New Seat Reservation System for Japanese National Railways -Distributed Processing Network and High Efficiency Databases-

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INTRODUCTION

The development of a seat reservation system by JNR (Japanese National Railways) named MARS has been sustained by the growth in passenger transportation operations and the progress of computer technology in Japan. But passenger operations of JNR handled only 23 percent of total passenger traffic in 1985 and the growth in the share of JNR is trifling today. Therefore more efficient and economical operations are being demanded from all departments of JNR.

MARS is also required to evolve into an integrated sales management system which can handle efficiently not only seat reservations but also all commodities of JNR such as a wide variety of tickets and package tours. And for expanding terminal network into wider area, high efficiency of the database performance related to main on-line application processing is strongly required.

MARS 301, a new seat reservation system, has been developed to meet these requirements. This paper describes the distributed processing networks and high efficiency databases of this system.

HISTORY OF THE DEVELOPMENT OF MARS

Before the computerized reservation system was introduced, booking of JNR trains had been handled manually. The first experimental system for seat reservation became operational in 1960, when computer technology was rudimentary. This system was called MARS 1 (Magnetic electric Automatic Reservation System), intended for reservation of 4 trains (2,320 seats per day) on Tokaido Trunk Line between Tokyo and Osaka. A full-fledged introduction of the system on a nationwide basis, however, was initiated with MARS 101 in 1964. MARS 101 was an on-line real-time system employing a computer of "the second generation", which was able to accommodate 3,000 seats reservations per day.

Since then, to cope with rapid growth in the number of passenger seats resulting from extension of the Shinkansen, etc., MARS system was replaced and improved step by step, expanding its services. MARS 101 through 104 were introduced at intervals of one and a half to three years. The maximum number of available seats showed a progressive increase from 30,000 to 500,000. In 1970, each system of MARS 102, 103 and 104 was converted to MARS 105 and all booking of reserved seats has come to be processed by MARS 105 since 1973.

MARS 105 adopted a tandem configuration to process huge volumes of transactions and to handle 1,000,000 seats reservations per day. This system consisted of a front-end system, the Communication Computer subsystem (CC) and a back-end system, the File Computer subsystem (FC). The CC itself was a tightly coupled multiprocessor system and one operating system controlled two processors that shared a common main memory. The FC was composed of two single processors, FC 1 and FC 2.

Two more on-line systems for seat reservations were connected to MARS 105. One was a group and party reservation system, called MARS 202. The system provided information on seat availability over long periods and could reserve up to 980 persons in one operation. Additionally it could handle complete package tours, including hotel accommodations, cars, meals, etc. to meet the growing demand for fast and easy holiday reservations.

The other was a telephone reservation system called MARS 150. This system, introduced in 1975, made it possible for customers to reserve Shinkansen seats by use of touch-tone telephones. The inquiry data is keyed in through a telephone and the response is given in human voice by an audio response system. After that, tickets for the reserved seats were issued from a terminal of MARS 105 using the reservation number included in the voice response.

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In 1982 the development of MARS 301 has been stated. In the first step of the development, a preliminary subsystem of MARS 301 which controls new terminal has been built. Then it absorbed the function of MARS 150. Finally it was connected to MARS 105.

OUTLINE OF MARS 301

Since MARS 105 and 202 were introduced in the early 70's, it gradually became difficult to expand their services to customer demands for lack of hardware capacities.

In 1985, a new seat reservation system called MARS 301 was introduced to replace MARS 105 and 202. As stated in the introduction, the preliminary subsystem of MARS 301 was already under operation to handle terminals which support new functions,before the completion of the total function of MARS 301.

MARS 301 is an integrated sales management system and handles not only seat reservations but all commodities of JNR, thereby improving services to customers and facilitating clerical work at ticket counters. Besides a specially-designed terminal for MARS 301 is able to issue various kinds of tickets such as ordinary fare, entrance, special charge and pass-type tickets in addition to reserved seat tickets. Moreover the terminal is able to print out all kinds of tickets with Chinese characters and pictures of dot pattern. It also encodes magnetically the information for automatic cancellation of reserved seats and price and for automatic ticket inspection on the back surfaces of these tickets. In addition, the time necessary for issuing a ticket is very short on account of the distributed processing on the terminal communication network.

MARS 105 and 202 had independent train and seat information files. However MARS 301 maintains only a unified database containing such information to insure maximum utilization of available passenger seats.

It operates on an on-line basis continuously with only a few operators under the control of specially-designed system consoles which watch the basic status of each processor and reduce operation time and operators'errors. As for background batch processing, MARS 301 maintains large databases on disks up to 20 G bytes including marketing data, inspection settlement data and statistical data. All of daily and monthly reports are made through accesses to these databases under the

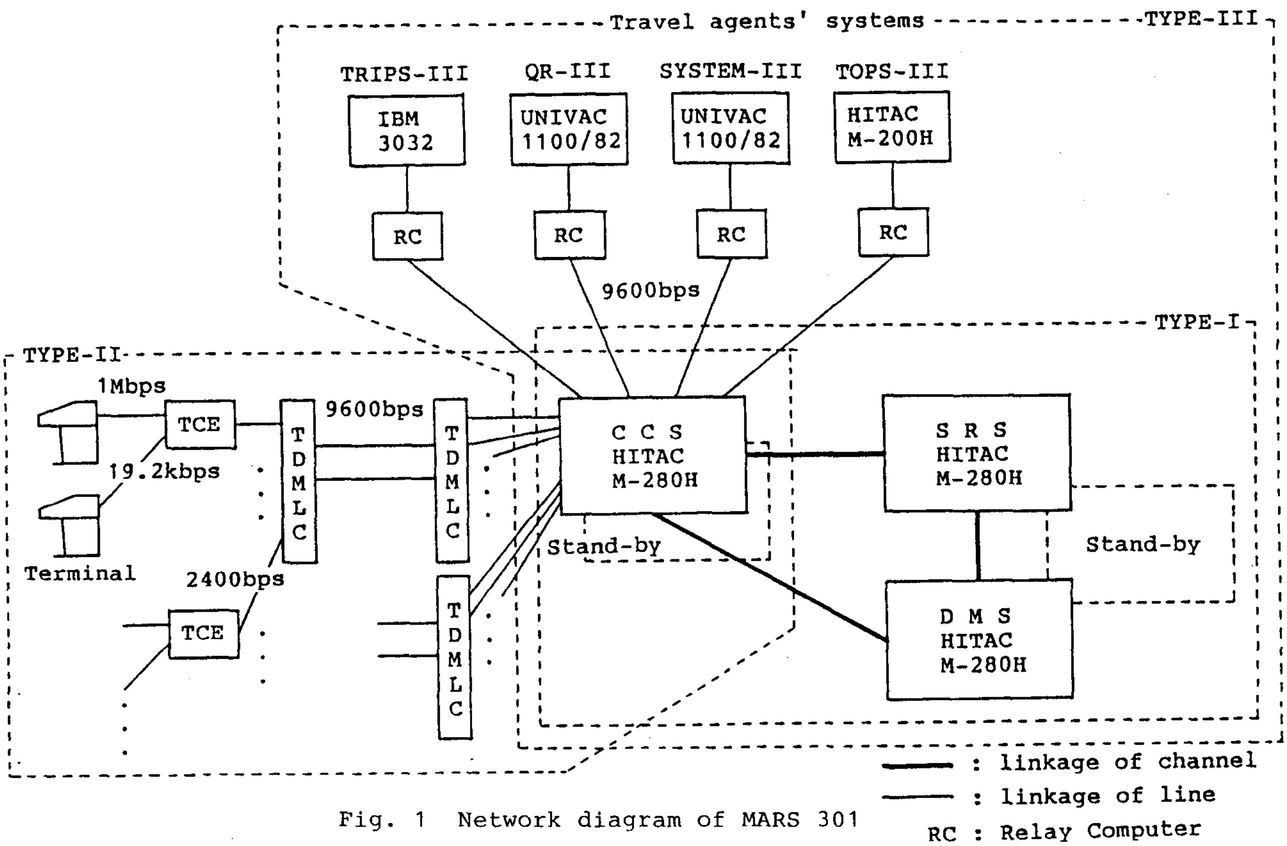

Fig. 1 Network diagram of MARS 301

control of automatic operation facilities.

MARS 301 has three types of distributed processing networks illustrated in Fig. 1. Type I is a triangular network of the subsystems at the central site, namely computer complex systems with high performance. The peak traffic totals more than 2,000,000 transactions per day. Type II is a terminal communication network on which the distributed processing is implemented to shorten issuing time of tickets. Type III, a travel reservation on-line network, is the on-line linkage of MARS with computer systems of four major travel agents in Japan. This network contributes to expansion of the sales networks in the market and improves efficiency in selling integrated tour packages.

DISTRIBUTED PROCESSING NETWORKS AND DATABASES

Triangular network of the subsystems at central site

MARS 301 consists of three computer subsystems connected to each other via channels: the Communication Control Subsystem (CCS), the Seat Reservation Subsystem (SRS) and Data Management Subsystem (DMS). These are functionally-distributed systems to process huge volumes of transactions amounting to more than 100 calls per second at peak.

CCS controls all of the networks, terminal status and traffic flows to SRS and DMS. Moreover, CCS is a back-up system for the terminal communication network and operates on an on-line basis day and night. It also controls an audio response system for telephone reservation facilities in place of MARS 150.

SRS maintains the central database and processes the main on-line applications for reservation. Most of the seats can be reserved for one month in advance. For party passenger travel, reservation is able to be handled for any date within six months. When no seat on the requested train is available, several alternative trains with vacant seats are selected automatically in SRS and displayed at the terminal through CCS.

DMS has a passenger information database containing complete records of the travelers' itineraries to make adjustments easy and instant, in case a passenger needs to change a train or a whole itinerary before a trip. This database is available mainly for party passenger travel. DMS also processes selling operation of tour packages through the travel reservation on-line network replacing MARS 202. The large databases for batch jobs processed in DMS are updated midnight, after all the transaction trail data have been collected from CCS and DMS.

To secure high reliability and availability, CCS is provided with a dedicated stand-by computer and SRS/DMS with common one. Monitoring facilities for a hot stand-by system supervise and will switch each processor to a stand-by one, if any trouble occurs.

High efficiency database in SRS

In the top season for travelling such as summer vacation, there comes so many traffic for seat reservations. One of the most significant features of seat reservation business in JNR is that requirements of bookings concentrate on some specific and small number of trains. Also the trains which bookings are concentrated on vary from hour to hour and season to season. Therefore it cannot be a solution for improving efficiency to distribute the database in simple manner.

In SRS, for improving efficiency of the central database, as shown in Fig. 2, the part of the database is copied dynamically onto the main memory during the processing. The database copied from the central database contain all the information about the fixed number of trains. The strategy to determine which train should be on the memory is followed by the order of arrival of the booking transactions. The coping process continues until the volume of the copied database from the central database reaches some fixed value. Afterwards main on-line application processing concerning reservation is continued by using both copied database on the memory and the central database.

In this method, the more transaction for some trains concentrate, the more increase the probability that the information for the trains is on the memory. Also as copied database are replaced at fixed interval, it can follow the changes of the requests timely.

The value of the fixed interval for data swapping mentioned above is very critical for the strategy. Because the more frequently database is changed so that the probability that adequate trains are on the memory becomes high, the more overhead time for database reloading is required. We fixed the value by results of several simulations on real booking transaction data.

At the designing stage, we decided system parameters, that is, the number of CPUs, channels and controllers and

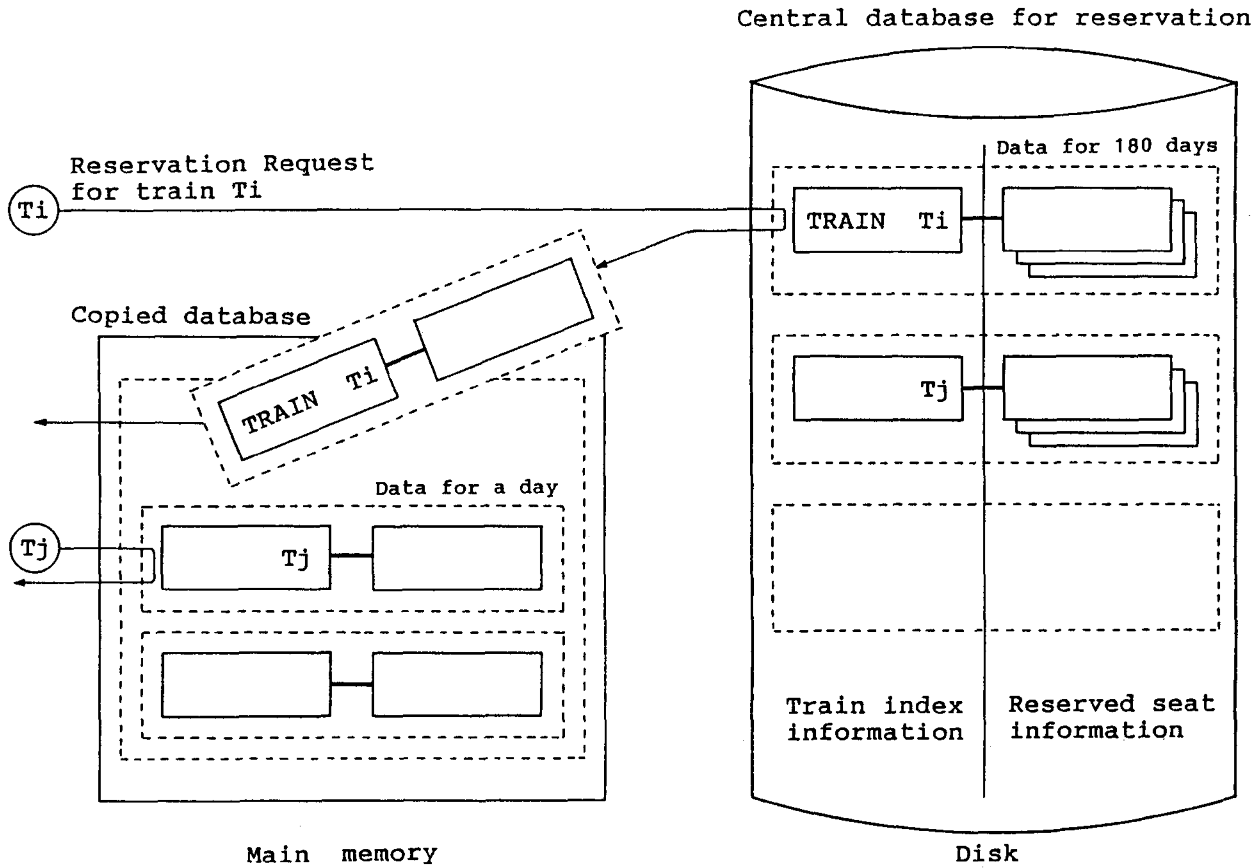

Fig. 2 Data allocation strategy in SRS

capacity of main memory, and secondary storages, etc., by determining some hit rate which is plotted on Fig. 3 as horizontal dot lines. The hit rate is a probability that requirements are satisfied by the copied database on the main memory. The above one is for the cases without seats, the other is with reservations. The capacity of the copied database is limited upto 1.5 MB while the capacity of the central database is 5,000 MB. Also the number of transactions into the system is more than expected in the designing stage. Under these severe conditions, by swapping train database at every 30 seconds, we have good hit rates as shown in Fig. 3, and consequently fine throughput time for booking process.

Terminal communication network

JNR has a privately owned nationwide communications network with a total length of 38 million circuit-Km, in which the dedicated network of MARS is included. The network utilizes a variety of transmission media such as cable circuits, microwave and coaxial cable circuits. Optical fiber cables and domestic communications satellites are also beginning to be introduced.

A new terminal designed for MARS 301 has been developed to issue various kinds of tickets which are printed in Chinese characters and are encoded magnetically. The terminal which includes a console, a CRT display, a ticket printer and a journal printer, is directly connected via half-duplexed 1 Mbps or 19.2 Kbps lines to a terminal control equipment (TCE).

Each TCE may connect up to six terminals. The TCEs are connected by fully-duplexed 2,400 bps multidrop lines to a time-division multiplexer line concentrator (TDM-LC). Each TDM-LC has a central TDM-LC at the central site connected to it by two fully-duplexed 9,600 bps lines. For redundancy, either one of a pair of lines can handle the entire traffic if necessary, or it can fall back to a 4,800 bps mode if the line conditions are degraded.

The TCE includes several microprocessors, a 1.5 M bytes memory and two 20 M bytes disk units and stores a part

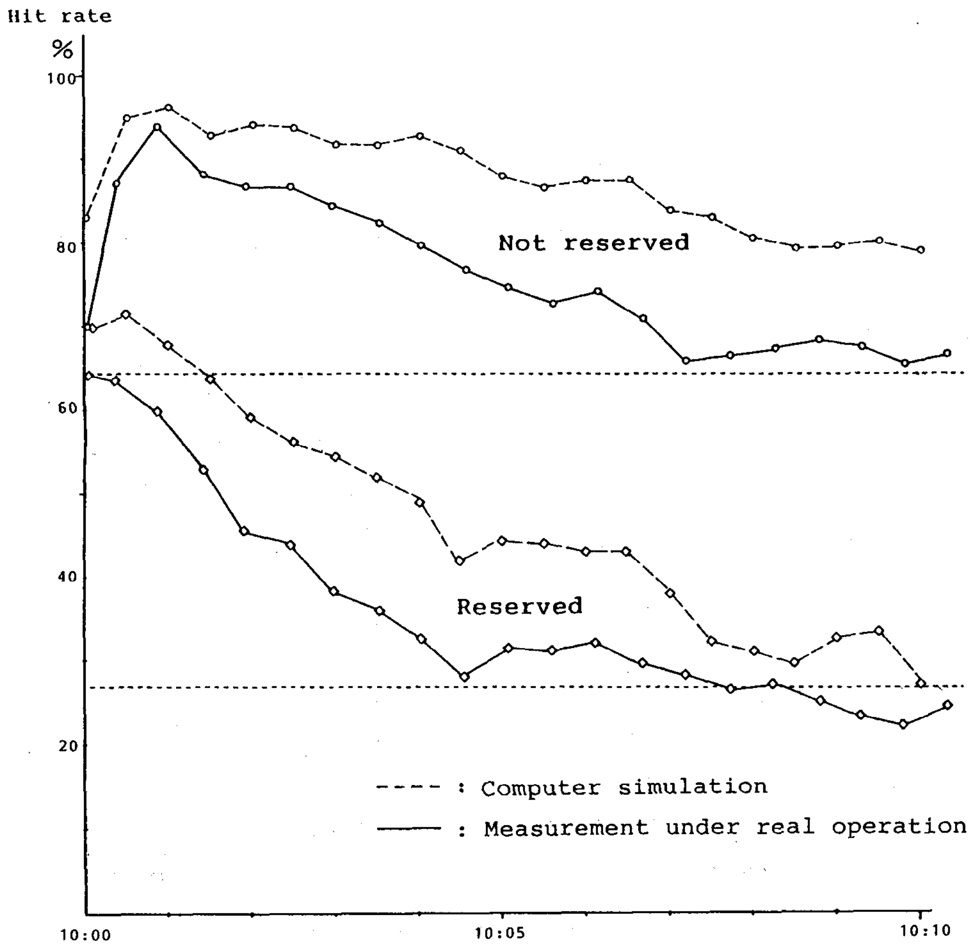

Fig. 3 Hit rates of train information Data

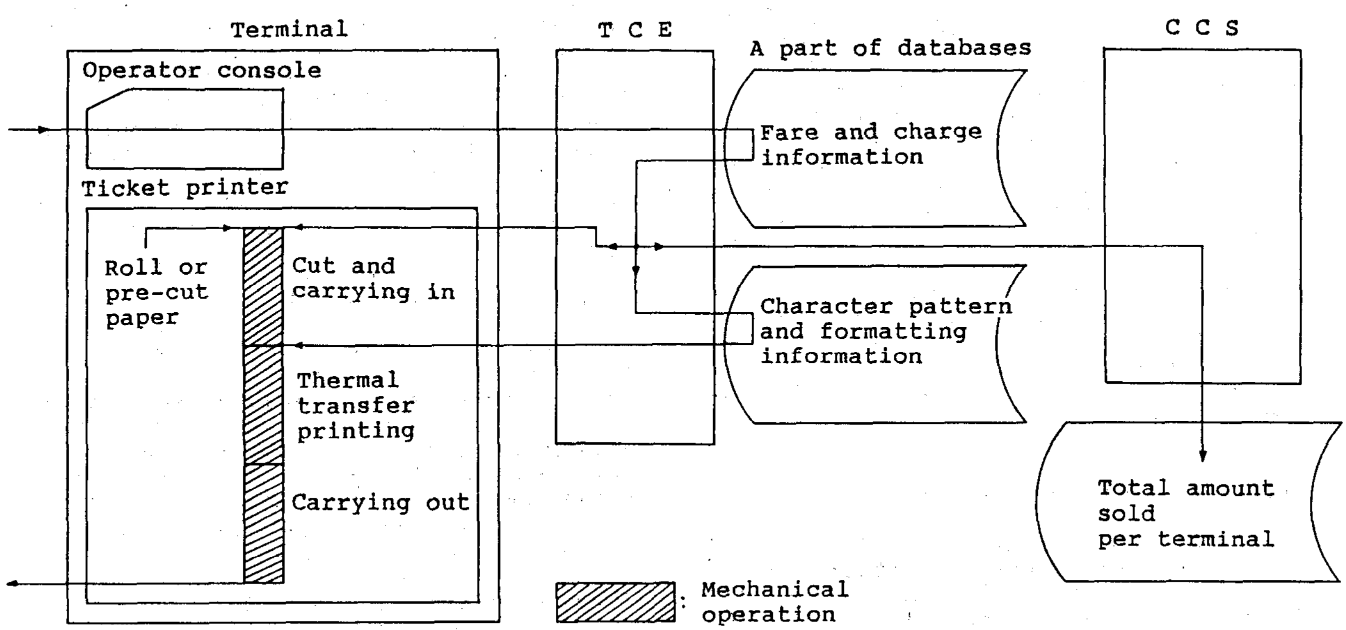

Fig. 4 Example of message flow in TYPE-II network

of the database for fare and charge. It can thereby process to sell fare and pass-type tickets independently of CCS, with issuing time of less than 4 sec. But a TCE is controlled by CCS whenever it processes to issue reserved seat tickets and sum up the sales. In addition, code conversion, editing and output formatting functions are done by TCEs. The use of such a TCE reduces the amount of data to be transmitted to and from CCS.

Fig.4 shows a message flow of the local distributed processing by the TCE. CCS also helps recovery from troubles of hardware and software of TCEs and maintains the databases included in TCEs remotely.

Distributedly located databases in TCE

As stated before, for high speed ticket issuing process, vertical distributed processing is adopted between terminals, CCS and TCE. For doing this, partial data of fare and charge which is contained in CCS are copied and placed on each TCE distributedly.

As more than 100 number of TCEs are distributed over the country, databases and software on TCE should be maintained remotely. In the fare and charge database in CCS, there are many kind of informations ,whose capacity is 250 MB ,as a unit of all the combination of original and destination station pairs. On the other hand, it is sufficient for TCE to have copied database with high utilization in each area, whose capacity is 7 MB. As the copied database varies in each TCE, it is difficult to identify the contents individually before the operation. So similar method like the central database in SRS is adopted, that is, data are copied from CCS by the order of related transaction arrivals. As the probability that a certain number of transactions requires the information with high usage is high, independent and approximately optimal sub-databases are copied on each TCE.

When maintenance is required, copied database on every TCE are cleared by the instructions from CCS and the process stated above is repeatedly applied. As shown in Fig. 5, upon the arrivals of the related transactions, modified data are sent to TCE. Therefore there is no interruption of on-line processing for maintaining data.

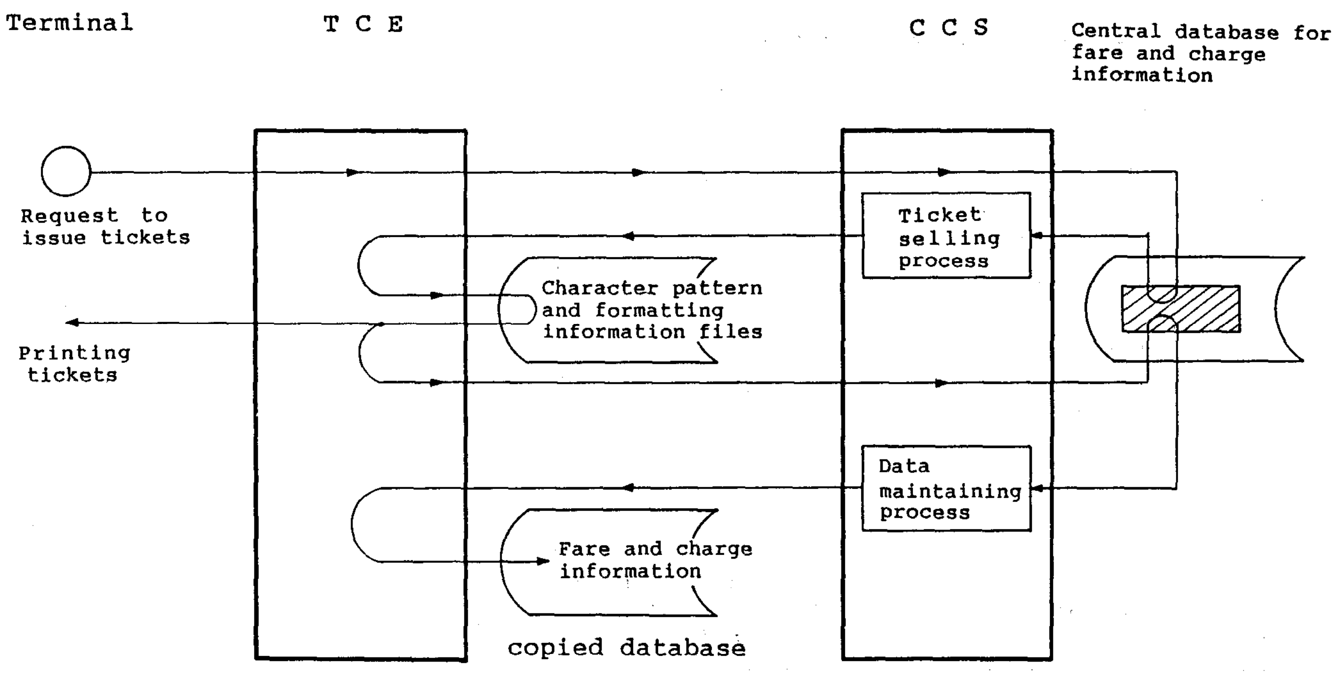

Fig. 5 On demand maintenance process

Travel reservation on-line network

The travel reservation on-line network provides a linkage of MARS with four major travel agents'systems via data relay computers by 9,600 bps communication lines. Each agent's system is also an on-line computer system mainly intended for selling tourist commodities such as hotel accommodations. This computer network is very large in scale and unrivaled in the variety of information processed. Since domestic tours are sold as commodities by each system, they can be a great boon to travelers. On the other hand, the network enables MARS and these systems to expand both sales networks in the market and to improve efficiency in selling planned tour packages. A planned tour package means a tourist commodity which is offered as a preset model course. Various tickets required for the tour, such as reserved seat tickets, fare tickets, hotel accommodation coupons and sight-seeing coupons, are combined in one set and sold as an integrated package.

The facilities of each local system are incorporated into the over-all network as distributed functions. In selling of JNR's tickets through the network's, for example, MARS processes booking of agent's system translates code information into printing images of tickets and issues tickets for the reservation seats. Thus JNR's ticket sales network additionally comprises more than 1,000 terminals connected to other agents' systems. It is possible in the same way for MARS to sell tourist commodities such as hotel accommodations of agent's systems.

The selling operation of a planned tour package requires sophisticated and distributed processing through the network. In this case, some course files for planned packages are prepared in advance, containing indices of accommodations necessary for these packages. Fig. 6 illustrates how a course file is divided into parent and child parts related to commodities of each system. Every time a request for selling the package enters the system, the commodities indicated by each part of the course file are secured separately in each system on an on-line basis.

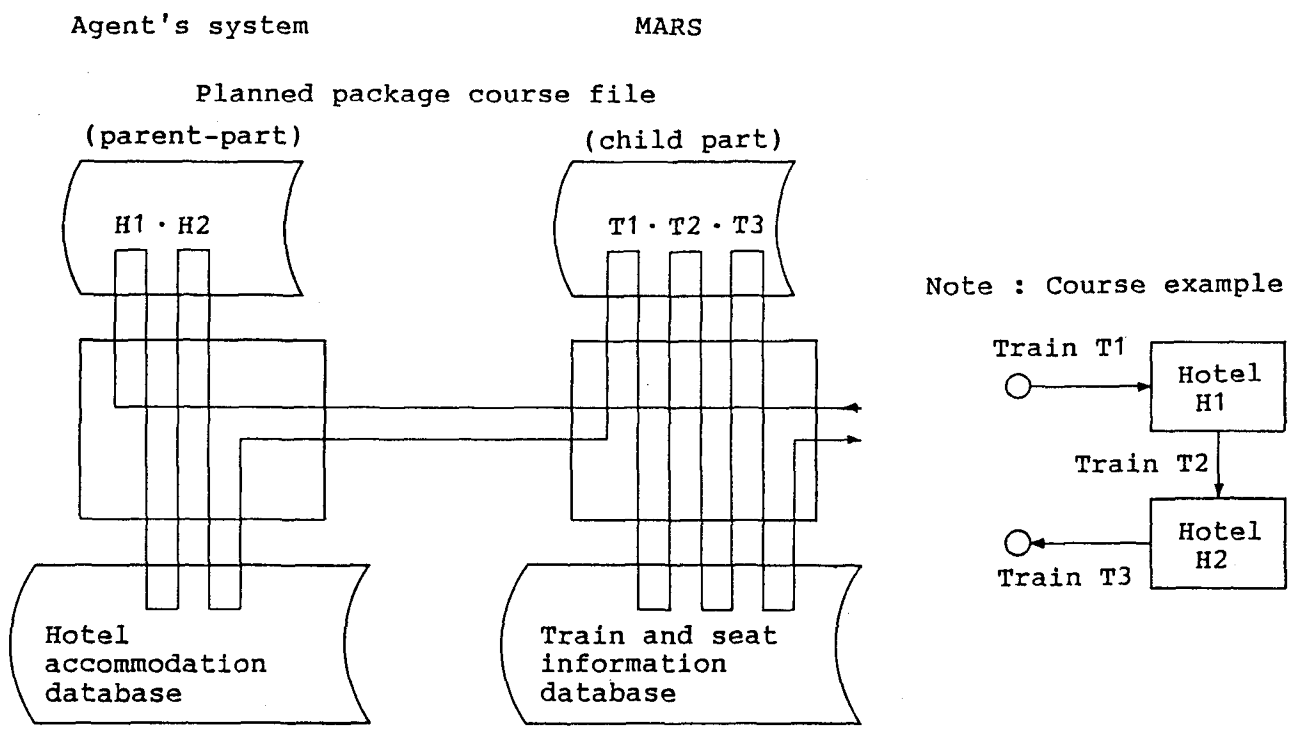

Fig. 6 Example of a distributed processing by TYPE-III network

It is another important purpose of this linkage to improve the efficiency of JNR and the travel agents in settling the accounts. In the past, JNR's tickets were mostly sold manually by travel agents. The agents spent considerable amount on labor on account settlement oprations, because the number of JNR's tickets accounted for about 70 percent of all that the agents handled and the total volume of sales was very large. The network attempts to computerize these operstions and improve efficiency in settling the accounts. For this purpose, it is possible to transmit data necessary for daily operations to other systems. These data include marketing data, inspection settlement data and statistical data. As each system sells various commodities of other systems through the network, the checking of daily sales volume is one of the most important jobs. At the end of each working day, it confirms the number of tickets and the revenue.

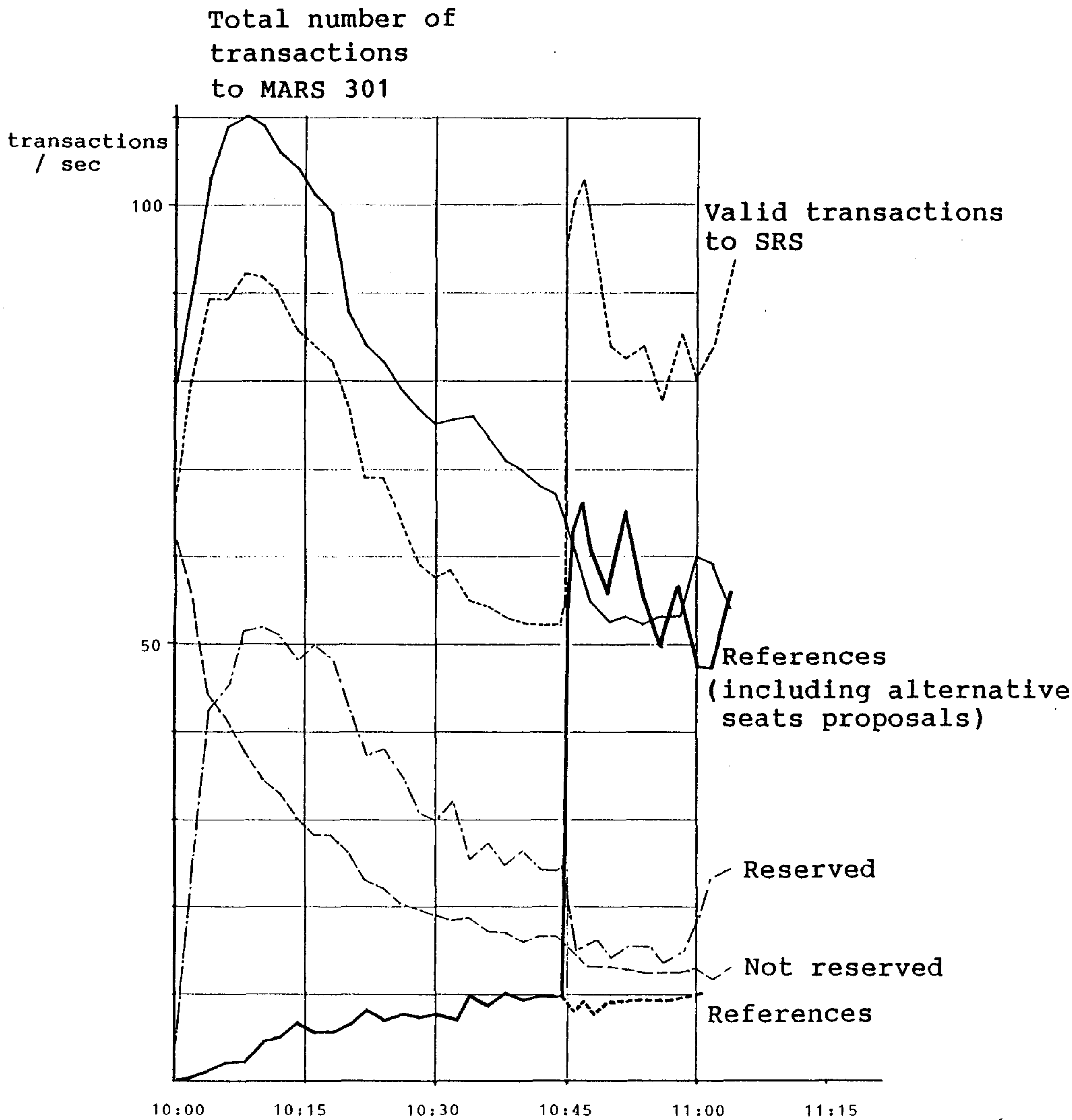

Fig. 7 Number of transactions in time series (1985. 7.18)

PERFORMANCE EVALUATION

The efficiency of main databases is confirmed by simulations and measurements under real operations at several times. For example, Fig.7 shows the number of input transactions into all the systems of MARS 301 and SRS on some day of summer vacation season in July, 1985. Also Fig. 8 shows the transition of utilization of CPUs, disks and data channels in SRS. The figures explain that the system keeps moderate value for on-line operation.

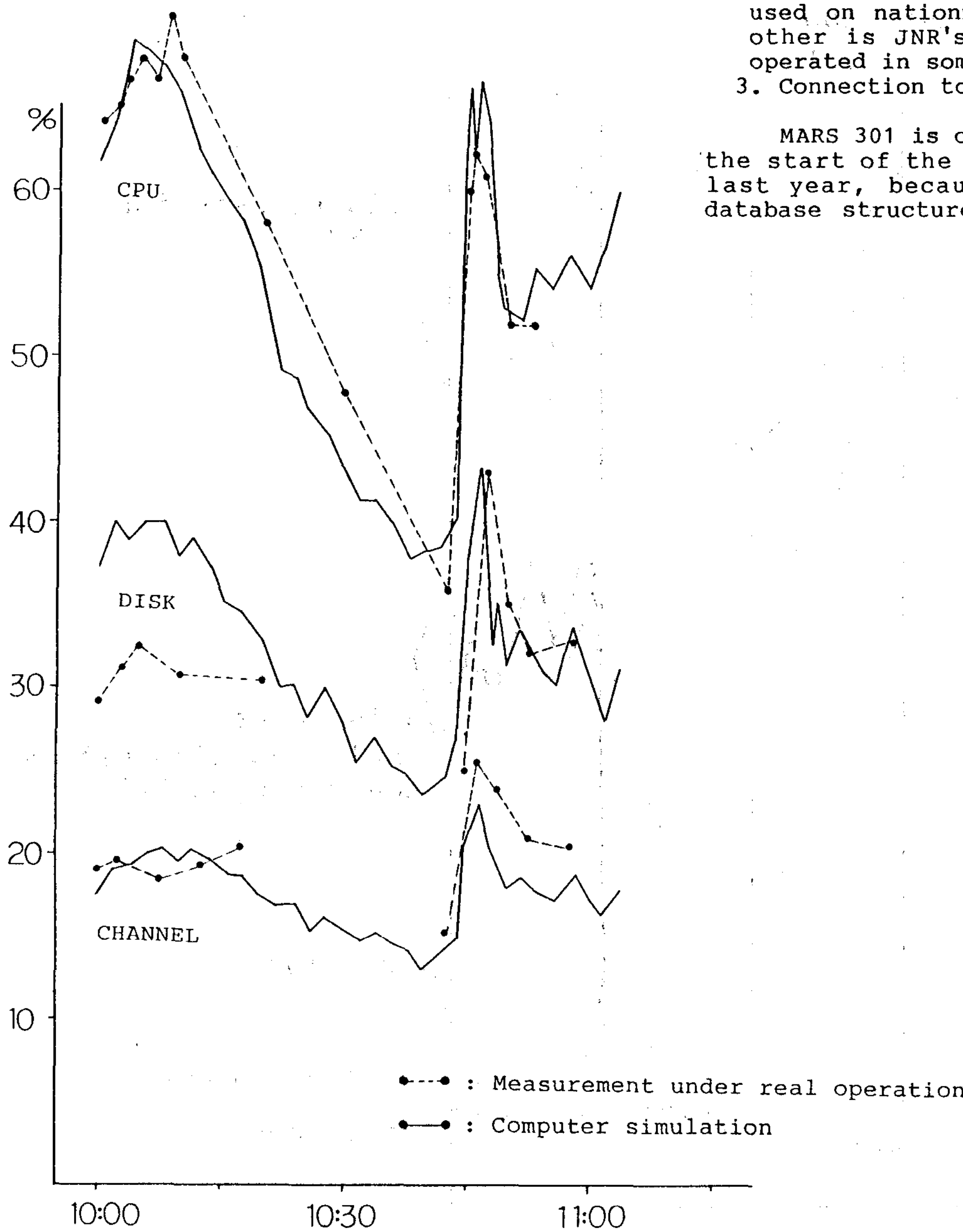

Fig. 8 Utilizations in SRS(Seat Reservation Subsystem)

SUMMARY

Newly developed total sales management system, MARS 301 has mainly three types of distributed network and high efficiency databases. In addition to the topics described here, network of MARS 301 is being expanded to include the following functions.

1. Personal computer terminals which can access via packet switching network.
2. Information offering to videotex network; one is CAPTAIN which is developed and operated by NTT, and used on nationwide bases, the other is JNR's which are currently operated in some local areas.
3. Connection to the JNR credit system.

MARS 301 is operated smoothly since the start of the system, Spring of the last year, because of high efficient database structure.