Shinkansen Traffic Management System for Mutual Direct Operation of Sanyo Shinkansen and Kyushu Shinkansen

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OVERVIEW: The SIRIUS supervisory system for the Kyushu Shinkansen manages traffic, rolling stock, and other aspects of line operation. The system was commissioned in March 2004 to coincide with the commencement of operations on part of the Kagoshima route of the Kyushu Shinkansen (between Shin-Yatsushiro and Kagoshima-Chuo Stations). The system was subsequently upgraded in November 2010 in readiness for the commencement of operations along the entire line (between Hakata and Kagoshima-Chuo Stations) in March 2011. To support through-trains running on both the Sanyo and Kyushu Shinkansen railway lines, the system includes interconnections with the COMTRAC traffic management system for the Tokaido and Sanyo Shinkansens. To provide the high level of reliability demanded by a Shinkansen system, the automatic route control equipment at the heart of the system features the new CF-1000/FT fault-tolerant model with synchronization control of four-fold CPU redundancy at the OS level.

INTRODUCTION

OPERATION between Hakata and Kagoshima-Chuo Stations along the Kagoshima route of the Kyushu Shinkansen commenced when the full line opened in March 2011. The line connects to the Sanyo Shinkansen line at Hakata Station. Some trains provide mutual direct operation, called the Sanyo-Kyushu Shinkansen service. This operation improves customer service, including avoidance of any need to transfer at Hakata Station.

To ensure that this through-train service operates smoothly, the respective control centers for the Sanyo and Kyushu Shinkansens must simultaneously monitor the progress of each train and perform integrated management (see Fig. 1). The traffic management system for the Tokaido and Sanyo Shinkansens is called the computer-aided traffic control system (COMTRAC), and the traffic management system for the Kyushu Shinkansen is called the super intelligent resource and innovated utility for Shinkansen management (SIRIUS). To achieve integrated management across both control centers, these two systems interconnect and share the information they require in realtime. Specifically, the shared information includes train diagrams (train operation schedules), operating conditions and predictions, and train running results.

Because the Kyushu Shinkansen has an important role as a major railway artery in the region, it demands a system with a high level of reliability and availability. The equipment used in the system includes highly reliable servers and clients, and the traffic management system in particular uses the new CF-1000/FT fault-tolerant model in the programmed route control (PRC) subsystem.

The new CF-1000/FT model features four-fold central processing unit (CPU) redundancy using four blade servers and voter units that use the majority voting system to implement the redundancy function. It also features synchronization control at the operating

Fig. 1—Control Room for Kyushu Shinkansen.
The control room that manages train operation provides various user interfaces for coordinating train movements and performing manual control from operation desks. The control room also provides enhanced visual presentation with large display panels that provide an overview of information such as train position and equipment status.

system (OS) level to implement a fault-tolerant model that is not hardware-dependent.

This article describes how the interconnection between Shinkansen traffic management systems is used to support through-train service, and the adoption of a fault-tolerant model to ensure a high level of reliability.

SYSTEM OVERVIEW

The SIRIUS supervisory system for the Kyushu Shinkansen was installed in 2004 to coincide with the opening of a section of the Kagoshima route of the Kyushu Shinkansen. The system consists of the following four subsystems, and the upgraded system for the full line uses the same configuration.

(1) Planning subsystem

This is used to produce the patterned diagram and revised diagrams (to accommodate special trains and other unscheduled situations) for Shinkansen operation. These include the train association, the rolling stock plan, and the crew plan.

(2) Operations subsystem

In addition to producing the actual diagram based on the patterned and revised diagrams produced by the planning subsystem and augmented by the trainset configuration plan, this subsystem also manages the train running result and records of rolling stock operation. It also performs automatic control of trains based on the diagram, including notifying affected locations of any changes in the diagram in accordance with actual operating circumstances (see Fig. 2).

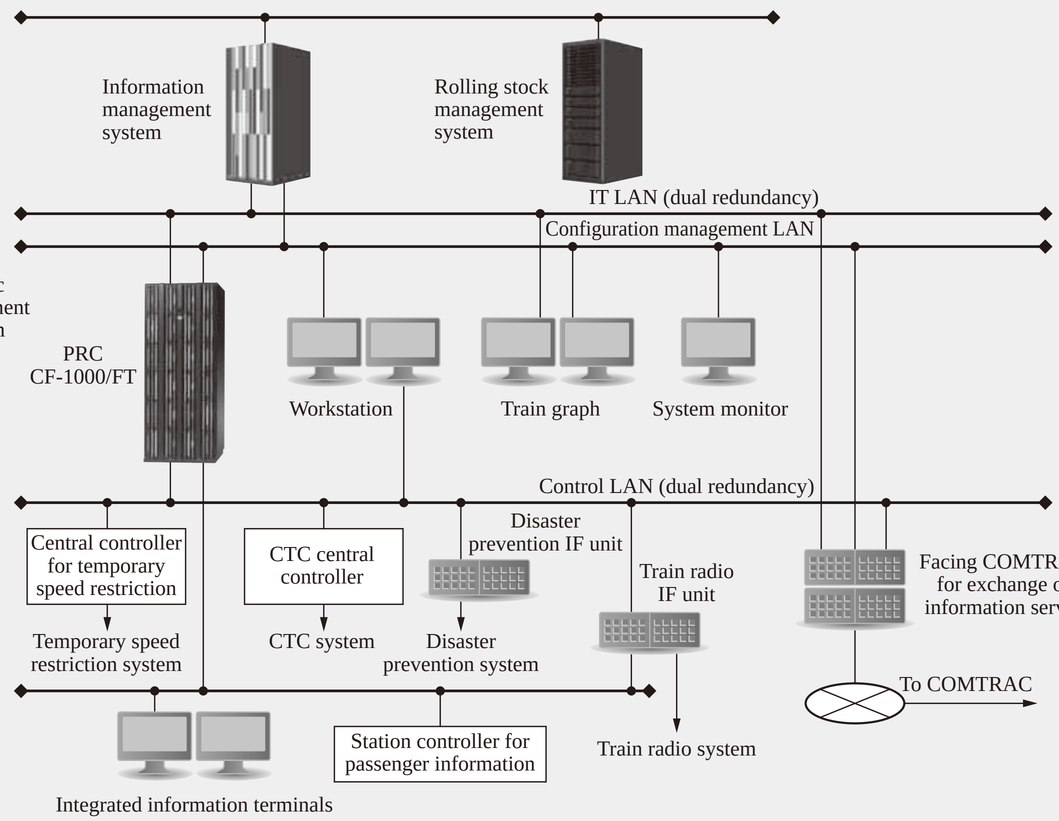
(3) Work management subsystem

This controls use of electric power by the Shinkansen trains and by wayside equipment. It also prepares and manages plans for performing rolling stock inspections and other daily maintenance work.

(4) Monitoring subsystem

This supplies information for preventing disasters along the line to relevant locations, such as rainfall, wind speed, seismic data, and rail temperatures. This subsystem also monitors position and status information from in-service rolling stock.

The newly implemented interconnection between systems primarily involves the operational subsystem. The operational subsystem consists of an information management system, traffic management system, and



IT: information technology LAN: local area network PRC: programmed route control CTC: centralized traffic control IF: interface
COMTRAC: computer-aided traffic control system

Fig. 2—Configuration of SIRIUS Supervisory System for Kyushu Shinkansen (Operations Subsystem).
The main components are an information management system and traffic management system.

train radio system, with the information management and traffic management systems being responsible for exchanging data with COMTRAC.

This exchange of data with COMTRAC is performed by the "facing COMTRAC for exchange of information server." This server has an active/standby configuration to ensure communications reliability.

USE OF SYSTEM INTERCONNECTION FOR DATA COORDINATION

The information exchanged between SIRIUS and COMTRAC by the operations subsystem can be broadly divided into daily information such as the scheduled and actual diagrams managed by the information management system, and information that varies in realtime such as the operational status and predictions managed by the traffic management system.

The following sections give an overview of the information that each system exchanges with COMTRAC.

Information Managed by Information Management System

The railway tracks used by the Kyushu Shinkansen are also used by trains run by other operators. For this reason, the information management system must maintain rolling stock plans for all rolling stock permitted to travel on the Kyushu Shinkansen railway line as part of through-train service. In the case of SIRIUS, this means maintaining train diagrams and rolling stock plan diagrams for services running between the Osaka Rolling Stock Depot and Hakata Station as well as services that operate on the line between Hakata and Kagoshima-Chuo Stations used by the Kyushu Shinkansen.

To maintain data consistency between the two systems and ensure data reliability, SIRIUS receives the train diagrams and rolling stock plans for the Kyushu Shinkansen held by COMTRAC and cross-checks this information with its own train diagrams and rolling stock plans.

Similarly, SIRIUS and COMTRAC exchange their train running results of rolling stock plan to ensure that these records remain mutually consistent.

Information Managed by Traffic Management System

Although the traffic management system maintains diagrams covering the railway line from Osaka Rolling Stock Depot to Kagoshima-Chuo Station, it is only responsible for control of the line between Shin-Tosu and Kagoshima-Chuo Stations. So that the traffic management system will have access to the operating conditions and predictions for through-trains, including for sections of track that are outside its scope, the following four types of information are exchanged in realtime via the interconnection between the two systems.

(1) Result data on train departures and arrivals
(2) Order of train departures
(3) Train position and delay information
(4) Train running predictions

Result data on train departures and arrivals are received from COMTRAC and stored in SIRIUS's diagram data for display on the train graph in the control room.

Information on the order of train departures from Hakata Station and Hakata Rolling Stock Depot received from COMTRAC is combined with departure order information held in the SIRIUS diagram for display on workstations in the control room. Also, departure order information from the two systems is cross-checked as part of automatic route control.

Train position and delay information for the railway between Osaka Rolling Stock Depot and Hakata Rolling Stock Depot is received from COMTRAC.

Finally, for the train running predictions, because these need to take into account the operational status along the Sanyo Shinkansen railway line, the predicted diagram is received from COMTRAC and used to produce the prediction for the Kyushu Shinkansen railway line. The predictions from the two systems can also be coordinated by sending the prediction generated by SIRIUS to COMTRAC (see Fig. 3).

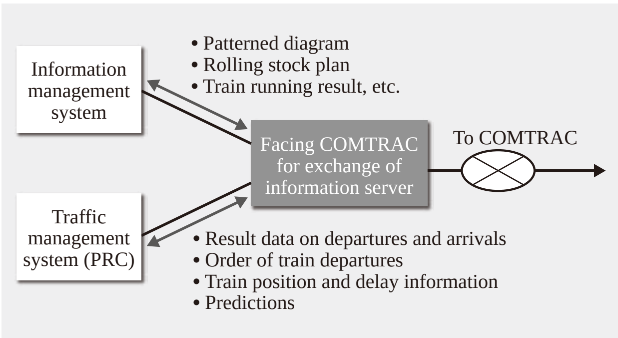


Fig. 3—Overview of Information Exchange Using Facing COMTRAC for Exchange of Information Server.
The facing COMTRAC for exchange of information server connects to the information management and traffic management systems via the network to relay information to and from COMTRAC.

CF-1000/FT FAULT-TOLERANT MODEL INFORMATION AND CONTROL PLATFORM

Hitachi has supplied numerous realtime servers for control system applications that demand high reliability and realtime control, with experience stretching back over 30 years. For systems that require even higher levels of data reliability and continuity, Hitachi has also released a fault-tolerant model that is designed for data consistency and system availability.

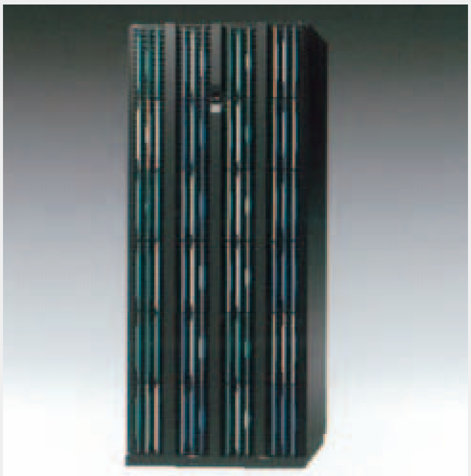
Developed by Hitachi based on know-how it has built up over time, the CF-1000/FT delivers a high level of availability and data reliability using a loosely coupled architecture with four-fold redundancy. The architecture consists of a CPU unit with four-fold redundancy provided by four blade servers and a four-way voter unit that uses the majority voting system to implement redundancy, with all of these components being linked together via a network (see Fig. 4).

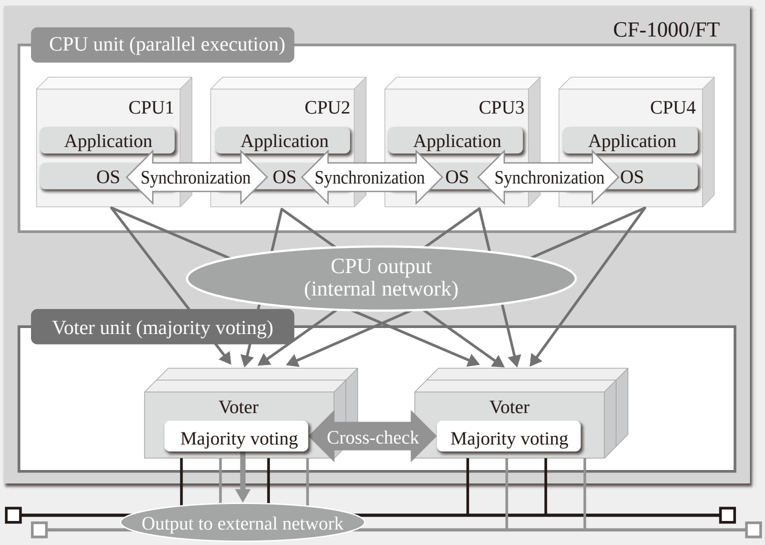
Separate instances of the application program run in parallel on the four CPUs and pass their respective processing results to the voter unit. The voter ensures that data processing is performed with high reliability by using the majority voting method to compare the received data and output them to the external network.

Use of four CPUs for parallel execution means that the majority voting method will produce the correct output if one of the CPUs has a fault. This ensures high availability as parallel execution can continue while also maintaining data reliability. Moreover, because synchronization of the parallel application programs is handled at the OS level, synchronization is not hardware-dependent and this allows ongoing performance improvements to be implemented by upgrading the processors. The synchronization control method also ensures that things like process execution sequence and input are kept in step at the OS level to eliminate any variation between CPUs, meaning that parallel execution can be implemented without requiring the applications to perform their own synchronization.

The voter unit handles majority voting on the data from parallel execution. It achieves a high level of reliability by running a highly reliable proprietary Hitachi realtime OS and by using hardware that features extensive fault detection functions, such as error checking and correction for the memory and internal buses. To ensure an even greater certainty of data reliability, each voter unit consists of two separate computers that cross-check their majority voting results. The voter units also have redundant subunits that can switch over instantaneously to the backup in the event of a fault. This means that the system can continue to operate while also ensuring data continuity.

This loosely coupled architecture with four-fold redundancy and OS-level synchronization control gives the CF-1000/FT a high level of fault tolerance and expandability (which provides the flexibility to keep up with ever-improving hardware), delivering the data reliability, continuity, and other features demanded by information and control systems.





CPU: central processing unit OS: operating system

Fig. 4—Architecture of CF-1000/FT Fault-tolerant Model.
The photograph on the left shows the CF-1000/FT hardware, and the diagram on the right shows how parallel execution and majority voting are performed.

CONCLUSIONS

This article has described how the interconnection between Shinkansen traffic management systems is used to support through-train service, and the adoption of a fault-tolerant model to ensure a high level of reliability.

One year after service commenced along the full Kagoshima route of the Kyushu Shinkansen, SIRIUS continues to operate successfully. Hitachi intends to continue working on system development using the fault-tolerant model and other technologies, as well as the newly developed interoperation functions provided by system interconnections.

REFERENCES

(1) M. Harada et al., "Upgrade to SIRIUS Kyushu Shinkansen Supervisory System in Preparation for Opening of Full Kyushu Shinkansen Line," Railway & Electrical Engineering **22**, No. 8, pp. 28-32, Japan Railway Electrical Engineering Association (Aug. 2011) in Japanese.

(2) K. Yamasaki et al., "Shinkansen Transportation Control System Linking with the Conventional Line through High-Reliability Technology," Hitachi Hyoron **87**, pp. 723-726 (Sep. 2005) in Japanese.

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