B-system: New Solution for Seamlessly Interconnecting Track-side and On-board Systems over Network

Hiroaki Koiwa
Satoru Ito
Masakazu Matsuo
Yoshinori Okura
Tomoaki Ishifuji
Tomoichi Ebata

OVERVIEW: The fundamental concept of the ubiquitous information society is the ability to obtain needed information whenever and wherever one wants. In the context of enhanced railway passenger services, this means above all providing passengers with access to the network anytime and anywhere whether in railway stations or on-board trains. Equally important considering the greater intelligence of railcars themselves, is the need for more advanced on-board operating systems that are seamlessly connected to track-side systems. As a comprehensive rail system integrator, Hitachi has responded to these needs and at the same time contributed to more convenient and efficient rail systems through the development of a sophisticated broadband network system for trains—dubbed the B-system—that not only significantly increases the capacity of on-board networks but also supports seamless continuous interconnection between on-board and track-side systems.

INTRODUCTION

As the ubiquitous information society has become more pervasive, demand has emerged for smarter railcars endowed with greater intelligence and more advanced on board operating systems and passenger support services based on seamless and continuous connectivity with track-side systems. Hitachi's solution was to construct an overarching environment that incorporates all the separately implemented legacy on-board systems (e.g. train control equipment) and track-side systems (e.g. train traffic control system) into a single vast integrated railway information control

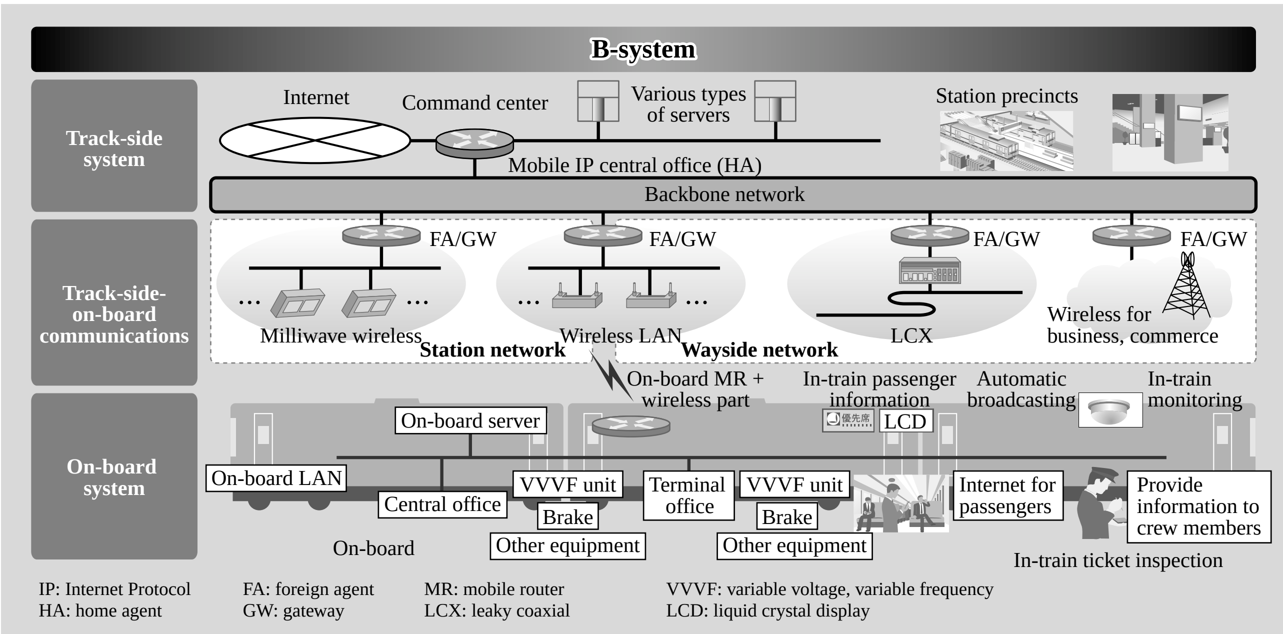

Fig. 1—B-system Target Range.
The B-system target range can be divided into three elements: track-side system, track-side-on-board communication, and on-board system.

system that provides seamless network connectivity between track-side and on-board communications equipment.

Adopting this approach, Hitachi has already developed a range of products—from higher end host systems to intelligent terminals deployed on-board trains and on the wayside—that are part of this comprehensive solution called the B-system (broadband network system). In this paper we will take a closer look at the new B-system solution that provides seamless connectivity over the track-side-on-board network.

B-SYSTEM DEVELOPMENT CONCEPT

Hitachi is committed to its new concept of the A-train plus the B-system that combines A-train's sleek new environmentally-friendly rolling stock with B-system's high-speed broadband on-board capacity. B-system products now in development and production will provide high-speed on-board networking to support

(1) tighter, more efficient control over on-board equipment,

(2) collection and transmission of vast amounts of sensing data from on-board equipment to track-side support enabling remote maintenance, and

(3) close interconnection between control systems and track-side systems to provide information services for both passengers and crew.

ON-BOARD NETWORK SYSTEM

On-board Transmission Information

Advances in data transmission technology have opened the way to greatly extended on-board information capabilities including crew, maintenance personnel, and passenger support services, better control command delivery capabilities, and more. Indeed, Hitachi is now developing a whole range of products as part of its train monitoring system initiative to meet these needs by substantially increasing on-board network capacity and tighter integration and cooperation between information systems.

Essentially there are three kinds of information carried over on-board networks:

(1) Control command information: including commands for powering, braking, and other operations that are directly involved in running the train. The volume of data is quite small, but obviously the fail-safe and realtime nature of this information is critically important.

(2) Monitoring information: consists of data from displays in the cab showing the operating status of the train, fault detectors, and various other detection capabilities, as well as data from the air-conditioning system and other on-board equipment that is not directly related to running the train. This involves a moderate amount of data, and some degree of realtime capability.

(3) Service information: mainly supports passenger services such as video and audio passenger information in train cars, video data for door checking and other monitoring purposes, etc. This data is irregular (aperiodic) and generally does not require realtime capability. Note that the interface for this type of data with on-board information equipment should comply with familiar general-purpose IT.

As trains themselves become increasingly intelligent, we can anticipate that on-board networks will also evolve toward greater capacity and diversity to support more intense equipment monitoring, reliable delivery of commands, and other detailed control capabilities needed for (1) and (2), and to support the standard equipment enabling barrier-free access for (3).

On-board Network Equipment System

Fig. 2 represents a family of Hitachi's train monitoring system series that flexibly covers these various needs. For example, the type T system carries all three kinds of information—control, monitoring, and service—at the same time, and thus markedly reduces the amount of wiring used by the on-board

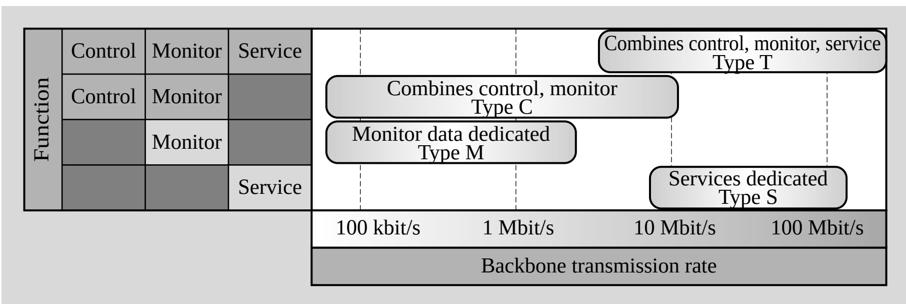

Fig. 2—Hitachi's Train Monitoring System Series Overview.
Faced with growing expectations of more advanced and diverse on-board information equipment capabilities, this system provides the functionality to support the required types and combinations of information.

LAN. Note that the type T system is implemented in such a way that priority is always given to control command and monitoring control information over the service information, so the delivery of essential control information is never delayed or adversely affected by the service data, which is much more voluminous. Table 1 lists the four train monitoring system's subsystems, highlighting the features and capabilities of each.

Implementation of On-board Information Control System

Passenger information is a major part of the service data system. Traditionally, announcements and passenger information have been provided as graphic information services using an LED (light emitting diode) display system in the cars. In order to upgrade passenger services with more diversified information content and video advertising, we would like replace the LED system with in information display system based on LCDs (liquid crystal displays). The main stumbling block is that this would require new deployment of dedicated wiring involving many worker-hours of labor to install.

Here the type S (service) subsystem offers a better alternative, for it permits installation of LCDs using the twisted pair wiring that is already in place, and thereby minimizes the work of upgrading the system. We envision increasingly intelligent on-board equipment in the years ahead, including LCD-based display devices. And because type S is IP (Internet Protocol)-compliant, the system can flexibly accommodate new functional capabilities that evolve in the future (see Fig. 3).

TABLE 1. Features of Each Train Monitoring System's Product
Transmission medium and features of each product. The products are tailored to the nature and functionality of the on-board information transmitted.

Name	Medium	Feature
Type T	Coaxial cable	• Redundant transmission for fail-safe performance • Integrated control and information systems • Carries control commands to reduce wiring • Bolsters monitoring functions, simplifies logic controller
Type C	Twisted pair	• Redundant transmission for fail-safe performance • Carries control commands to reduce wiring
Type M	Twisted pair	• Specialized for carrying monitor data • Single transmission
Type S	Twisted pair	• Specialized for carrying service information • Single transmission

SEAMLESS TRACK-SIDE-ON-BOARD NETWORK SOLUTION

Development of railway services leveraging communication between track-side and on-board equipment means of course that the equipment and terminals on trains are connected to track-side systems, so the train itself becomes a mobile sub-network. This involves seamless transmission of data back and forth between fast-moving trains and track-side network, and this has focused much attention on mobile IP technology as the best way to achieve this. Mobile IP is a standard technology enabling mobile terminals that are traveling from one IP network to

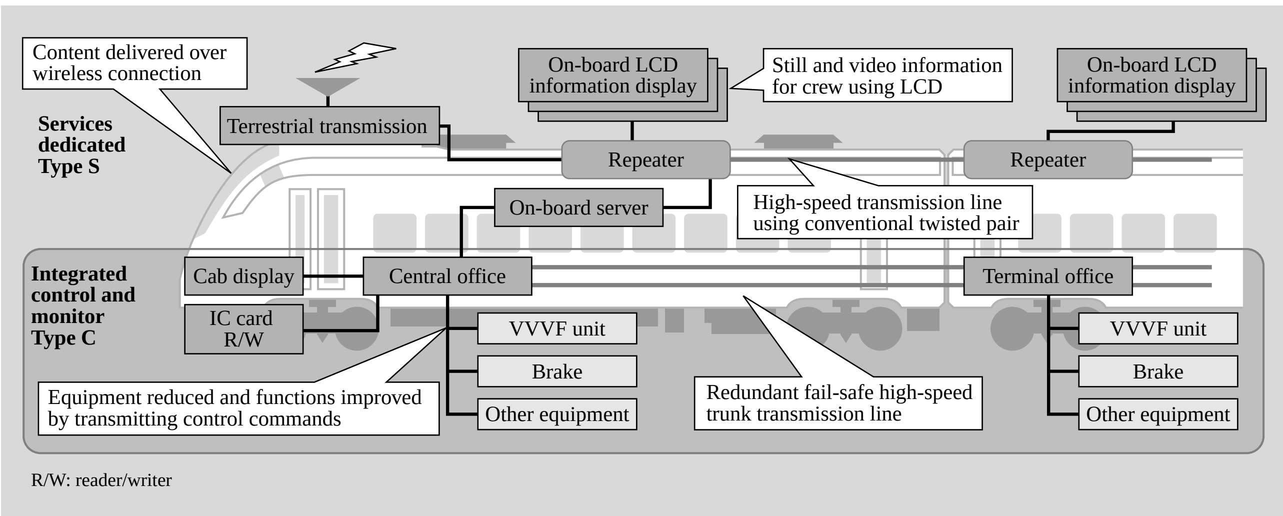

Fig. 3—Schematic On-board Information System Using Hitachi's Train Monitoring System.
Type S can flexibly accommodate extended functions.

another IP network to connect with multiple mobile IP routers along the way and deliver packets ahead to a forward destination.

Unfortunately, the standard mobile IP technology cannot simply be applied as is to fast-moving trains because packets of information are sometimes lost when the signal is handed over from one router to the next, so some supplemental technology is needed specifically to address that problem. In addition, mobile IP for rail must also be augmented with a special wireless transmission scheme optimized for efficient frequency reuse in long-distance continuous wireless cells covering rail lines. To supplement mobile IP we have developed two key technologies that markedly improve the performance and reliability of communication between track-side systems and high-speed trains: a communication middleware and a milliwave wireless continuous transmission scheme.

Communication Middleware

When standard mobile IP technology is applied to communication between track-side and on-board train systems, handover from one router to the next can take several seconds, and loss of packets during these intervals is a serious problem. Normally the TCP (transmission control protocol) ensures that lost packets are retransmitted, but handover occurs so frequently when the mobile is a fast-moving train that the resend processing cannot keep up so data packets are lost. It was this unacceptable situation that led us to develop middleware that improves the functionality of the standard mobile IP technology while ensuring more reliable communication.

The middleware resides in the mobile IP network, both on-board the train and track-side, and provides the following basic middleware functions (see Fig. 4):

(1) The track-side middleware sends duplicate copies of each packet to the current wireless zone (where the train is currently located) and to the forward wireless zone (where the train is headed), so delay time for the retransmission of packets at handover is minimized.

(2) Packets that are lost due to handover or noise are immediately detected using serial transmission numbers that are assigned to each packet, and the retransmission of lost packets is handled by the middleware on the train and on the track-side.

(3) Handover is achieved much faster through mutual interaction of the on-board and track-side middleware than by mobile IP.

Note that the middleware does not affect the operation of routers or other network equipment. It simply coexists and complements the functionality of standard mobile IP technology.

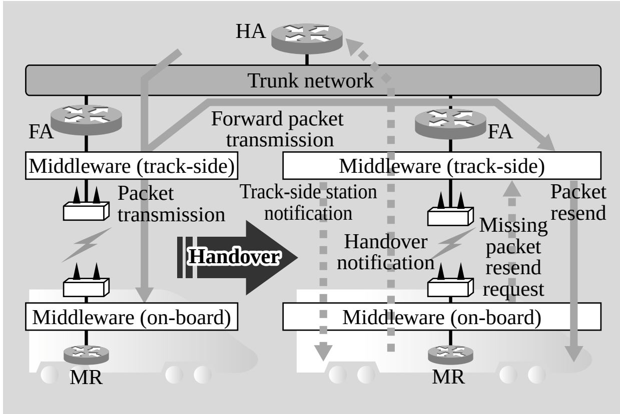

Fig. 4—Schematic of Communication Middleware Operation.
Coexists but enhances the functionality of standard mobile IP to improve the reliability of high-speed mobile communication.

Continuous Wireless Transmission Scheme

Seamless continuous communication between track-side and on-board equipment requires a string of overlapping wireless communication zones supported by multiple track-side base stations deployed all along the rail line. To prevent radio interference between zones, adjacent base stations use different frequencies to communicate with each other, so this means that the on-board wireless equipment must be able to accommodate different frequencies. This led to our development of a continuous wireless transmission scheme that controls the radio transmission of the track-side base stations and is the essential heart of the on-board wireless equipment. When the train is traveling, the on-board wireless equipment sends out periodic communication request signals searching for base stations in the vicinity that will support communication. From among the responses, the wireless transmission scheme specifies the closest base station ahead and automatically uses that base station to send and receive data for a fixed interval of time. During that interval, all communication with other base stations that were not specified is suspended.

By transmitting just to the track-side base station specified by the on-board wireless equipment, the base station's transmission timing can be time-division controlled. This is very advantageous, for it effectively suppresses radio interference with adjacent base stations even when the frequency used occupies just a single channel, so the on-board wireless equipment also only needs to deal with a single channel.

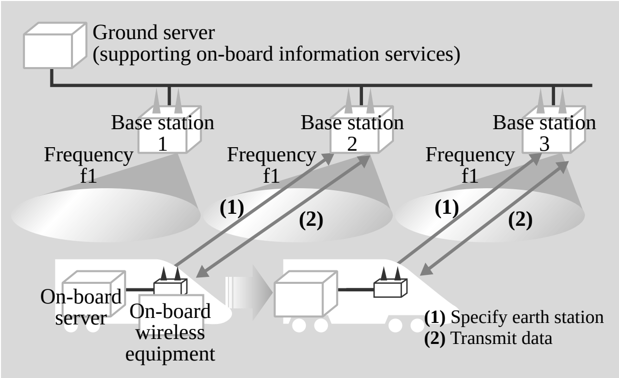

Fig. 5—Schematic of Continuous Wireless Transmission Scheme Operation.
On-board wireless equipment uses base station transmission control to suppress interference with adjacent communication zones, thus permitting high-speed communication using a single frequency.

These capabilities of the Hitachi's continuous wireless transmission scheme technology enable the wireless equipment to be implemented more compactly and the track-side equipment is simplified, so additional track-side base stations can be easily constructed in a phased deployment. And because the scheme supports fast time division of base stations and highly efficient transmission, it is well suited for high-speed wireless transmission such as milliwave wireless (see Fig. 5).

CONCLUSIONS

Here we presented an overview of B-system, a sophisticated broadband network solution developed by Hitachi that significantly increases the capacity of on-board networks and supports seamless continuous interconnection between on-board and track-side systems. As a comprehensive rail system integrator, Hitachi is committed to further leverage the company's expertise in information and communication technologies to further enhance the safety, efficiency, and convenience of railway systems.

REFERENCES

(1) M. Futagawa et al., "New Solutions for Railway Information Services of the Broadband Age," *Hitachi Hyoron* **85**, pp. 467-470 (July 2003) in Japanese.
(2) K. Ishida et al., "New Train Control and Information Services Utilizing Broadband Networks," *Hitachi Hyoron* **85**, pp. 553-556 (Aug. 2003) in Japanese.

ABOUT THE AUTHORS


Hiroaki Koiwa
Joined Hitachi, Ltd. in 2001, and now works at the System Solution Department, the Transportation System Division, the Industrial Systems. He is currently engaged in the development of system engineering for transportation system-related information technology.


Satoru Ito
Joined Hitachi, Ltd. in 1989, and now works at the Rolling Stock Electrical Systems Design Department, Mito Transportation Systems Product Division, the Industrial Systems. He is currently engaged in the development of information control equipment for trains. Mr. Ito is a member of The Institute of Electrical Engineers of Japan (IEEJ), and The Institute of Electrical and Electronics Engineers, Inc. (IEEE).


Masakazu Matsuo
Joined Hitachi, Ltd. in 1982, and now works at the Transportation Control Systems Engineering Department, the Transportation Information Systems Division, the Information & Telecommunication Systems. He is currently engaged in the development of information services for transportation systems.


Yoshinori Okura
Joined Hitachi, Ltd. in 1988, and now works at the 3rd Department of Systems Research Department, the Hitachi Research Laboratory. He is currently engaged in the research and development of network applications and technology and wireless radio technology. Mr. Okura is a member of IEEJ and The Institute of Electronics, Information and Communication Engineers (IEICE).


Tomoaki Ishifuji
Joined Hitachi, Ltd. in 1989, and now works at the Wireless Radio System Division, the Central Research Laboratory. He is currently engaged in the research and development of wireless radio solutions for consumer products. Mr. Ishifuji is a member of IEEE and IEICE.


Tomoichi Ebata
Joined Hitachi, Ltd. in 1991, and now works at the 4th Research Department, Systems Development Laboratory. He is currently engaged in the research and development of industrial networks and systems.