Convergence of Information Technology and Control Systems in Railway Transportation Service Systems

Tetsuya Ogawa
Hideki Osumi
Satoru Nagai
Masakazu Ito
Hiromitsu Kato, Dr. Eng.
Takumi Fushiki, Dr. Eng.

OVERVIEW: Railways play an important role in Japan and the country has well-developed railway services both in its major cities and on inter-city routes. Railway services have evolved in part as a way for people to commute to work or school and mission-critical systems have been implemented to support railway operations and ensure that services are punctual even during the morning and evening rush hours when train operation timetables are particularly busy. Coordination between these mission-critical systems will also be a requirement for the ongoing future development of railway services. We intend to continue contributing to the development of social infrastructure through railway systems by supporting, across different systems and different railway operators, services that provide links to other communities and are part of the social framework through the convergence of information and control technologies we have built up over many years and by strengthening their role in a service platform.

INTRODUCTION

TRANSPORTATION of people is increasing as our society grows and the demand for railway services that can provide high-speed and high-capacity transportation is becoming greater. The number of train rides taken in Japan in 2006 was 22,243 million, more than anywhere else in the world by some margin, making Japan one of the world's leading railway nations(1).

A major feature of railway systems in Japan is that urban areas are served by a number of different railway operators resulting in complex railway networks that operate in a high-density environment with mutual interconnections and various different fare structures. For inter-city transport, high-speed Shinkansen services operate with a frequency not seen anywhere else in the world. These Japanese railway systems have allowed railway operators to provide a high degree of punctuality and improved convenience for passengers. As a result, Japan's railway systems are recognized for giving their users a high level of peace of mind about transportation and for having made a major

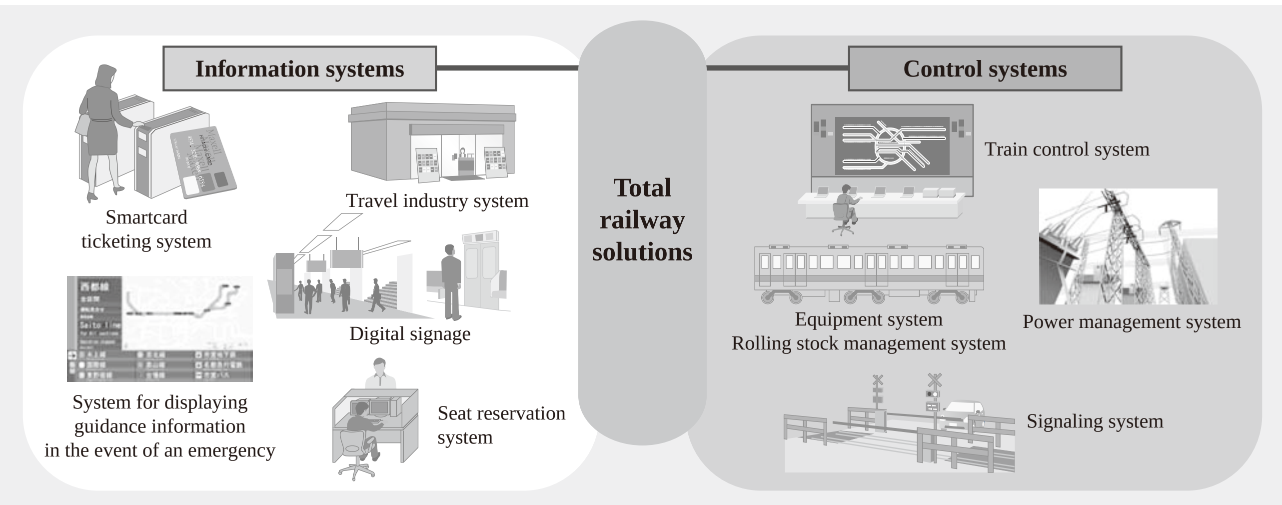

Fig. 1—Information and Control Systems that Support Railways.
Mission-critical systems for information and control respectively support today's railway systems.

contribution to the country's economic progress.

In recent years, railway operators have moved beyond providing a means of transport to transform themselves into lifestyle partners who help underpin people's daily activities by utilizing their transportation network which spans the entire country to construct comfortable lifestyle spaces on the routes that link railway stations and centers of activity. As a total solution partner who supports these railway operators, Hitachi supplies total solutions for railways in which information and control converge and which cover not only mission-critical railway systems such as power distribution equipment, rolling stock, signaling, seat reservation, and train control but also a wide range of other fields extending as far as lifestyle services such as distribution systems and financial systems.

This article gives an overview of mission-critical railway systems together with an outline of services in which information and control converge and the technologies that support them.

INFORMATION AND CONTROL SYSTEMS THAT SUPPORT RAILWAYS

The mission-critical systems that support railways can be broadly divided into information systems and control systems (see Fig. 1). The following sections describe the information and control systems with which we have been involved in the past together with their technical features.

Mission-critical Information Systems

(1) Seat reservation system

The MARS (multi-access reservation system) developed and operated by Railway Information Systems Co., Ltd. links to terminals in JR (Japan Railways) Ticket Offices ("Midori-no madoguchi"), the Internet, and the travel industry systems of major travel agencies and JR companies to provide a wide range of services and products to meet the needs of railway users. These include tickets (including tickets with designated seating), monthly and other passes, event tickets, accommodation vouchers, and group travel.

Since its origins as a seat reservation system in the 1960s, MARS has led the world as a byword in online systems, always incorporating the latest in information and communications technology. As the sales policies of the various JR companies have become more diverse and developed independently since the breakup and privatization of Japanese National Railways service, the system was upgraded to MARS501 in 2004 to provide a prompt and flexible response to the requirements of the different JR companies and to improve its expandability and maintainability[2].

(2) Smartcard ticketing system

The first smartcard ticketing system to appear for railway services in Japan was the Suica* system of the East Japan Railway Company introduced in 2001 which can now be used in all of Japan's major cities. A network extending from Hokkaido to Kyushu was established in March 2010 which allows compatibility of various different smartcards.

In addition to the convenience of non-contact operation and security, smartcard ticketing also supports the reliability of payment processing by allowing data to be checked at center systems. Prevention of illegal use is handled by the center systems that manage the smartcards. The data produced each time a smartcard is used at a ticket gate, ticket vending machine, or other railway station system are aggregated on station servers installed in each railway station and the data from each station are in turn collected by a center system to manage monetary balances and maintain usage records for each card. Other services include reissuing lost cards and printing out details of card usage.

Mission-critical Control Systems

Two representative examples of mission-critical control systems introduced by East Japan Railway Company to support railways operation are the COSMOS (computerized safety maintenance and operation systems of Shinkansen) for the Shinkansen and the ATOS (autonomous decentralized transport operation control system) for the Tokyo region.

COSMOS entered operation in November 1995 based on key concepts that included a major reorganization of business operations, promotion of labor-saving practices, increased speed, support for more diverse transport planning, and provision of more comprehensive services for railway users. COSMOS performs integrated management of the full range of Shinkansen transport control tasks including the preparation of train operation timetables and other types of planning, train operations, and equipment monitoring, control and maintenance. It is a large, wide-area distributed system comprised of seven subsystems[3], [4].

ATOS supports the very high density of train operations in the Tokyo region and commenced operation on the Chuo Line in 1996 with the aim of

* Suica is a registered trademark of East Japan Railway Company.

improving services for railway users and providing safe and reliable train control. ATOS is a large distributed rail transport control system that is used not only for train control but also to automate passenger guidance and manage maintenance work using a maintenance management system[(5), (6)].

Both COSMOS and ATOS use an autonomous distributed architecture to perform automatic control of signals and points on lines with high traffic densities. These unique systems deliver better efficiency and improvements in dispatching for lines with high traffic density, including functions that were outside the scope of previous train control systems such as predicting the future location of trains, disseminating information about timetable changes to train crews, and distributing regulatory information including weather data.

CONCEPTS BEHIND SERVICES AT CONVERGENCE OF INFORMATION AND CONTROL

Enhancements to mission-critical information and control systems have helped boost the operational efficiency of railway operators and improve services for railway users. What is believed necessary to help the railway industry achieve further progress in the future is to provide transport services with better safety, comfort, and convenience from the perspective of railway users along with the construction of comfortable lifestyle spaces. We believe that the convergence of mission-critical information and control systems will allow the provision of new services for railway users that go beyond what can be achieved with the conventional arrangement of railway systems (see Fig. 2).

For example, an abstracted model of the railway system as a way for people to move around will contain data about the transportation and actions of people. Through the “visualization” of transportation and actions by converting this huge amount of data into knowledge, services for individuals can be refined, transport operations can be made more efficient, and better passenger services can be provided.

Implementing these convergent services will require: (1) ways of achieving flexible coordination of information and control systems despite their different characteristics, and (2) ways of converting huge amount of data into knowledge and performing optimum control of the overall system. The following section describes the technical framework for turning these convergent services into reality.

TECHNICAL FRAMEWORK FOR CONVERGENT SERVICES

System Requirements for Implementing Convergent Services

Implementing services in which information and control converge will require the linkage of relationships between the data managed by the various information and control systems so that this data

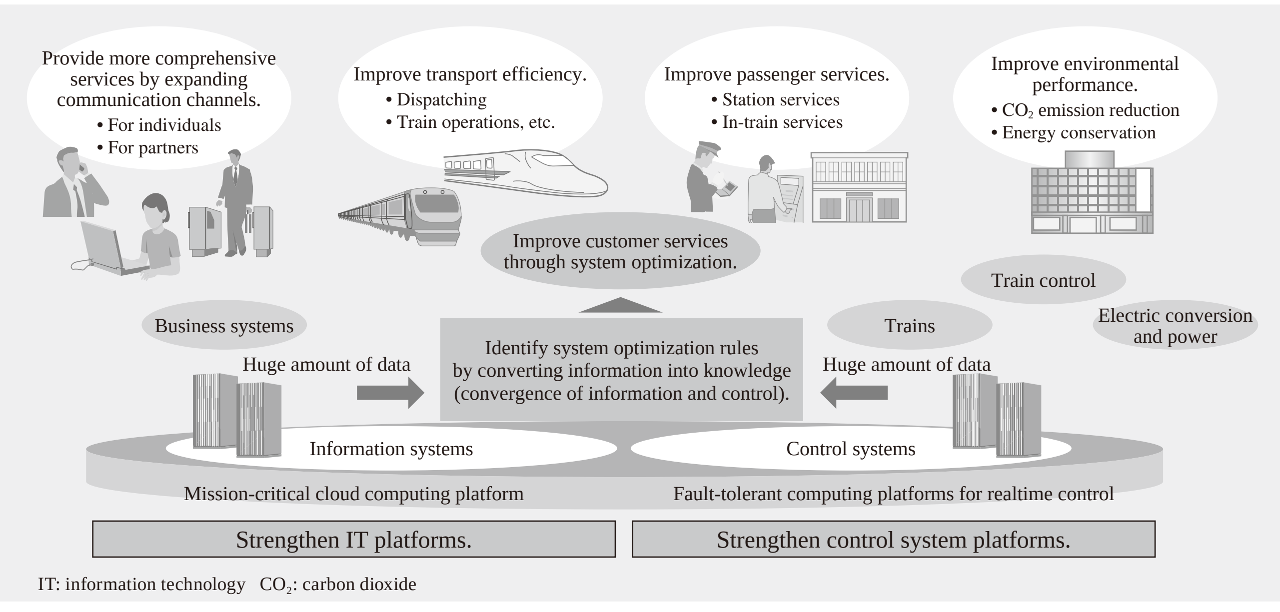

Fig. 2—Overview of Services Made Possible by Convergence of Information and Control.
Customer services oriented to the perspective of railway system users can be provided through the convergence of information and control systems and their use for knowledge creation.

can be used across different systems in ways that go beyond what the previous structure allowed. One way of realizing this linkage is to manage the data from all of these systems together in a central database. However, the problem with this approach is that the effects carry over to all the other systems if some data items in a particular system need to be extended. Accordingly, data federation techniques are required that maintain the independence of the individual information and control systems.

The huge amount of data will be shared across the entire railway system when exchanging data between these independent systems. Scalability is required to the system in order to handle the ongoing increase in data quantity when extracting knowledge from the data. Similarly, realtime knowledge processing will be required to incorporate the results of "visualization" of transportation and actions.

Hitachi proposes two technologies to meet these requirements: an "information and control coordination platform" and a "knowledge service platform" (see Fig. 3).

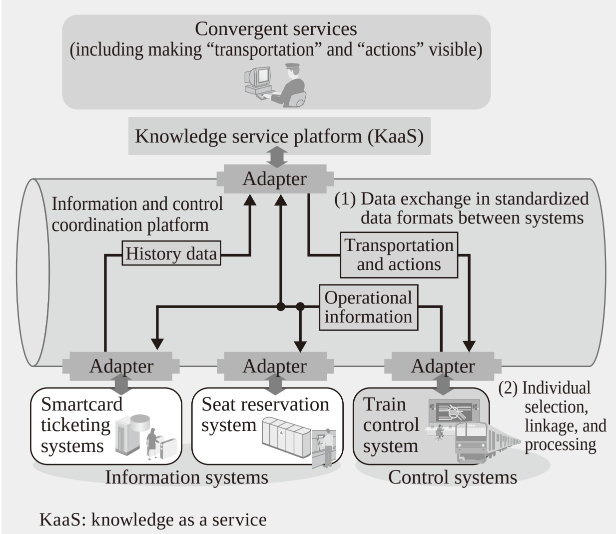

Fig. 3—Convergence of Information Systems and Control Systems in System Architecture for Services.
Knowledge processing of huge amount of data can be achieved using an "information and control coordination platform" to provide loosely coupled coordination of various information and control systems together with a "knowledge service platform."

Information and Control Coordination Platform

The information and control coordination platform uses a bus architecture to connect different independent systems and provides a mechanism for converting the data generated by individual systems into a standard format. This allows a greater level of data sharing for exchanging data between systems than is possible with the existing arrangement of individual systems. By using separate adapters to select, link, and process the required data, the train control and other individual systems can implement loosely coupled data federation by converting data into a form suitable for use within a system without affecting other systems. Also, the adapters used to interface to control systems include mechanisms for prioritizing the cyclic processing of the control systems while handling access requests from the information systems. This allows the coordination of information and control systems without degrading the coherence of important control functions.

Knowledge Service Platform

The knowledge service platform will provide convergent services with high added-value by extracting and utilizing the knowledge contained in the huge amount of data being exchanged on the information and control coordination platform. Hitachi has proposed a KaaS (knowledge as a service) platform that provides techniques for extracting valuable knowledge from the huge amount of data produced by social infrastructure(7). The use of KaaS to perform realtime extraction of the required information from the large amount of information contained in these huge amount of data allows services to be provided that are tailored to the transportation and actions of individual people.

The adoption of parallel distributed processing in KaaS provides a system configuration with a high level of scalability that can cope with future increase in data volumes simply by adding computing resources without having to make program changes.

CONCLUSIONS

This article has given an overview of mission-critical railway systems together with an outline of services in which information and control converge and the technologies that support them.

We intend to create new businesses that can further improve services for railway users as well as developing technologies for this business.

We are also looking to apply the concept of convergent services described in this article at a number of different railway operators to provide optimal transport services in terms of the overall railway network together with savings in system development and operating costs through system sharing. Meanwhile, recent years have seen ongoing activity in the area of smart cities equipped with social infrastructure that delivers a sustainable lifestyle and environment while alleviating global warming, and railway systems have come to be recognized as a form of transport with a low impact on the environment. By applying the convergent services concept to smart cities also, we believe that it can help optimize mobility across all parts of the social infrastructure and improve energy efficiency.

To make a reality of smart cities and coordination between different railway operators, we aim to contribute to progress in social infrastructure through railway systems by packaging our combined information and control technologies with knowledge creation techniques and supplying the required technologies and systems based on the needs of our business partners.

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ABOUT THE AUTHORS

Tetsuya Ogawa
Joined East Japan Railway Company in 1996, and now works at the ATOS Project, Electrical & Signal Network System Department. He is currently engaged in the development of ATOS.

Hideki Osumi
Joined Hitachi, Ltd. in 1996, and now works at the ATOS Center, Transport Information Systems Division, Information & Control Systems Company. He is currently engaged in the development of railway transportation systems. Mr. Osumi is a member of The Institute of Electrical Engineers of Japan (IEEJ).

Satoru Nagai
Joined Hitachi, Ltd. in 1997, and now works at the Transport Management Systems & Solution Department, Transport Management & Control Systems Division, Transportation Systems, Rail Systems Company. He is currently engaged in the development of railway transportation systems.

Masakazu Ito
Joined Hitachi, Ltd. in 1979, and now works at the Transportation Information Systems Division, Information & Control Systems Company. He is currently engaged in new business development for the railway industry. Mr. Ito is a member of the Information Processing Society of Japan (IPSJ).

Hiromitsu Kato, Dr. Eng.
Joined Hitachi, Ltd. in 1995, and now works at the 1st Research Department, Yokohama Research Laboratory. He is currently engaged in research into information and control system architectures. Dr. Kato is a member of the IPSJ, The Society of Instrument and Control Engineers (SICE), and The Institute of Electrical and Electronics Engineers, Inc. (IEEE).

Takumi Fushiki, Dr. Eng.
Joined Hitachi, Ltd. in 1998, and now works at the Green Mobility Research Department, Hitachi Research Laboratory. He is currently engaged in research into railway transportation systems. Dr. Fushiki is a member of the IPSJ.