New Train Control and Information Services Utilizing Broadband Networks

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OVERVIEW: Hitachi, Ltd. has done much to improve the efficiency, the utility, and the convenience of railroad-related systems through the development of diverse onboard control equipment, ground operations management systems, and maintenance support systems. Now thanks to recent advances in broadband networking technology already evident in businesses, households, and cities, more and more systems are being interconnected and all sorts of new services are being made available at an accelerated pace. There is a strong expectation and desire that railroad systems can similarly be made more efficient and convenient by using these same technologies to interconnect many onboard train and ground systems. Responding to these needs, Hitachi has been an industry leader in developing broadband network infrastructures for trains and to link onboard systems with external ground systems. In the company's capacity as a railroad system integrator, Hitachi has also been instrumental in making railroad systems more convenient and efficient by networking onboard equipment and by linking onboard systems with ground control systems.

INTRODUCTION

FACED by the demographic reality of a declining birthrate and more elderly population, fierce competition from other modes of transportation, and growing environmental consciousness of society, the railroads are demanding greater efficiency from their systems, while also seeking to provide advertising, information services, and other new business initiatives in stations and onboard trains that will attract additional riders.

In the case of ground-based systems, operational efficiency has been markedly improved and many new information services have been made available by using broadband networks to interconnect various systems and equipment. And as more and more systems are networked, advanced services will be made available at an accelerated pace as a result of the multiplier effect.

By leveraging these broadband networking technologies to support transmissions aboard trains and between train and ground systems, Hitachi is improving the efficiency of train controls and maintenance while also making good progress in realizing new services for train crews and passengers alike.

This paper will provide an overview of recent broadband network initiatives proposed by Hitachi for use on board trains and between trains and ground systems, and highlight some of the new control and information services made possible by these broadband initiatives.

NEW TRAIN CONTROL AND INFORMATION SERVICES UTILIZING BROADBAND NETWORKS

Hitachi is making good headway in developing more convenient and efficient railroad systems by implementing broadband networks on trains, and using these high-speed large-capacity networks to interconnect onboard equipment and ground systems (see Fig. 1).

Fig. 2 shows that, by implementing onboard networks using broadband networking technologies, a host of new capabilities become available besides the delivery of ordinary control and monitoring data including integrated transmission of maintenance data, more advanced control data, and a great variety of video and other kinds of information. Indeed, broadband will enable the integration of much new control data together with many new information services including:

(1) More efficient control with closer links to onboard

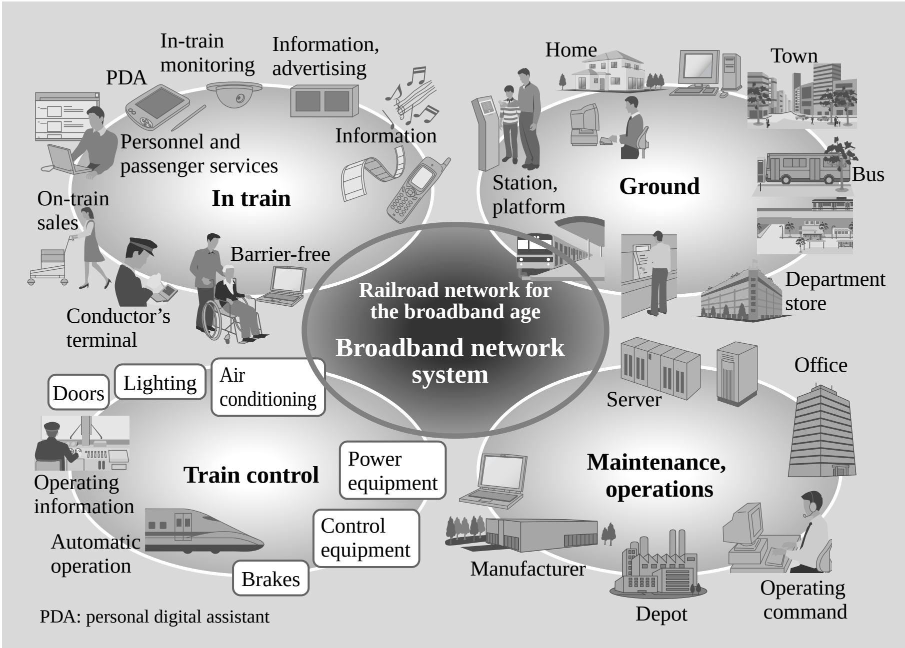

Fig. 1—Overview of New Control and Information Services Using Broadband Networks.
By interconnecting trains with ground systems over a seamless broadband network, Hitachi is able to provide new train control capabilities, new services for both crew and passengers, access to maintenance and operations management support data, and a wide range of other ground services.

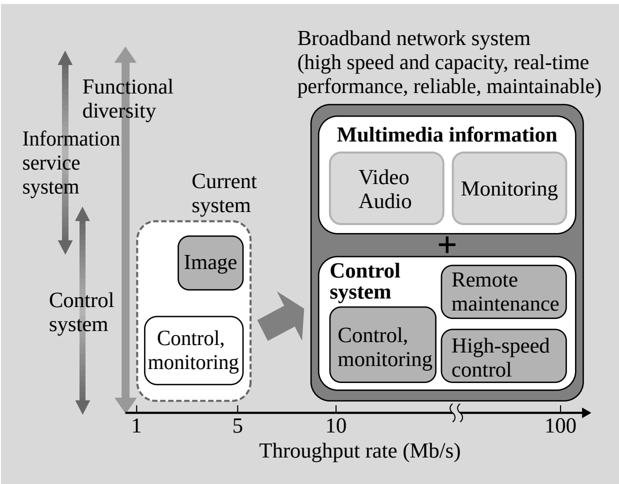

Fig. 2—Functional Integration Through a High-speed, Large-capacity Network.
Control, remote monitoring, and on-train surveillance capabilities are integrated using a high-speed, large-capacity network.

equipment
(2) Better maintenance by collecting large amounts of sensing data and sending the data to ground systems
(3) More and better information services for train crews and passengers by linking train control and ground systems.

ONBOARD NETWORKS

Onboard networks carry critical control information, so it is imperative that these networks are not only fast but also highly reliable. While basing our approach on general-purpose Ethernet* technology, essentially what we have done is to develop a number of reliability enhancing technologies including GHz-band RF (radio frequency) transmission, data bypass transmission, and control priority transmission.

Communication errors sometimes occur on trains as a result of the ambient noise level caused by inverters and other equipment. Moreover, the electrode surfaces of electrical couplers between cars tend to deteriorate when cars are separated, and this makes it easy for connections to fail. To address these issues, we separated common mode noise from transmission signal frequencies thereby eliminating interference from noise, and we developed GHz-band RF transmission technology, which effectively prevents connection failure due to high-frequency radiation.

The data bypass transmission enables communication to continue uninterrupted even in the event that backbone LAN (local area network) equipment should fail. Onboard networks are implemented as fully redundant systems, so if the first LAN fails, the data is automatically copied and rerouted over the second LAN. Even in the unlikely event of a double failure, these capabilities support an extremely high level of reliability so control data is not interrupted.

Also, by implementing the onboard network so that data for both train control and for information services

* Ethernet is a registered trademark of Xerox Corp.

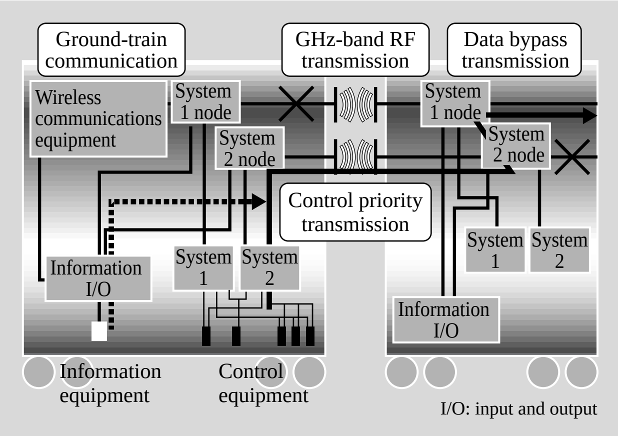

Fig. 3—Onboard Network Configuration.
A high-speed reliable onboard LAN based on general-purpose technologies is used to transmit train control data and information service data at the same time.

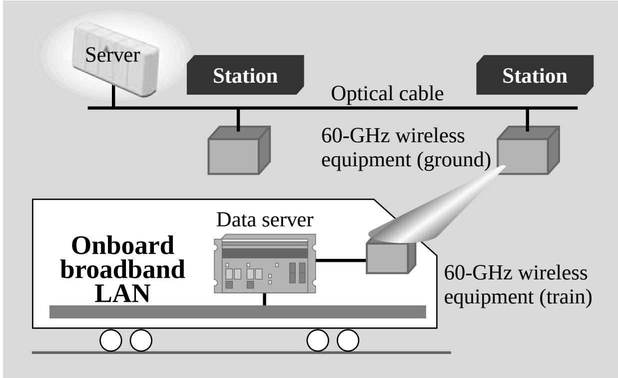

Fig. 4—Overview of Spot Transmission System.
Using 60-GHz wireless equipment capable of high-speed 100-Mb/s transmission, large quantities of content and maintenance data can be sent to the train while the train is briefly stopped in a station or even as the train passes through a station.

TABLE 1. Onboard Network Features

	Features
Flexibility	Ethernet-based backbone LAN
Fast and highly reliable	GHz-band RF transmission (100 Mb/s, coaxial) Control data bypass transmission (continues to work in the event of double failures) Control transmission cycle: 10 ms
Data services	Control data always has priority.
Less wiring on trains	General-purpose LAN to reduce wiring (Ethernet, CAN, RS485)

are transmitted concurrently, the amount of wiring used by the backbone LAN will be substantially reduced. Ports for both data equipment and control equipment are installed at trunk nodes, but data coming in through the port for the control equipment is never adversely affected by incoming data for information services (even when this data is voluminous), because data for control equipment is always assigned first priority (see Fig. 3).

General-purpose networking technologies, primarily Ethernet and CAN (controller area network), are used to interconnect equipment. This has permitted a transmission scheme in which the wiring is concentrated in close proximity to the equipment, so the amount of wiring is significantly reduced (see Table 1).

TRAIN-GROUND SYSTEM TRANSMISSION

Development of communication technologies linking train and ground systems is critically important to provide faster onboard information services. This led Hitachi to develop 60-GHz wireless equipment that uses the millimeter-wave band for high-speed wireless communications. Full-duplex 100-Mb/s communications is supported using the 59-to-66 GHz millimeter-wave band for communication. The transmission power is less than 100 mW, and the communication range is 100 to 200 meters.

The 60-GHz wireless equipment is a high-speed communication system, so by installing wireless equipment in stations and other wayside locations, very large quantities of data can be transmitted to the train including video content and maintenance data for onboard equipment in a very short period of time while the train is briefly stopped at a station or even as the train passes through a station without stopping (see Fig. 4).

TRAIN CONTROL SYSTEM

The new onboard network supports more advanced train control capabilities including train-set total torque control and the electric-air brake blending control. When the rail surface become wet due to rain, the adhesion between train wheels and tracks is reduced and this causes the train to slip and skid when the train accelerates. This not only reduces acceleration performance, it also makes the ride less comfortable for passengers. The front driving axle is especially susceptible to slippage when adhesion is reduced. In the past, this has been dealt with by reducing the torque of the first car in advance when it rains to prevent slippage of the first car. The problem with this conventional approach is that the torque on the front driving axle is kept in a reduced state longer than necessary, and this causes inverter loads to become uneven and brake disks to wear unevenly, which has the effect of reducing the maintenance cycle.

Train-set total torque control using the onboard network reduces the torque just for the inverters causing the slipping and skidding, and only when slipping and skidding actually occur. How this works is illustrated in Fig. 5: the amount of torque on the front driving axle is successively reduced with each slip or skid, and the insufficient amount of torque is allocated to other cars that are not slipping or skidding. In effect, the amount of torque for the entire set of cars is held constant, and this prevents a loss of acceleration performance and also prevents slipping and skidding from adversely affecting the comfort of the ride. Furthermore, since the torque of the first car is only reduced when slipping or skidding actually occurs, uneven distribution of inverter loads and uneven wear on brake disks is prevented, so the maintenance cycle is extended. Based on the total train-set torque control technology, we are now investigating how to extract the maximum regenerative energy and implement energy saving controls in the electric-air brake blending control system. Energy savings can also be achieved by running at a constant speed that maximizes efficiency.

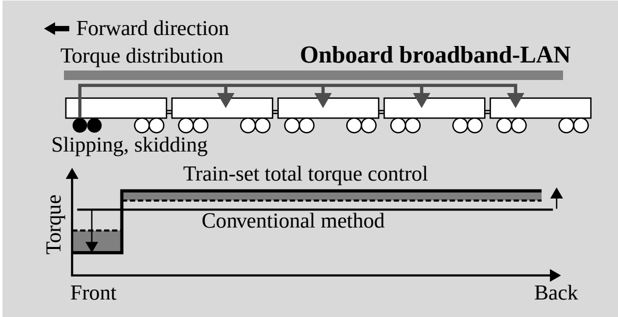

Fig. 5—Train-set Total Torque Control.
The front car is prone to slippage in the rain when rail surfaces are wet. Torque in the front car is successively reduced with each skid, and operational performance of the train as a whole is improved by distributing the torque to the other cars that do not skid.

MAINTENANCE SYSTEM

An advanced, labor-saving maintenance system is implemented by exploiting the high-speed transmission capabilities of the onboard broadband network. Various types of sensors are deployed throughout the train, and the onboard network collects data from the sensors. When an abnormal reading is detected, the data before and after the incident is sent to the ground-monitoring center using 60-GHz wireless equipment. The monitoring center pinpoints the problem using abnormal analysis technology, formulates a theory explaining why the event occurred, and relays the information back to the train where it is stored in the onboard network. As it accumulates this kind of troubleshooting knowledge, the onboard network becomes increasingly intelligent and better able to anticipate and diagnose problems (see Fig. 6).

In addition, the onboard maintenance data can be correlated with location data, and this helps determine if the problem can be traced to the tracks or other wayside equipment. For example, if several trains detect an anomaly at exactly the same location, this strongly suggests that the problem can be attributed to the wayside equipment at that location. On the other hand, if just a single train detects the problem, then it is likely that the problem has something to do with the train and not the location.

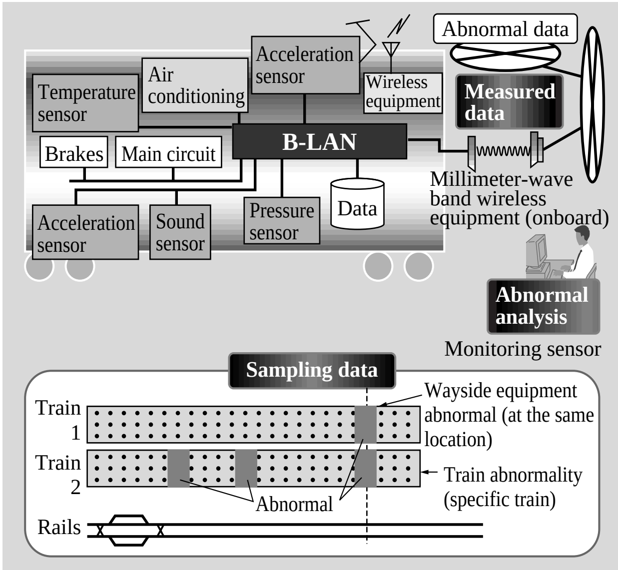

Fig. 6—Maintenance System.
Maintenance operations are markedly improved using less labor by deploying sensors throughout the train, collecting sensor data using the onboard network, and sending the data to ground-side systems for analysis using 60-GHz wireless equipment.

INFORMATION SERVICES

Deployment of broadband networks on trains and linking trains with ground systems would give train crew members access to an array of ground systems that would promote more efficient onboard operations and better service to passengers. These would include transportation systems such as transportation planning and operational management systems, and customer-

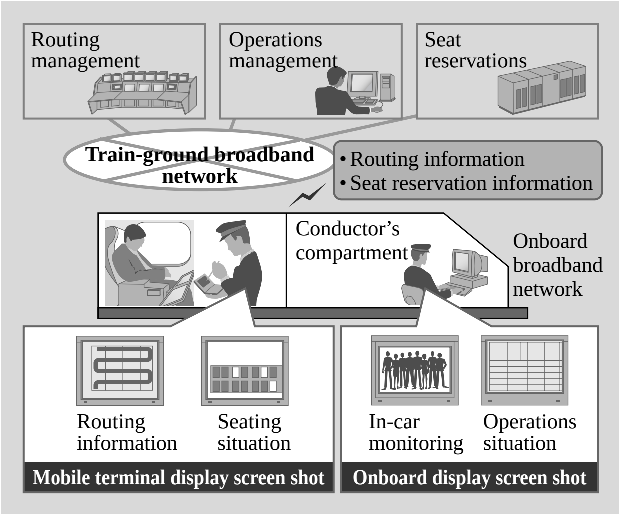

Fig. 7—Overview of Operations Support Information Services. Deploying a seamless broadband network between trains and ground systems provides train crews with a wide range of useful operational support data services.

oriented services such as seating management systems. Broadband networks would also permit a diverse range of information services to be made available to passengers.

Fig. 7 illustrates some of the operational support information services that could be provided to train crew. For example, the latest updated operations plans, operational data, and other essential data for running a railroad could be sent to the train in realtime over the broadband network and on a terminal in the conductor's compartment. The information could then be made available to the rest of the train crew on mobile terminals using the onboard network. Of course, information can also flow in the opposite direction. For example, train crew might want to send detailed video and audio information data back to the central command to document some incident that occurs in the passenger car. This new ability for the central command and train crew to exchange and share critical information enables more precise executions of procedures and operations.

CONCLUSIONS

This paper presented an overview of a scheme proposed by Hitachi for deploying broadband networks on trains and linking trains with ground systems, and highlighted some of the intelligent control capabilities and new services that could be provided over such networks.

Building on its solid achievements in broadband and other IT solutions, Hitachi plans to extend its control and information service offerings, onboard data systems, and train-ground system service support capabilities in the company's capacity as a leading railroad system integrator to steadily improve the performance, the efficiency, and the overall convenience of railroad systems.

REFERENCE

(1) M. Futakawa et al., "New Solutions for Railway Information Servicers of the Broadband Age," *Hitachi Hyoron*, **85**, pp. 467-470 (July 2003) in Japanese.

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