Development of a Crew Schedule Data Transfer System

We developed a crew schedule data transfer system where crew schedule data is transferred from the transport planning system to the train monitor system onboard via train crews’ tablet PCs as temporary data storage to replace our conventional IC card based system. Currently, each IC card carried by JR East train drivers in the greater Tokyo area contains operation time data for the train they are responsible for to be displayed on the onboard monitor and warn of speed restrictions. But storing data to each card is not only time-consuming for crew administrators, but also costly. We therefore focused on simplifying the system. The new system provides smoother train crew support functions than the conventional system, especially during crew operation rescheduling.

Keywords: Tablet, IC card, Bluetooth communications, Transport planning system

1 Introduction

Most JR East drivers in the greater Tokyo area carry an IC card with them when on duty. The IC card stores data such as timetables if the trains the driver is responsible for and kilometerage of stations on the routes of those trains, and this data is used for purposes such as assisting the duties of the driver. By inserting the IC card to the card holder of the onboard monitor before starting the train, the driver transfers the data (hereinafter, the “crew schedule data”) to the train.

IC cards have been used for long time due to their high reliability; however, we face the following issues today.

・ Unit price of the IC card is high.
・ The data needs to be generated and updated daily per crew schedule from the transport planning system as necessary, making transport management complicated.
・ Due to small capacity, the IC card can store only the data of a specific crew schedule. So, if the train the driver is assigned to is changed at operation disruption, the driver cannot transfer the necessary data to the new train nor use some crew support functions.

Taking those issues into account, we developed and verified the following functions with an aim of achieving crew schedule data transfer from the transport planning system to trains via the tablets crews currently carry.

・ We developed a crew schedule data transmission server to obtain crew schedule data from the externally connected server of the transport planning system.
・ We developed an app for tablets by which crews can obtain the necessary crew schedule data from the crew schedule data transmission server and transfer that to trains using tablets.

2 Overview of Development

2.1 Overview of the System

Fig. 1 shows the system configuration. Crew schedule data is transferred from the transport planning system to trains in the following order.

(1) The crew schedule data is exported to the external connection server of the transport planning system (periodically and at manual operation)
(2) The crew schedule data transmission server periodically accesses the external connection server to obtain newly exported crew schedule data if there is any. Data obtained is deleted from the external connection server.
(3) The crew schedule data transmission server analyzes the obtained data and stores that in its database.
(4) By operating a tablet, the crew accesses the crew schedule data transmission server and transfers the necessary data from the database on that server to the tablet.
(5) By placing a near field communication (NFC) identification card on the reader, the crew establishes tablet - train communications and exports the crew schedule data to the train.

In order to avoid affecting the existing functions of the crew support app included in crew tablets having functions such as...
transferring timetables in operation disruption, we developed the aforementioned system as a function within that app.1)

2.2 Crew Schedule Data
The crew schedule data output from the transport planning system is defined as follows.
· The data is generated from the transport planning system for each crew schedule. The data name is uniquely identified by a combination of setting items.
· The data is exported from the transport planning system to the external connection server in the following two patterns. Periodic transmission: Automatically exported at a specified time (when the transport planning system is out of service) Manual transmission: Manually updated and exported by crew offices and the like in urgent or special cases
· In periodic transmission, the crew schedule data for three days (same day and next two days) of individual crew offices is compressed into zip files (hereinafter, the “crew schedule data files”) and exported to the external connection server.

2.3 Development of the Crew Schedule Data Transmission Server
The external connection server of the transport planning system and the crew schedule data transmission server developed in this project are connected by file transfer protocol (FTP) communications only, so there is a risk of theft of IDs and files exchanged in the communications path. As a countermeasure, we enhanced security by connecting those servers with closed network lines and adopted a communications method where the communications path cannot be seen from outside.

The crew schedule data transmission server periodically obtains crew schedule data files from the external connection server of the transport planning system. We set an interval at which data is obtained that takes into account re-obtaining of the data if any of them are damaged when decompressing. The interval can be changed, and when put into practical use, we will have to reconsider the interval and method of obtaining the data according to the data volume and performance.

The procedure by which the crew schedule data transmission server obtains the crew schedule data from the external connection server is as follows.
(1) Obtain crew schedule data files
The crew schedule data transmission server confirms that crew schedule data files are present on the external connection server and obtains all the files if present. The crew schedule data files obtained are saved in folders on the crew schedule data transmission server.
(2) Store crew schedule data
The crew schedule data files obtained are expanded, and they are saved if properly expanded. If the same data is already present, it is substituted with the newest data.
(3) Register to database on crew schedule data transmission server
The crew schedule data saved on the server is analyzed and information needed when obtaining data by tablets is saved to the database.
(4) Delete files on external connection server
The crew schedule data transmission server deletes crew schedule data files obtained from the external connection server after completing the process of obtaining crew schedule data.

2.4 Development of an App for Tablets
2.4.1 Obtaining Crew Schedule Data from Crew Schedule Data Transmission Server Using Tablet App
Crews obtain crew schedule data from the crew schedule data transmission server by operating the tablet. The operations to obtain the data are “input of crew schedule number (mainly at start of onboard duty)” and “input of train number (mainly at change of train assigned)”. Even when inputting the train number, the crew schedule number including the train number input is searched and the crew schedule data linked with the crew schedule is obtained. Therefore, in either input pattern, the data is imported to the tablet per crew schedule.
(1) Obtaining data by crew schedule number
In designing a user interface for the tablet, we followed the screen structure and the like of the existing crew support app. Crews can also obtain the crew schedule data when inputting the crew schedule number to the tablet before starting onboard duty. Fig. 2 shows an image of system processing when a crew schedule number is input.

(2) Obtaining data by train number
In incidents such as operation disruption, crew assignment to trains is sometimes changed by crew managers. At that time, crews can obtain the crew schedule data including the train newly assigned to by inputting the new train number to the tablet. Fig. 3 shows an image of processing to obtain crew schedule data when a train number is input.

To obtain crew schedule data, the tablet app searches and narrows down the crew schedule data required according to the following conditions.
[Condition 1] Crew office code of the crew schedule data matches the code of the crew office to which the crew belongs or that of the crew office responsible for the newly assigned train.
[Condition 2] Train number included in the crew schedule data matches the train number input.
crew schedule data, a given time range is defined as the time range to search in. [Condition 3]

If there are still multiple crew schedules after narrowing down, the data (train number, departure time, section assigned, depot responsible) is sent to the tablet, and the crew chooses the crew schedule data to be imported. Fig. 4 shows the screen transition for obtaining crew schedule data by inputting train number.

2.4.2 Crew Schedule Data Transfer to Trains by Tablet App

For the crew schedule data transfer to trains by the tablet app, we adopted the following connection and communications method as a function within the existing crew support app.

When a crew member places an authentication NFC card on the onboard card reader, the tablet receives a connection request from the train and establishes tablet - train communications (Bluetooth handover method).

- Tablet - train communications is by Bluetooth (ver. 3.0) communications.

- In the crew schedule data transfer from a tablet to a train, the first sector information (8 KB) is sent first as in the current system using IC cards. Then, according to the request from the train, the nth sector information (8 KB) corresponding to the train number assigned is sent.

We decided the specifications and produced the tablet interface while confirming the data flow of the train and the tablet corresponding to workflow the crew. Fig. 5 shows an image of the flow of crew schedule data transfer to trains.

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**Fig. 3** Image of Processing when Train Number is Input/Output

**Fig. 4** Image of Screen Transition (When Train Number is Input)

[Condition 3] Departure time of the train newly assigned is within a given time range from the current time.

On the crew schedule data transmission server, there can be more than one crew schedule that includes the train number input from the tablet (for example, depot responsible for train 1M: A depot on B Line and C depot on D line). Therefore, the system narrows data down to the crew schedule data assumed to be needed by the crew. [Conditions 1 and 2]

Next, on the crew schedule data transmission server, there is more than one crew schedule with the same crew schedule number to be operated on the different days. As crews are not likely to be assigned to the train in the distant future, the system sets in advance a time range to search so as to narrow down the crew schedule data. Setting as the start point the time when a crew member inputs a train number to the tablet to search the
Implementation and Consideration of Verification Tests

We carried out verification tests of crew schedule data transfer from the transport planning system to trains using tablets and considered issues for putting that into practical use.

3.1 Obtaining Crew Schedule Data from Transport Planning System by Crew Schedule Data Transmission Server

3.1.1 Confirmation of Obtaining Crew Schedule Data

We confirmed that crew schedule data is obtained as specified from the external connection server of the transport planning system by the crew schedule data transmission server. We also confirmed that the crew schedule data transmission server obtains the crew schedule data with the most recent time stamp and registers that to the database regardless of whether the crew schedule data files are exported from the transport planning system to the external connection server by periodic transmission or by manual transmission.

3.1.2 Measurement of Time Required for Obtaining Crew Schedule Data

Based on log data and the like gained in testing of connections with the transport planning system, we calculated the time required to obtain crew schedule data to check for problems when put in practical use.

Due to restraints of the test environment, crew schedule data of only a few crew offices was exported to the external connection server of the transport planning system. In actual operation, crew schedule data of all crew offices that currently use IC cards will be exported to the external connection server in period transmission at a specified time, and the crew schedule data transmission server will subsequently obtain all the data at the same time.

(1) Time measured in the tests

We measured time required for processing as follows.

1) Obtaining: Time required for obtaining crew schedule data files from the external connection server by the crew schedule data transmission server

2) Decompressing: Time required for decompressing crew schedule data files by the crew schedule data transmission server and deleting the files from the external connection server

3) Overall processing: Time required for 1) and 2) and all processing including crew schedule data analysis and storage to the database of the decompressed data

Table 1 shows the processing time measured for each of the above. Fig. 6 shows the overall processing time according to data size. It demonstrates that the processing time is in proportion to the data size.

(2) Estimation assuming practical operation (for all crew offices involved)

As the volume of data was limited in this tests, we calculated based on the test results the total processing time from obtaining crew schedule data of all JR East crew offices involved from the external connection server of the transport planning system to registering the data to the database on the crew schedule data transmission server. First, we figured out the data volume per instance of crew schedule data from Table 1. Next, we calculated the total data volume on the assumption of that being the crew schedule data for all crew offices involved. Then, based on the processing time per data volume shown in Fig. 6, we gained the total processing time calculation result of approx. 91 minutes.

If crew schedule data is changed at a crew office and manually sent during the aforementioned processing, such data has to be processed along with the data exported in periodic transmission, so shorter data processing time will be needed in actual operation in future.

Processing took a long time in this project because the crew schedule data transmission server obtained and decompressed crew schedule data files and sequentially analyzed and imported crew schedule data to the database on the server. One possible measure to shorten time is to increase total processing speed by conducting in parallel the processing for analyzing crew schedule data obtained and exporting that to the database by the crew schedule data transmission server. Multiplicity of parallel processing depends on the number of cores of the server, so a server with more cores will enable more multiplied processing.

<table>
<thead>
<tr>
<th>No.</th>
<th>Number of crew schedule data instances</th>
<th>Data volume (KB)</th>
<th>Processing to obtain (ms)</th>
<th>Processing to decompress (ms)</th>
<th>Overall processing (ms)</th>
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<td>64,934</td>
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</tbody>
</table>

Fig. 6  Overall Processing Time for Data Volumes
3.2 Obtaining Crew Schedule Data from Crew Schedule Data Transmission Server Using Tablet App

3.2.1 Confirmation of Obtaining Crew Schedule Data
We confirmed that crews could obtain using the tablet crew schedule data linked to the crew schedule number and/or train number input. We also compared the crew schedule data the transport planning system exported to the external connection server with the crew schedule data obtained from the crew schedule data transmission server using the tablet and confirmed that those were the same data.

3.2.2 Time Required for Obtaining Crew Schedule Data
Crews must be able to quickly obtain crew schedule data in all sorts of situations, such as at change of train assigned in operation disruption. We therefore verified time required for obtaining crew schedule data.

1) Time required for obtaining crew schedule data by inputting crew schedule number
   The system process flow from crew inputting crew schedule number to the tablet to completion of importing crew schedule data is as follows.
   1) Input crew schedule number to the tablet at start of onboard duty.
   2) Set crew schedule number to the crew support app.
   3) Search crew schedule data on the crew schedule data transmission server.
   4) Obtain on the tablet all crew schedule data required.

   We checked the time required for 1) and 2) from the processing time by the existing crew support app and for 3) and 4) from the log data, finding that average time was approx. 2.9 seconds. It can be said that the time is at the level where there would be no problems in terms of obtaining data when the crew starts duty on the train duty.

2) Time required for obtaining crew schedule data by inputting train number
   The process flow from inputting to the tablet the number of the train newly assigned in situations such as operation disruption to completion of importing crew schedule data is as follows.
   1) Input train number to the tablet when the train assigned is changed.
   2) Search in the crew schedule data transmission server for crew schedule data meeting conditions.
   3) Determine crew schedule number including the train number input by the crew selecting one of the possible sections shown on the tablet.
   4) Obtain all crew schedule data required into the tablet.

   We checked the time required for 1) and 2) from the log data of the crew schedule data transmission server and found that the average time was 0.036 seconds. As the average time required for 4) was 2.9 seconds as mentioned above, we can say that crew schedule data can be obtained in about 3 seconds, excluding the time for selecting by the crew in 3).

If we store crew schedule data of all crew offices, the processing time for 1) and 2) above will increase in proportion to the data volume increase. However, we will be able to deal with that by choosing a database server based on the data volume and verifying in performance checks in advance of practical use that there is no effect on actual operation.

3.3 Crew Schedule Data Transfer to Trains by Tablet App

3.3.1 Confirmation of Crew Schedule Data Transfer
We used a crew schedule data reader board simulation PC in the communications verification test between tablets and trains. As the simulation PC had no function equivalent to that of an onboard monitor, we could not carry out function checks in the actual flow image, so we confirmed the following three items by different methods.
   · Time required for drawing on the onboard monitor display image of crew schedule data transferred from the tablet
     → Used reference time required for image drawing by a similar function of an existing car.
   · Check of contents of image drawing on the onboard monitor display of the crew schedule data transferred from the tablet
     → Used contents of image drawing by a similar function of an existing car.
   · Check of error message on the onboard monitor display at communications error between a tablet and a train
     → Confirmed error was detected on the console display of crew schedule data reader board simulation PC.

In the tests of connection with trains, we confirmed the following three items.

1) Crew schedule data transferred to trains via tablets by the system developed in this project match the crew schedule data imported to trains from the transport planning system via existing IC cards.

2) As specified for the interface decided on in this project, placing an authentication NFC identification card on the reader establishes tablet – train communications and enables data transmission and reception. No data is transmitted to and/or received by a terminal other than that specified by the authentication NFC identification card.

3) Crew schedule data specified on the tablet to be transmitted is transferred to the train.

When verifying 1), we found that file generation date of the file was different from the date of writing data to IC cards, but all other content matched. File generation date is the date when the transport planning system generates crew schedule data, and that is automatically exported. Writing of data to IC cards and generation of data to be exported to the external connection server are performed at different timing, so the file generation date does not match the date of writing data to IC cards. As other items matched each other, we confirmed that the mechanism where crew schedule data is obtained by tablets and transferred to trains was achieved without problem. In verification of 2) and 3), we found no problems.
3.3.2 Time Required for Transferring Crew Schedule Data

Based on the measurement results in the train connection test, we calculated time required for transferring crew schedule data in the actual workflow assumed. Table 2 shows processing time required for each workflow.

A driver enters the driver’s cab and starts driving after completion of processes No. 1 to 5. Adding up the measurement time results in the train connection test, the time from placing an authentication NFC card on the onboard reader to crew schedule selection screen being displayed (No. 1 to 3) is 5.2 sec. in total, the time from selecting a train number on the crew schedule selection screen to the operation information screen being displayed (No. 4 and 5) is 4.4 sec. in total. This demonstrates that all processes from No. 1 to 5 are completed within 9.6 sec. in total. In cases such as crew transferring to a train with the same train number, the crew does not need to select a train number on the crew schedule selection screen. In such a case, the train requests nth sector information from the tablet after the crew obtains the first sector information in process No. 2, so time required for screen display in No. 3 is not needed, and all processes up to No. 5 will be completed within 6.1 sec.

In actual operation, a certain amount of time is required for the crew to select a train number between processes No. 3 and No. 4, and the time required for screen display (in No. 3 and 5) in this project is estimated time. However, we can say that the time required for the processes from placing and authentication NFC card on the onboard reader to displaying the operation information screen is acceptable for actual operation.

Table 2  Processing Time per Workflow

<table>
<thead>
<tr>
<th>No</th>
<th>Details</th>
<th>Processing time (sec.)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Time until Bluetooth connection made between onboard monitor and tablet</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Time from making Bluetooth connection until train obtains 1st sector data from tablet</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Time from completion of obtaining 1st sector data to displaying crew schedule selection screen on onboard monitor</td>
<td>3.5</td>
<td>Onboard device processing time (estimated)</td>
</tr>
<tr>
<td>4</td>
<td>Time from selecting train number in crew schedule selection screen on onboard monitor to train obtaining nth sector data from tablet</td>
<td>0.9</td>
<td>Specified sectors to be obtained on a simulation device due to having no onboard monitor</td>
</tr>
<tr>
<td>5</td>
<td>Time from receiving nth sector data to displaying operation information screen on onboard monitor</td>
<td>3.5</td>
<td>Onboard device processing time (estimated)</td>
</tr>
<tr>
<td>6</td>
<td>Time from displaying crew schedule data screen on onboard monitor to train obtaining remaining data</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

4 Conclusion

In this development project, we aimed for job innovation and cost reduction by using tablets crews now carry instead of conventional IC cards. We developed a crew schedule data transmission server and a tablet app, and we confirmed that the tablet app can obtain the latest crew schedule data from the transport planning system as needed and transfer the data to trains without affecting functions of the existing crew support app. In the future, we will proceed with development for putting the system into practical use.

Reference: