Overview of the Next-generation Railway Operation System in the Tokyo Metropolitan Area

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The Research and Development Center of JR East Group launched a project in 2008 with a goal of innovating the railway operation system in the Tokyo metropolitan area to contribute through R&D to further improving customer satisfaction, particularly quality of transportation services in the Tokyo metropolitan area. That was done in line with the establishment of JR East's long-term management plan, "JR East 2020 Vision—Challenge—". This article introduces an overview of the next-generation railway operation system in the Tokyo metropolitan area and the status of development related to that.

1 Introduction

JR East Group prepared its long-term management plan "JR East 2020 Vision—Challenge—" in April 2008, and it is tackling a variety of issues under that plan. The vision sets forth "heightening customer satisfaction even further" at the top of ongoing efforts, with cross-sectional approaches as the way to solve issues and improve customer satisfaction.

In railway business, the Research and Development Center of JR East Group launched in 2008 a project on the next-generation railway operation system in the Tokyo metropolitan area that covers the area within 50 km from central Tokyo. The aim of the project is to innovate transport service in the Tokyo metropolitan area so that we may put efforts into improving customer satisfaction, particularly improving the quality of transportation services in the Tokyo metropolitan area.

2 Concept of the Next-generation Railway Operation System in the Tokyo Metropolitan Area

2.1 Envisioned Condition

The following points were brought up at the start of the project as items to keep in mind in envisioning conditions when considering short-distance transport in the Tokyo metropolitan area for the next 10 to 20 years.

(1) Impact on transport demand of the change of population structure in the Tokyo metropolitan area by an aging society with fewer children, the tendency to marry later, decrease of working and producing population and influx of foreign people
(2) Impact on transport aspects in variation depending on the time period, day of the week and the season of the change of social structure (diversified working and studying styles and lifestyles such as increased inner-city living)
(3) More sophisticated customer needs in security and safety (higher safety and ensured security), convenience (barrier-free access) and service and hospitality (higher service quality), due to changing user manners and public morals and advanced social services
(4) Impact on transport modes of worsening global environmental problems and fuel price fluctuation

Later effects of major changes in social situations include those of large economic fluctuation since autumn of 2008, the Tohoku earthquake and tsunami of March 11, 2011 and the post-quake supply and demand of energy. The Tohoku earthquake and tsunami in particular provided many lessons on what items need to be considered in response to major disasters and post-disaster issues such as recovery and securing operations. Future energy policy changes also need to be considered. Such issues must be organized and applied as items to keep in mind.

2.2 Overall Image of the Next-generation Railway Operation System in the Tokyo Metropolitan Area

Train operation is a large-scale total system using rolling stock, wayside equipment and a large staff including crews and maintenance personnel. A variety of systems related to train operation have thus been developed. Each system has developed and has been deployed separately, incorporating needs and technologies of the times. But while they may work well locally, they have developed into a system that it would be difficult to call optimum.

With the next-generation railway operation system in the Tokyo metropolitan area, we work to rethink past systems that had developed independently to give functional allocation with less waste and redundancy. That is done by focusing on the flow of information and utilizing ICT. By an approach that educes necessary functions and puts functional needs at the forefront, we are aiming for an ideal system for the future that achieves safety, resilience, flexibility and low cost operation, reduced burden on the environment in Tokyo metropolitan area transport.

The main fields that the next-generation railway operation system in the Tokyo metropolitan area applies to are transport management and transport operation control for dispatch, route control for stations and train control and monitoring for trains (Fig. 1).

The data transmission routes connecting those fields include dedicated radio such as digital train radio, general-purpose broadband radio including WiMAX (Worldwide Interoperability for Microwave Access) and next-generation IP networks. From a standpoint of using ICT, future increased speeds and greater

capacity need to be considered regarding data transmission routes.

Methods of communications between trains and dispatch and between trains and stations (between wayside and onboard equipment) have slower transmission speeds than between wayside equipment only as with transmission between dispatch and stations. The amount of information that can be acquired onboard is thus very small. Attention therefore needs to be paid especially to technical trends for mobile radio and consideration actively made on application of successes in communications technologies when reviewing function allocation.

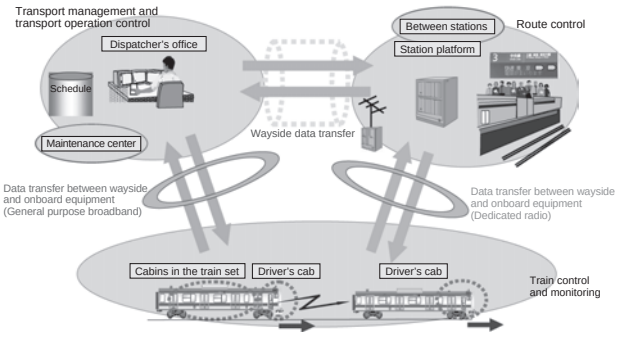

Fig. 1 Image of the Next-Generation Railway System

3 Overview of Development for the Next-Generation Tokyo Metropolitan Area Railway System

Here we will give an overview of development in the three key fields of the next-generation railway operation system in the Tokyo metropolitan area. Those fields are, as previously mentioned, transport management and transport operation control, route control and train control and monitoring.

3.1 Research on Transport Management and Transport Operation Control

In future Tokyo metropolitan area transport, two things will continue to be important for improving customer satisfaction. Those are flexible transport according to passenger demand (movement patterns) and appropriate and timely information to passengers and staff, both in normal operation and in operation disruptions. To achieve those, the transport management and transport operation control system should meet the following requirements (Fig. 2).

(1) System for accurately identifying situation

When performing work such as operation rescheduling to recover from operation disruption, we have to do that while providing information with consideration of the congestion level on the platform and in the trains and the top destinations of passengers at the time if we are to minimize customer dissatisfaction. In such cases, the closer to real-time the information on passenger volume (congestion in trains and stations) and on passenger movement patterns (embarking/debarking stations and route) is, the better we can schedule trains taking into consideration movement patterns and destination of passengers. Such up-to-date information on passenger movement patterns will be useful in normal operation as well as in operation disruption. For example, such information will contribute to improvement of train timetables and to flexible train assignment to meet temporary increase of passengers at events, allowing us to achieve flexible transport.

To flexibly assign trains in line with passenger trends, we need a system to meticulously acquire and store information upon which decisions are made. We are thus considering a system that utilizes a large capacity communications network and that can be used for acquiring, storing and analyzing the various information on ever-changing passenger movement patterns data such as passenger load.

(2) System for supporting quick arrangement

To make quick arrangement in cases such as operation disruption, it is necessary to employ the know-how of skilled dispatchers, linking scheduling of both cars and crews. So, we are now proceeding with the development of an operation rescheduling support system that can batch suggestion up to schedule recovery instead of suggestions for management of each train individually. This system is characterized by its taking into consideration of passenger volume (mainly transport volume based on passenger load) instead of just making suggestions in line with scheduling of cars and crews.

In the future, the system could advance to the point that it provides information predicting passenger movement patterns as the patterns taken into consideration in support of operation rescheduling. A condition for this, however, is further progress in data storage and analysis.

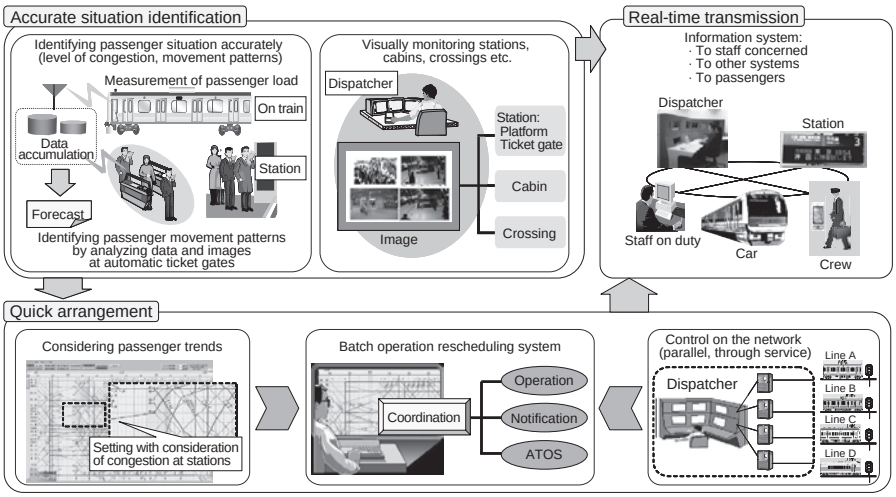

Fig. 2 Next-Generation Transport Management System

(3) System for quick transmission of information to departments concerned and passengers

Quick arrangement requires a means of communications to quickly inform of such arrangement. We thus need to be able to transmit through an information network the latest operation schedule to internal departments concerned, route control systems and train control and monitoring systems. For example, we are working to develop a function that utilizes WiMAX to transmit the new schedule when a change of crew scheduling occurs and show that on onboard displays.

We also need a function to provide information to passengers promptly via means such as information displays at stations and in cabins.

3.2 Development on Route Control

With the next-generation Tokyo metropolitan area railway system, one of our objectives is improvement of reliability by making the system simple. Simplifying, consolidating, and streamlining down wayside equipment by function allocation will contribute to reducing operation disruptions caused by equipment failure, and it will also reduce maintenance work and cost.

In development up to now, we have worked to develop a network-based signal control system to reduce the amount of signal cabling, improve work efficiency and simplify testing. That was done by changing control of signal equipment from voltage control to information control using optical networks. Following the first implementation of a network-based signal control system at Ichikawa-Ono Station on the Musashino Line, we are working on design and construction to gradually start use on the Keiyo Line (Tokyo–Soga) from the end of fiscal 2012.

However, logical controllers that control equipment such as signals, points, ATS-P and crossings are functionally independent, making for a complex system configuration. For the route control system, we are developing in steps logical controllers that can control those all in a single device.

As the first step, we are conducting development to organize and rebuild on a common platform control logic such as the station interlocking system and ATS-P system that have undergone function-oriented development, integrating and standardizing equipment as a logical controller for station yards (station yard LC). We are also simplifying the process of communicating control and feedback information to improve reliability, decrease design work and reduce costs. In preliminary development, we verified hardware and control logic. In the future, we will make calculation processing and control and feedback data structure highly independent by function type such as interlocking and ATS-P as development for practical use of station yard LC. Through that, we are conducting development with a goal of building control logic that can determine and minimize the area affected when system repair work is done or disruption occurs (Fig. 3).

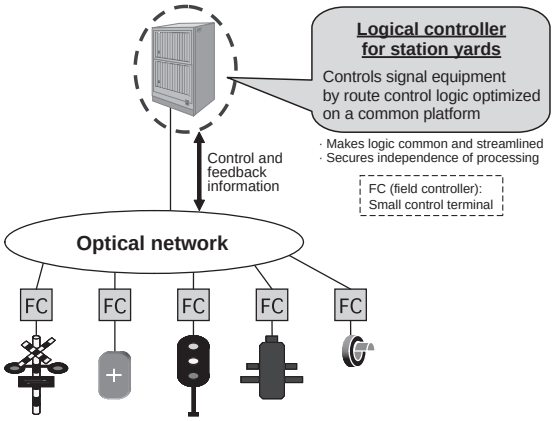

Fig. 3 Logical Controller for Station Yards (Station Yard LC)

We are aiming to introduce station yard LC as the successor to the electronic interlocking device used in applications such as the Autonomous decentralized Transport Operation control System (ATOS).

In the future, we envision integrating those station yard LCs and the functions (train position detection, train tracking, train control, etc.) of the Advanced Train Administration and Communications System using radio communication (ATACS) introduced to the Senseki Line. Field equipment such as wayside signals can be reduced by introducing ATACS, and the system can be made even more streamlined by integrating ATACS device functions and hardware, thus likely achieving increased reliability and reduced costs for the overall system. We see this as an issue to be studied along with studies on the Tokyo metropolitan area ATACS.

In the end, we expect the system to develop into a station integrated logical controller that integrates functions of interlocking, route control and displaying information to passengers (station timetable management) (Fig. 4).

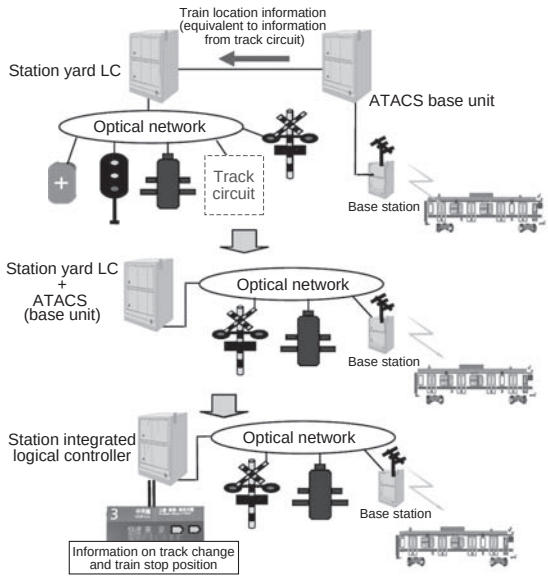

Fig. 4 Image of Function Integration of Station Yard Logical Controller

3.3 Development on Train Control and Monitoring

Development is underway for the INtegrated Train communication/control network for Evolvable Railway Operation System (INTEROS) under the development concepts of improving reliability and service and achieving compatibility with the next-generation railway operation system in the Tokyo metropolitan area and international standards for the train control/monitoring system (TCN). To be compatible with those concepts, the data transmission system needs larger capacity and improved expandability, so we employed 100 Mbps Ethernet as core

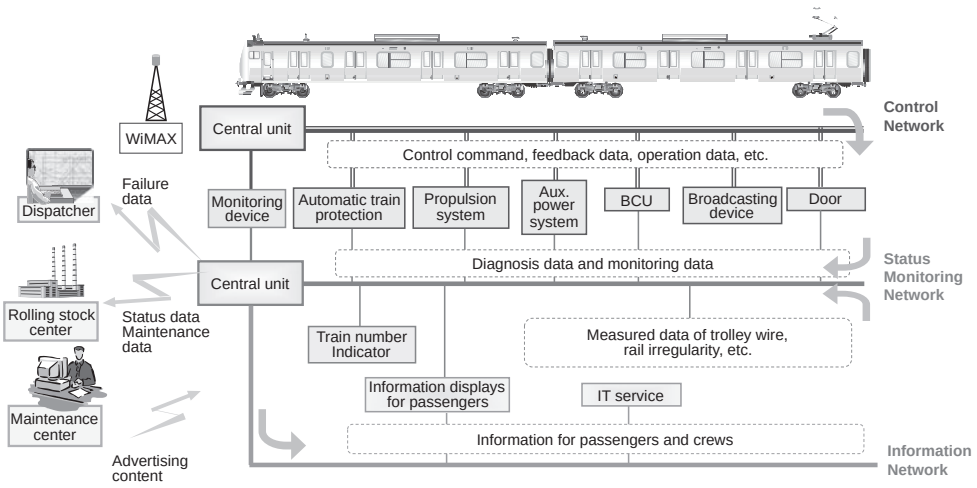

Fig. 5 Outline of INTEROS Networks

technology in the TCN. And to improve reliability, we studied a system configuration for which we had a goal of reducing the amount of hardware as much as possible by modifying functional allocation in the system, developing two methods.

Moreover, we separated the TCN by function into three networks: (1) control network that handles information on train control (2) status monitoring network that handles monitoring and maintenance information of onboard equipment and (3) information network that handles data including content such as videos and still images provided to passengers. By separating the control network from other networks, we aim to improve reliability of the overall system. With the large-capacity information network, we are making possible the enhancement of onboard services such as providing information to passengers and improving onboard security by adding and expanding equipment such as those for onboard ITC services. Monitoring devices for wayside equipment such as overhead contact lines and track are on an independent network on test trains, but we are considering interfacing it with the status monitoring network (Fig. 5).

We are also working on development using WiMAX for transfer of large volumes of data between onboard and wayside equipment. This includes transferring maintenance data compiled onboard to the wayside and updating content and onboard equipment software from the wayside (Fig. 5).

We are aiming for practical implementation of INTEROS with an eye on introducing it to the next new commuter EMU. Under that goal, we have equipped test trains with this system and are conducting a variety of tests.

Also, we have started development of the ATACS wireless communications systems for the Tokyo metropolitan area, envisioning future introduction in the Tokyo metropolitan area of the new ATACS system for train control where most of the control is done onboard. Development of specific functions under ATACS that will be required for the deployment in the Tokyo metropolitan area is also in preparation.

4 Conclusion

This article has provided an introduction to the status of development of the many elemental technologies we are working on for innovation of the next-generation railway operation system in the Tokyo metropolitan area. Fig. 6 shows the status of development for the development covered here. We expect that a long time will be needed to achieve our overall image of that system.

Equipment related to the system is gradually reaching its replacement period. We will proceed with development keeping in mind synchronizing with equipment update measures so that we are able to appropriately introduce at optimal timing developed elemental technologies at the opportunity provided by those measures.

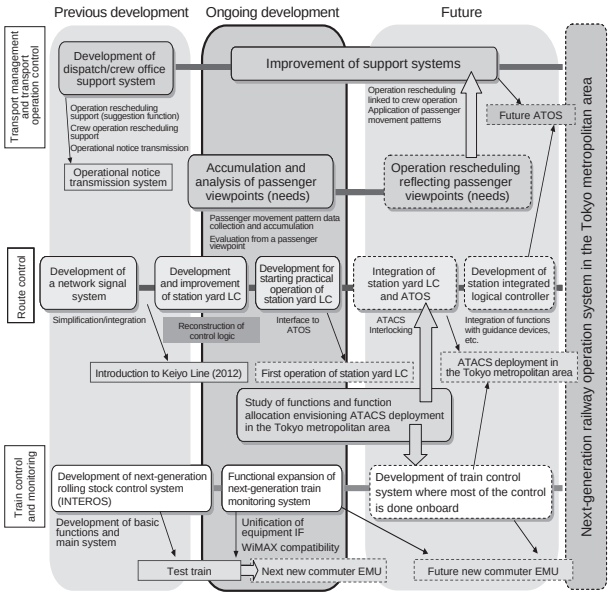

Fig. 6 Status of Related Development

Reference:

1) Tamotsu Kato, "Yuso no Anzensei Kojo to Okyakusama-shiko [in Japanese]," *JR EAST R&D REPORT* No. 79 (July 2008): 1–2

2) Fumihiko Henda, Satoshi Fukui, Ryosuke Furuta, "Shutoken Tetsudo System no Kakushin ni mukete [in Japanese]," *JR EAST R&D REPORT* No. 79 (July 2008): 3–7

3) Yasuyuki Nakamura, "Innovation of the Railway Operation System in the Tokyo Metropolitan Area," *JR East Technical Review* No. 15 (2010): 04–07