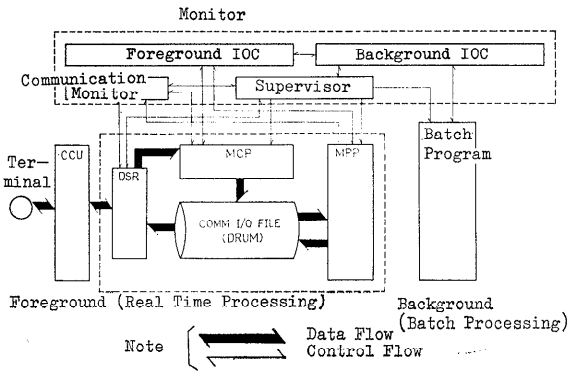

Fig. 3. Relations of Programs.

The supervisor program controls 3 tasks; MCP, MPP, and any background batch program. MCP is higher in the priority than MPP. And both of them are higher than any batch program. MCP mainly handles the freight data, and MPP deals with the multi-address telegrams and the system operating messages.

7. *Estimating the Transaction Volume*

Then the transaction volume should be estimated for the use of deciding the desirable processing ability of the computer. The transactions on the freight information were estimated based on the actual survey of the volume in Feb., 1969, and those on the multi-address telegrams were done in the same way.

8. *Functions of the System*

The functions of the system were also made clear when the system was built up. Table 2 shows the functions of general message switching systems, and in the table the functions the new system has are shown by the symbol "0".

Table 1. Estimation of Transaction Volume.

		Largest Scale			
		A	B	C	D
Freight	Sales	44,500	30	13,400	269
	Transportation	22,000	10	2,200	1,636
	Sub-Total	66,500	24	15,600	231
Total	(Including Telegrams)	79,800 (=66,500×1.2)		17,300 (=15,600×1.1)	

Note A: Transactions per Day
B: Rate of Concentration in the Busiest Hour (%)
C: Transactions in the Busiest Hour
D: Average Interval of Transaction Arrivals in the Busiest Hour (ms)

Table 2. Functions of the System.

	Functions	Does the new system have?	Notes
1	Various data or message switching	○	
2	Change of transmission speed	○	
3	Code Conversion	○	
4	Serial numbering	○	Serial numbering for the system is thought out.
5	Multi-addressing	○	Multi-address telegrams
6	Grouping of addresses	○	One address code contains several addresses.
7	Rerouting to an alternative terminal	○	Automatic and manual rerouting
8	Storing input data for some time	○	In case of misorder of lines or equipments or because of operational reasons
9	Grouping of transmission lines	○	For effective use of lines
10	Priority processing	○	
11	Error detection in incoming data	○	Detecting format errors, invalid addresses, etc.
12	Resending data by the request of terminals	×	No use of random file for resending by the request of terminals
13	Logging of data	○	Only important data are logged on magnetic tapes
14	Producing periodic system reports	○	Number of data in each queue, data counts, etc.
15	Status control of lines and terminals	○	Distinguishing normal lines and terminals from those in disorder
16	Testing lines and terminals	○	It is possible to test lines and terminals any time while the system is operative
17	Billing the users of the system	×	Not commercial system
18	Concurrent batch processing	○	Processing in the background area

9. *Computer*

The computer for the system was selected based on the following ideas.

(1) The computer would be large enough to be utilized as a local data switching computer, when the large scale data switching computer is placed in the center in future.

(2) A local data switching computer should process concurrently, in the future, the batch jobs now processed by a single computer in the regional divisions of JNR.

(3) The duplex system will be enough for the present switching computer. The computer, NEAC 2200 MODEL 400, was found to be the best, suited one.

10. *System Simulation*

Several months had passed since the system began to be built-up when the prototype of the control program was made. Then the processing time of a typical transaction on freight was calculated. The result is shown in Table 3. It shows that too much processing time is required to deal with the volume of transactions in the busiest hour.

Table 3. Processing Time of a Typical Transaction on Freight.

Processing Time by CPU (ms)	360
Time Required for Magnetic Drum I/O (ms)	100
Time Required for Magnetic Tape I/O (ms)	80

There were a lot of countermeasures discussed, and the control program should be reorganized to shorten the overhead time.

There arose a need to simulate the system, the aim of which is to set up a desirable CPU processing time of a typical transaction on freight. There were several cases picked up having different CPU processing time.

The results show that the CPU processing time would be desirable to be within half of the average arriving interval of the transactions at the computer. Therefore 100 ms to 150 ms will be desirable.

11. *Reconstruction of the Software System*

The followings are the countermeasures taken to shorten the CPU processing time.

(1) Change of the Processing Flow

As is shown in Fig. 4, the freight data are processed only in MCP, while in the conventional way, the data were processed in MPP through MCP.

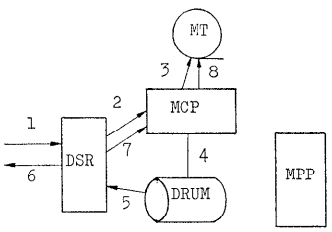

Fig. 4. Flow of a Transaction on Freight.

(2) Reconstruction of the Monitor Program

(a) Supervisor

The interrupt analysis routine and the dispatcher of the supervisor were reprogrammed.

(b) Communication Monitor

The communication monitor exclusive for this system was prepared.

(c) IOC

The IOC exclusive for the equipments used by the real time job was prepared.

The estimation of the processing time of a typical freight transaction after the above countermeasures were taken is shown in Table 4. The time was estimated almost a year before the system was completed.

Table 4. Estimation of CPU Processing Time of a Typical Transaction on Freight.

Routine	Processing Time per Once (ms)	Times	CPU Processing Time (ms)
Interrupt	2.6	15.4	41
DSR	4	9	36
MACROs			18
MCP			15
Total			110

12. *Controlling the System*

(1) Two-Job-Control

The real time job and the batch job are processed concurrently as mentioned above.

(2) Dynamic Buffer Control

The buffer control routine takes up a core buffer one by one from a buffer pool when necessary.

(3) Traffic Control

The terminals and the processing computer transmit data at random. And the switching computer has equipped with limited resources. In order not to stop the system operation because of the excessive traffic, the program is prepared for controlling the use of the resources.

13. *Data Format and the Standardization*

Various data are handled by the switching computer, and the data formats should inevitably be standardized.

The formats wereformed based on the following ideas.

(1) Not complicated (especially for the use between the computer and the terminals)

(2) So well standardized as to be used even in the future
(3) The items often used should be arranged before the others
(4) The items when not necessary could be negligible
(5) The freight data sent from the terminals should be in one block, the size of which will be limited to a certain number of characters.
(6) The other data can be sent in several blocks to the switching computer.

14. *Data Transmission Procedure on High Speed Lines*

The data transmission procedure between the computers should also be standardized for the future development. No intervention of operators makes it easier to establish the procedure. The procedure should be formed to eliminate useless steps and to prevent data from being lost.

To eliminate redundancy, the data link establishment and release phases are not used. To prevent data from being lost, ACK1 and ACK2 for acknowledgement are used interchangeably. This procedure has NAK1 and NAK2 for negative acknowledgement. NAK1 is used when a parity check error occurs. NAK2 is used almost when the system is in want of buffers.

15. *Closing*

The system was completed with more efficient processing ability than expected. The CPU Processing time of the completed system is decreased almost to the half of the value shown in Table 4.

About a half year has passed since the system was completed. During the term, the system has quite normally been operated, which may prove the design of the system successful.

In the closure, it should be mentioned that the project team was much obliged to Mr. Ozeki, former telecommunication section chief of JNR, and many other JNR and NEC members concerned with the work for the success of the system design.