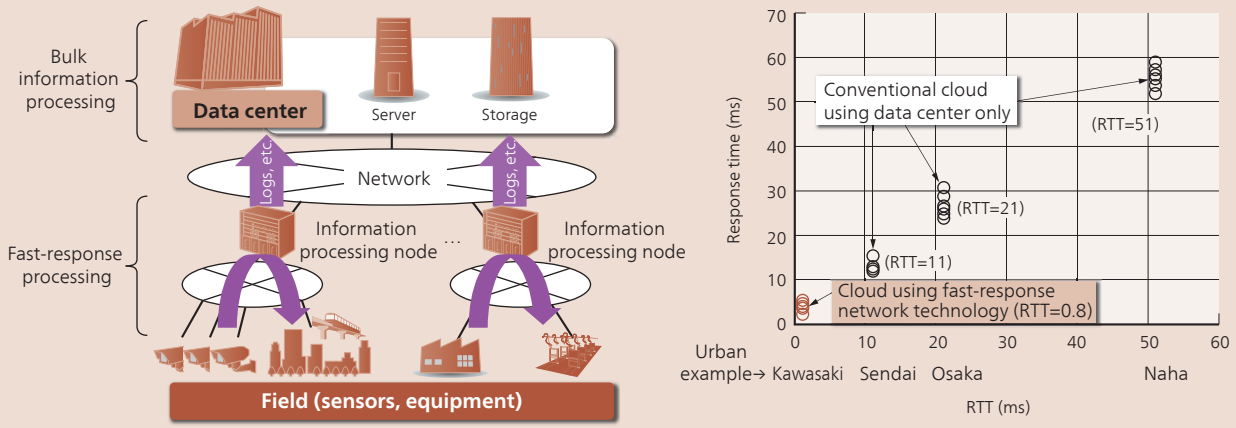


RTT: round trip time

1 Fast-response network technology

1 Fast-response Network Technology for Cloud-based M2M Services for Social Infrastructure

A newly developed fast-response network technology is used with cloud computing to implement machine-to-machine (M2M) services for power, transportation, urban services, and other social infrastructure.

The technology combines networked information processing nodes located near the field with a conventional remotely located data center, with the information processing nodes being used to process sensor data that requires a rapid response, and the data center being used for data mining and other bulk data processing applications. When a new sensor or control application (item of equipment) is registered with the cloud, it automatically searches for information processing nodes with sufficient spare capacity and with a communication delay that is within the service's requirements, and then allocates the processing nodes for the new sensor or equipment accordingly. Because this results in a shorter communication delay than conventional cloud configurations that use a data center only, it provides fast response times.

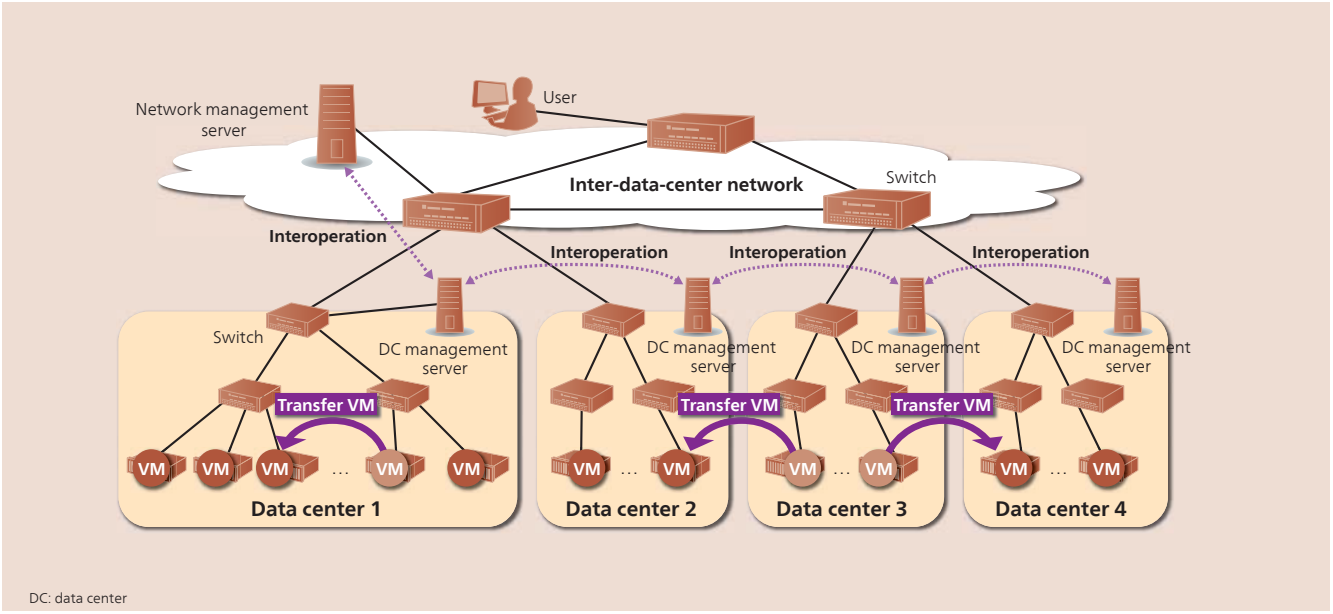
Hitachi conducted a demonstration in which information processing nodes were installed at Kawasaki (Kanagawa Prefecture) and Sendai (Miyagi Prefecture), with mock sensors and control applications located at Kawasaki and the data center at Sendai. The information processing node at the Kawasaki site was automatically selected to handle the processing for the mock sensors and control applications and achieved response times of 10 ms or better. Hitachi is currently working on enhancements to the technology to ready it for use in actual services.

Part of this research was conducted under the "Research and Development on Secure Cloud Networking Technologies (Intelligent Distributed Processing Technologies)" and "Research and Development on Cloud Service Infrastructure for Recovering Wide-area Disaster (High Reliable Cloud Services Platform Technology)" programs funded by the Ministry of Internal Affairs and Communications.

2 Technology for Reducing Cloud Power Consumption

One method for reducing power consumption by the data centers that form the cloud is to consolidate virtual machines (VMs) on a smaller number of servers during the night or at other times of low demand for services so that unused servers can be turned off. While achieving even larger power savings requires that this consolidation of VMs takes place across multiple data centers, if performed without consideration for network traffic, this risks degrading service quality due to the volume of data on the network exceeding its capacity.

In response, Hitachi has developed a technique for determining whether to consolidate VMs at times of low service demand while still maintaining communication quality. The technique combines a server that manages operating conditions at each data center with another that manages network traffic, and selects where to transfer VMs so as to ensure that adequate network capacity is still available at the new hosting site. In a trial in which a large cloud test system was configured with 1,000 virtual servers spread across four regions, power savings of approximately 30% were achieved by the VM consolidation technique making decisions within six minutes.



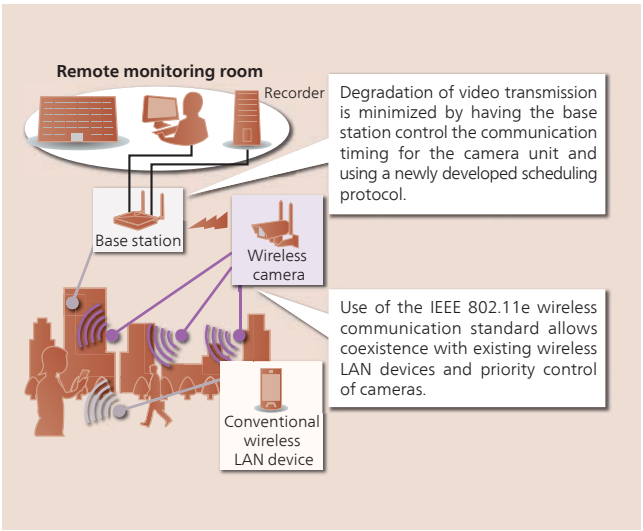
2 Technology for reducing cloud power consumption

In the future, Hitachi intends to expand uses for the new management technique beyond power saving to include such objectives as improving communication quality for cloud services and enhancing the reliability of communications used to support social infrastructure.

Part of this research was conducted under the "R&D on Cloud Service Infrastructure for Recovering Wide-area Disaster (Signaling Technology of Network Configuration for Sustainable Environment)" program funded by the Ministry of Internal Affairs and Communications.

3 High-quality Wireless LAN Transmission Technology for Video Surveillance Systems

Video surveillance systems have become more widely used in recent years to help create a safe and secure society. While most of these systems currently operate on fixed-wire networks, there is interest in the use of wireless networks to provide greater flexibility in where to locate cameras and to expand surveillance over a wider area. However, existing systems that operate on wireless local-area networks (LANs) are subject to interference from other wireless LAN devices such as smartphones or personal computers (PCs), resulting in frame loss and other degradation of the surveillance video.



3 Wireless LAN video surveillance camera system

In response, Central Research Laboratory of Hitachi, Ltd. and Hitachi Kokusai Electric Inc. have collaborated on applying the hybrid coordination function controlled channel access (HCCA) communication method specified in the IEEE 802.11e standard for wireless LANs to video surveillance systems, including the development of a proprietary communication protocol that minimizes degradation of video quality. When the new technology was trialed in a wireless video surveillance system, it succeeded in increasing the interval between frame loss events from the several minutes of previous systems to more than nine hours, reducing the frame loss frequency by a factor of 100 or more. This results in a highly reliable wireless video surveillance system with excellent economics.

4 Explosives Detector with Automatic Sampling

Hitachi has developed explosives detection technology that automatically and promptly detects minute quantities of explosive material on cards, luggage or other objects. It is intended to strengthen safety at airports, railways, and other public facilities. It uses a cyclone-type centrifugal separation and concentration technique to quickly and efficiently concentrate tiny particles released from the surface of the target materials by blowing air. It uses a mass spectrometry sensor incorporating highly sensitive proprietary technology for rapid detection of minute quantities of explosive materials. Hitachi has developed prototype boarding gates and luggage inspection machines fitted with this technology that are designed with use at airports or railway stations in mind, and plans further work aimed at commercialization.

This research was conducted under the "R&D Program for Implementation of Anti-Crime and Anti-Terrorism Technologies for a Safe and Secure Society" in the "Integrated Promotion of Social System Reform and Research and Development" funded

Partner: The Nippon Signal Co., Ltd.

Partner: Hitachi Power Solutions Co., Ltd.

4 Prototype boarding gate (top) and luggage inspection machine (bottom) fitted with explosives detection technology

by the Ministry of Education, Culture, Sports, Science and Technology.

5 Predictive Diagnostic Method for Preventing Unscheduled Shutdowns of Social Infrastructure

The social infrastructure equipment is expected to operate reliably. Hitachi has developed a predictive diagnostic method for these by utilizing machine learning and a form of data mining.

Whereas past methods based on thresholds for sensor data have failed to provide adequate detection of abnormalities, the new method prevents unscheduled shutdowns due to faults by providing early detection of problems. The method learns element which constitutes normal conditions of an item of equipment and then outputs an estimate the degree of abnormality based on the difference between normal and current conditions. A feature of this method is that, by learning in advance, it can achieve a high level of detection performance regardless of the operation environment.

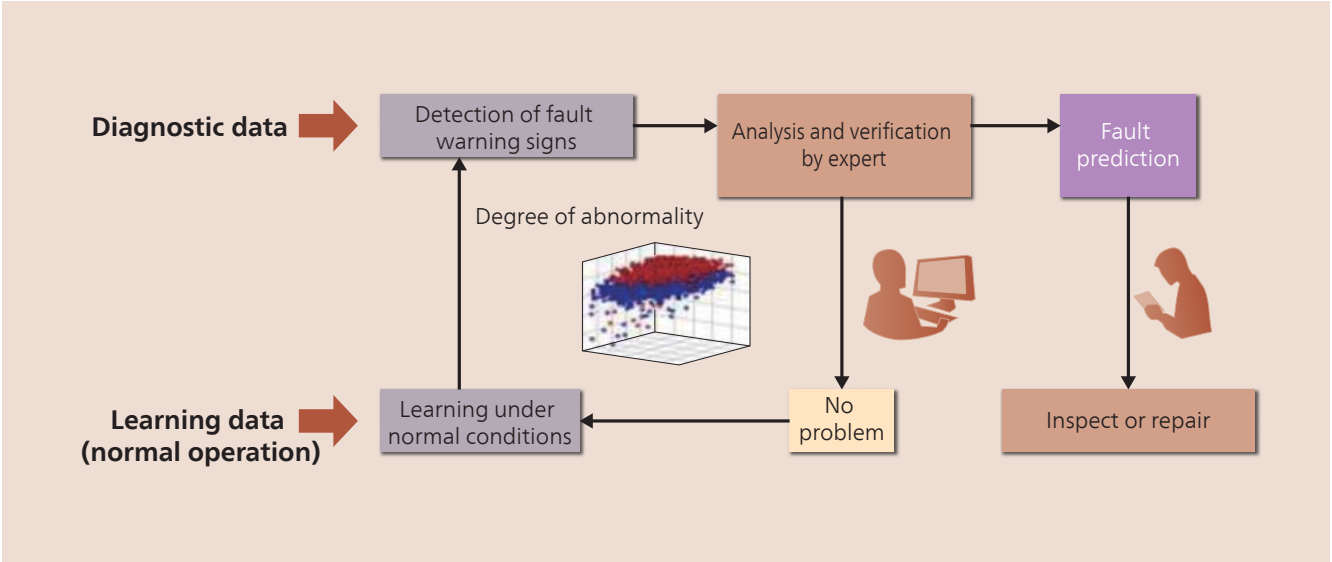
The technology has been adopted in the predictive diagnostics system product of Hitachi Power Solutions Co., Ltd.

6 Highly Efficient Amorphous Reactor for PCSs and UPSs

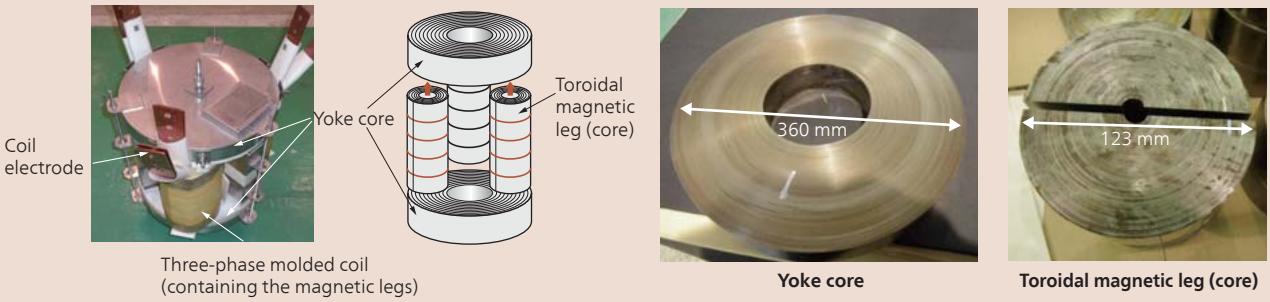
Hitachi Research Laboratory of Hitachi, Ltd. and Hitachi Industrial Equipment Systems Co., Ltd. have jointly developed an amorphous core with a new design for use in the filter reactors used in 400-kVA-class uninterruptible power systems (UPSs).

As the magnetic losses (iron loss) of the soft magnetic amorphous alloy are one-third to one-half those of previous materials, it provides a useful way to improve the efficiency of systems that include inverters. Unfortunately, the expected reduction in losses is difficult to achieve in practice because the high toughness of the amorphous alloy makes it impossible to obtain adequate forming accuracy when using the same core design as current reactors made from silicon steel sheet. In developing the new design, Hitachi solved this problem by devising a new method for forming a three-leg (three-phase) configuration made of toroidal cores in which the amorphous ribbon is wound in a circular (toroidal) pattern. Hitachi also developed a loss model that takes account of the layering of the ribbon and succeeded in reducing the prediction error of losses in three-dimensional magnetic field analysis from 30% to 10% or less. By using this model to optimize the design, Hitachi reduced losses by half and volume by 20% compared to the current model, achieving a 0.55% improvement in UPS efficiency.

The new amorphous core is also suitable for use in power conditioning subsystems (PCSs) for wind or photovoltaic power generation. The first model to use the new core will be a 100-kW photovoltaic PCS that is scheduled to commence production at Hitachi Industrial Equipment Systems in April 2014.



5 Predictive diagnostic method based on machine learning



6 UPS filter reactor and design of core

7 Technology for Evaluating Crashworthy Structures in Rolling Stock

The standards for rolling stock for overseas markets specify that their designs consider collisions between vehicles or with obstacles, and require them to use crashworthy structures that undergo plastic deformation to absorb the energy of impact in a collision. One way to increase energy absorption by crashworthy structures is to ensure that, rather than fracturing when a collision occurs, materials and welds undergo plastic deformation instead. Accordingly, it is important to be able to accurately predict fracturing at the design stage and thereby prevent it from occurring.

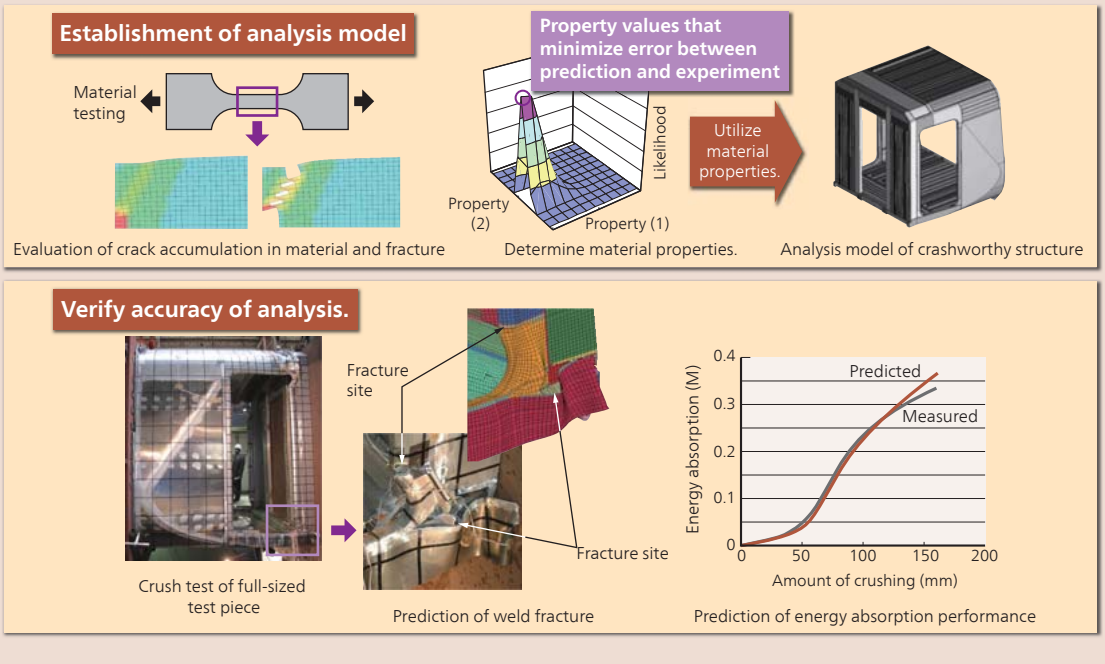
Hitachi has developed technology for evaluating crashworthy structures that features use of a collision analysis model that considers the accumulation of tiny cracks in the material, and use of a new method for determining by experiment the material properties that affect this accumulation of cracks. This allows accurate predictions to be made of where fractures will occur during a collision and the absorption of energy by the crashworthy structure. In the future, it will be possible to take steps at the design stage to reduce locations where fracturing will occur, and to design crashworthy structures with high impact performance.

Hitachi is using this evaluation technology in the development of crashworthy structures for rolling stock intended for European markets.

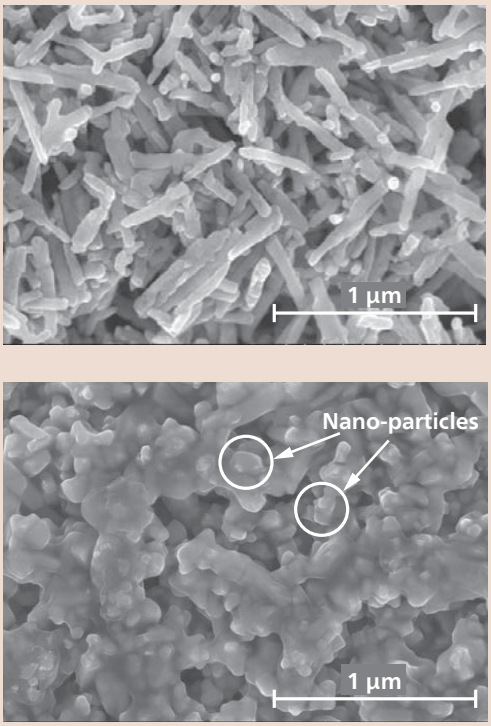
8 High-capacity Anode for Lithium-ion Battery

Increasing the energy density of lithium-ion batteries is important for improving the convenience of smartphones and other mobile devices or electric vehicles. In response to this requirement, there is a need to develop high-capacity anode materials that can improve on the 372-Ah/kg theoretical capacity of the graphite currently used in lithium-ion batteries. Hitachi has developed an anode made of iron oxide, a widely available, low-cost material that places a low load on the environment, and which has a high capacity of 1,000 Ah/kg or more.

Although iron oxide anodes have high capacity, they have suffered from the problems of a rapid fall off in capacity with charging and discharging, and poor charging and discharging efficiency. To improve charging and discharging efficiency, Hitachi has developed a technique for pre-doping the iron oxide



7 Example evaluation of energy absorption performance of crashworthy structure



8 Particle shapes for conventional iron oxide (top) and Li-doped iron oxide (bottom)

with lithium (Li). In the new Li-doped iron oxide, pre-doping with Li stabilizes changes in the crystal structure during charging and discharging. Also, the use of nano-sized particles reduces resistance to the charging and discharging reaction compared to conventional iron oxides. As a result, the charging and discharging efficiency of iron oxide has been improved by 70 to 80% over previous materials.

In the future, Hitachi intends to contribute to further improvements in the energy density of lithium-ion batteries by analyzing the relationship between crystal structure and charging and discharging mechanisms in more detail.

9 Sour Shift Catalyst

The coal gasification market consists of the market for power plants and the market for synthetic fuel plants that gasify coal and use it to produce light oil or methane gas. Shift catalysts are used to form carbon dioxide (CO_2) and hydrogen (H_2) from the carbon monoxide (CO) and steam in the gas produced by a coal gasification furnace, so that the CO_2 can be captured and stored in the case of a power plant, or to adjust the H_2/CO concentration to suit the synthesis reaction in the case of a synthetic fuel plant.

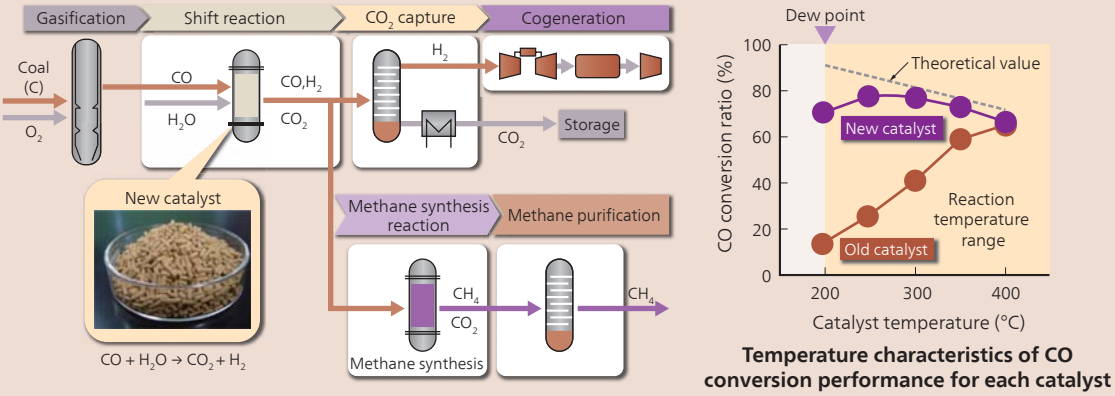
This newly developed sour shift catalyst has achieved higher reaction rate by spreading the reaction activity point across the carrier and by efficiently achieving the reaction activity point. This dramatically improves performance at the lower limit of the operating temperature range (200°C) compared to the catalyst used in the past. As a result, the amount of excess steam added to promote the reaction can be reduced. The shift catalyst boosts the efficiency of coal-fired power generation and reduces CO_2 emissions, and also reduces the cost of producing clean synthetic methane gas or light oil from coal.

In the future, Hitachi plans to work toward commercializing the catalyst by testing its reliability in actual systems.

10 Mobility Support Robot

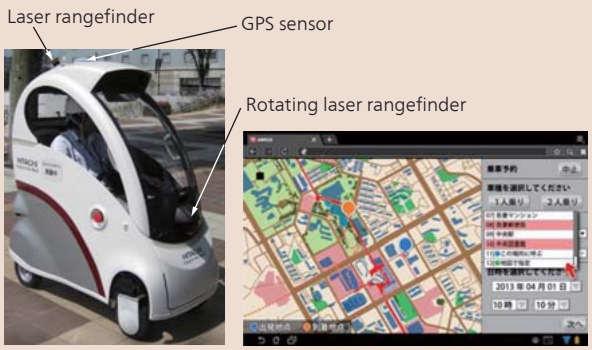
In anticipation of the extreme aging of society, Hitachi has developed a mobility support robot intended as a "last mile" short-distance mode of transportation providing mobility assistance for the elderly or others who have difficulty moving about. It has a function for autonomous travel to a designated point whereby it makes its own way to a location specified on a map displayed on a mobile device.

The robot incorporates a detailed three-dimensional (3D) geometric environment map of terrain and other features (including sidewalk altitudes) that it can use for highly accurate self-positioning by measuring its surroundings with a laser range-finder and comparing the results with the map. It uses this to travel through a city's pedestrian spaces, including along sidewalks, across over or underpasses, and indoors, to make its way directly to its destination. The 3D geometric environment map is produced using a technique that performs the precise merging of data on the surrounding topography collected by the robot as it moves along, sidewalk elevation data collected from



Temperature characteristics of CO conversion performance for each catalyst

9 Processes that use shift catalysts and the temperature characteristics of the new catalyst



10 Mobility support robot and example reservation screen on mobile device

electronic maps provided by the Geospatial Information Authority of Japan and by a highly accurate global positioning system (GPS).

In the future, Hitachi intends to make further improvements in the mobility support service functions with the aim of making it suitable for practical use.

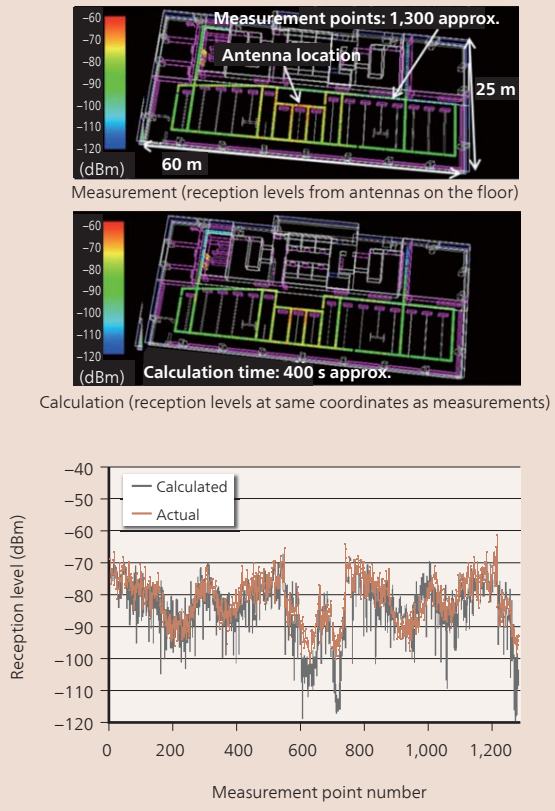
11 Support Software for Wireless Network Design

The rapid spread of smartphones, tablets, and other devices has created a need for wireless area designs that can handle the throughputs experienced in this era of high-volume data communications. A problem with past manual methods has been the large workload involved in tuning the designs, including on-site trial and error.

This newly developed support software for wireless network design provides guidance on where best to locate antennas when configuring wireless networks at corporate offices or other sites. This makes it possible to create high-quality antenna location designs that provide reliable wireless communications with a smaller number of antennas.

The software consists of a radio propagation simulator that performs fast and accurate calculations of radio signal reflection and transmission, and an antenna location search program that uses the results from the simulator. The simulator combines ray tracing, which treats the propagation of radio waves as being similar to that of light, with the finite-difference time-domain (FDTD) method for directly solving the electromagnetic wave equation. For the location search program, meanwhile, Hitachi was able to reduce the search time by 83% by using the simulation results to narrow down the search scope. The result is that the overall design and implementation schedule for a wireless network can be shortened by up to a half*, while also contributing to cost savings.

* Based on research by Hitachi, Ltd.



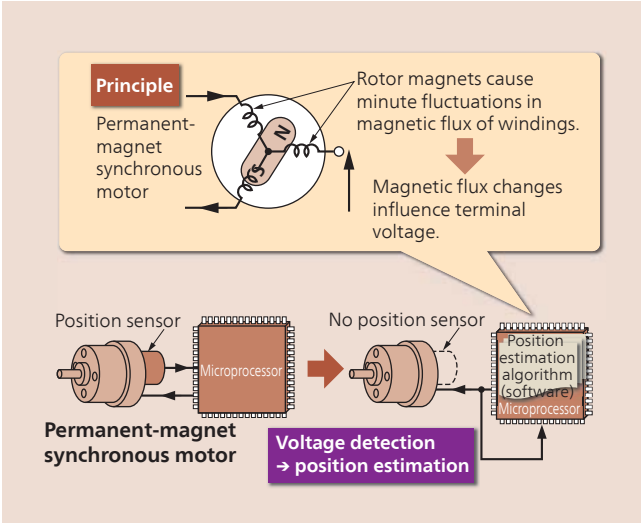
11 Comparison between floor model produced by radio propagation simulator and actual data

12 A Position-sensorless Drive Technique for Low-speed Operation of Permanent-magnet Synchronous Motors

Hitachi has developed a control technique for permanent-magnet synchronous motors that does not require a rotor position sensor. This technique achieves smooth start-up with high torque from a stop or from a low speed.

Eliminating the need for a rotor position sensor reduces the motor size and simplifies installation and maintenance. Furthermore, since this technique provides high torque at low speed, it helps expand the range of applications for permanent-magnet synchronous motors, being suitable for use in systems such as conveyors, elevators, and escalators.

In recent years, greater environmental awareness and efforts to reduce energy consumption have increased demand for highly efficient permanent-magnet synchronous motors. Convention-



12 Principle of new control method that does not require a position sensor

ally, permanent-magnet synchronous motors have required use of a rotor position sensor to achieve a smooth start-up. The problem with this is that a position sensor makes installation more difficult and adds cost and technical difficulties. Hence, a motor-drive system that does not require a position sensor is most desirable.

Against this background, Hitachi has developed a new technique that uses the motor terminal voltage to estimate the rotor position. Because the rotor magnet changes the magnet flux of each winding as it rotates, the terminal voltage contains information about its position. Accordingly, this technique can be applied to many kinds of motors with different designs. Hitachi has tested its operation at the rated torque on its axial-gap amorphous motors, which do not use rare-earth metals. Future plans include applying the technique to motors used in industry.

13 Coupled Fluid and Biological Analysis

Demand for biopharmaceuticals such as monoclonal antibody drugs has grown in recent years because of their ability to provide effective treatments with few side effects. These biopharmaceuticals are produced by culturing genetically engineered animal cells. When designing the process for plants based around bioreactors, providing an appropriate cell culture environment (hydrodynamic force generated by stirring, dissolved oxygen, dissolved carbon dioxide, uniformity of mixing, and foaming) is important to achieving high productivity and quality. Past culture process design used experimental cultures and computational fluid dynamics (CFD) analysis of the bioreactor to select the bioreactor design and stirrer shape that minimize the damage that the culture environment inflicts on cells.

This newly developed coupled fluid and biological analysis determines the appropriate bioreactor design, stirrer shape, and composition of nutrient additives, taking account of the formation of metabolites that impede cell growth and the influence that the spatial distribution of hydrodynamic force has on cell metabolism. Culture processes designed using this technique have demonstrated a 50%* improvement in productivity over past design methods when tested in 3-L and 200-L bioreactors.

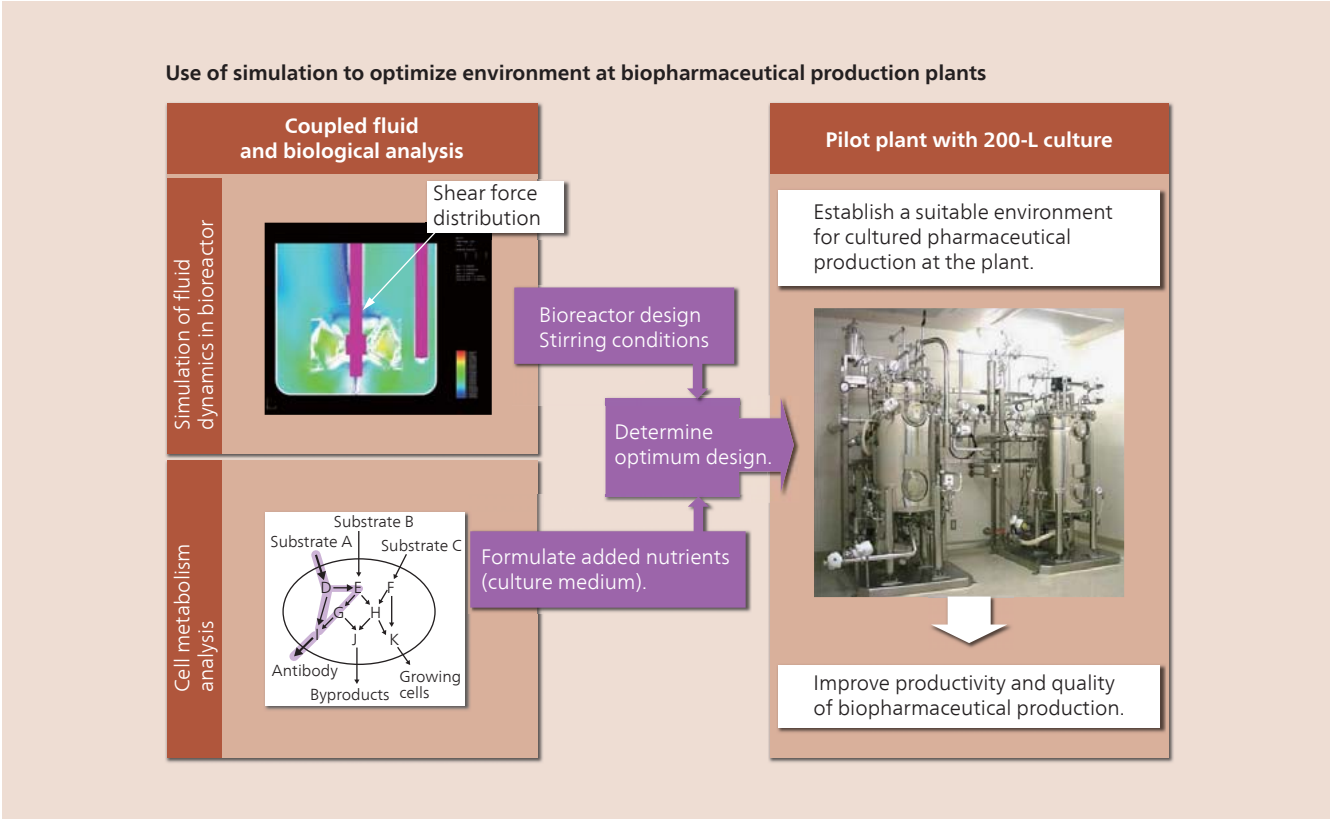
Hitachi is a member of the Next-generation Biopharmaceutical Production Technology Research Association (approved by the Ministry of Economy, Trade and Industry), the aims of which are to integrate processes and establish platforms for biopharmaceutical production. In the future, Hitachi intends to expand its technical capabilities and play a leading role in activities.

* Based on research by Hitachi, Ltd.

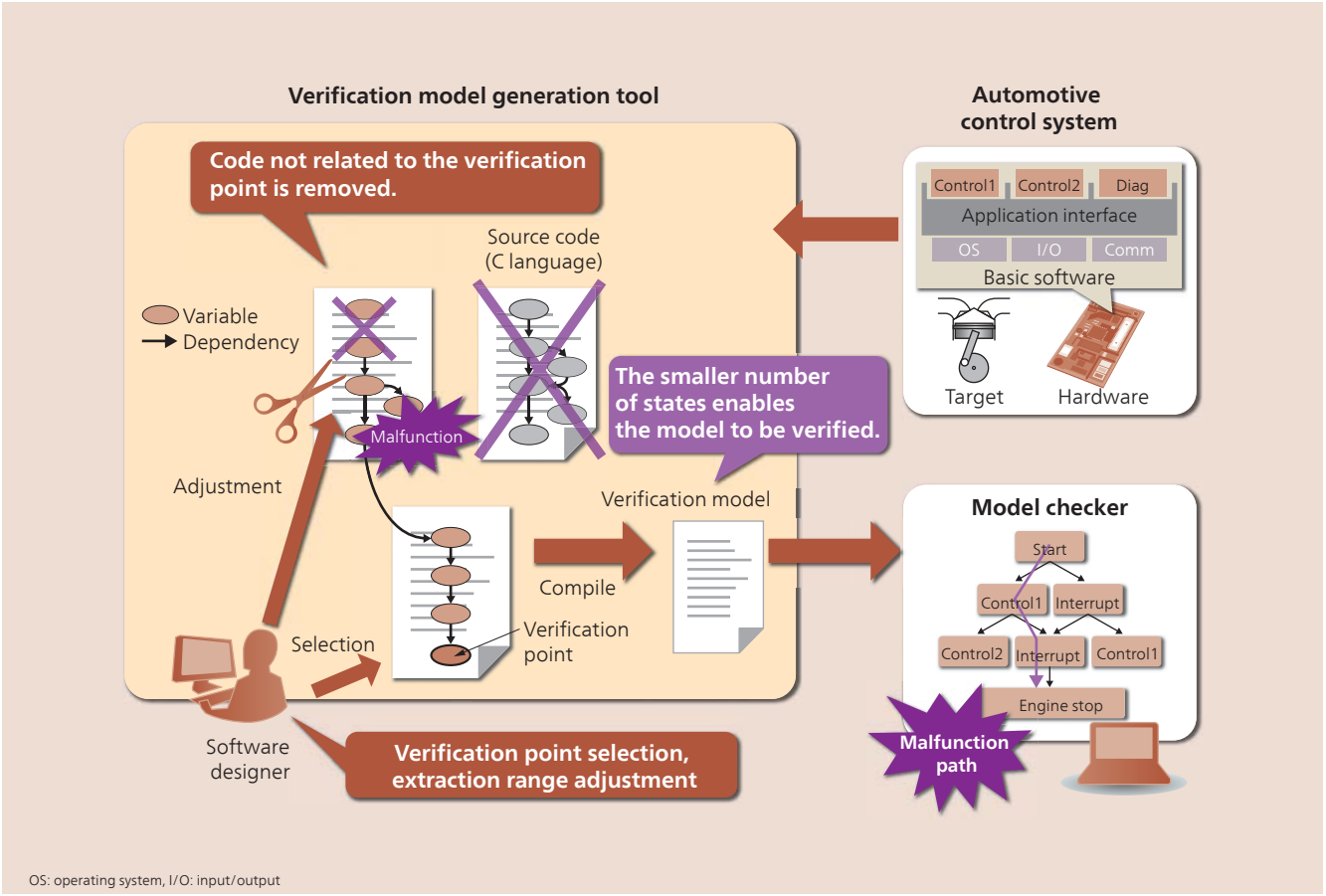
14 Formal Verification of Automotive Control Software

A formal method is a technique for describing requirements and designs using a language in which meanings are strictly defined. Model checking is one example of a formal method. It can be used to perform an exhaustive search of all software behavior states to detect malfunctions that could not be identified in the design phase. The advantage of model checking is that it can identify defects that would be difficult to find using conventional testing. Unfortunately, the problem with model checking when applied to large software is that the huge number of states means that verification requires too much computer resource to be practical.

A model generation technique has been developed to solve this problem. It analyzes the dependencies between variables in the source code to identify which parts of the code are related to the



13 Coupled fluid and biological analysis



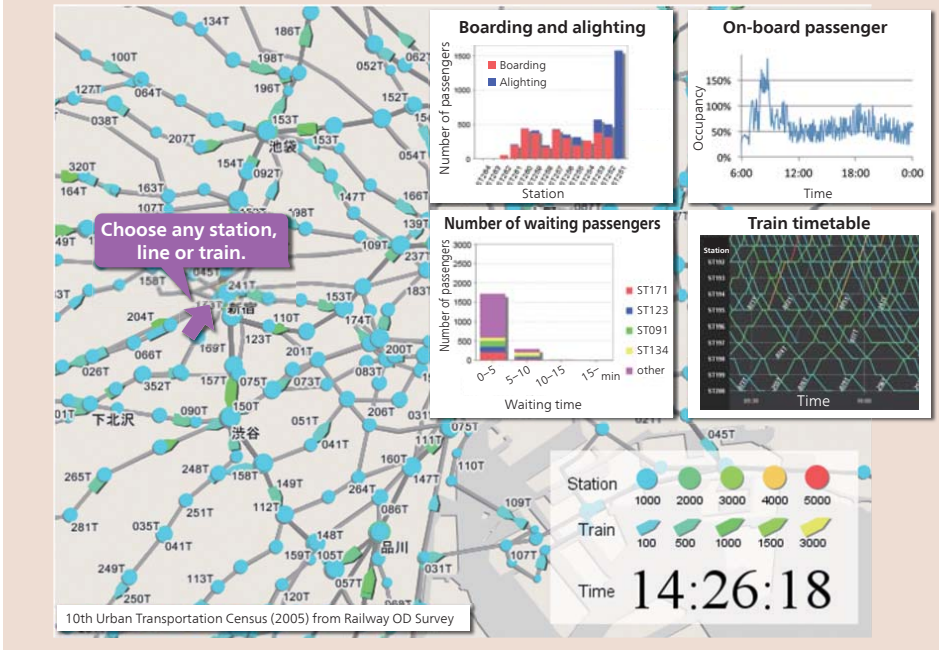
OS: operating system, I/O: input/output

14 Automated generation of verification model derived from source code

item to be verified. The verification model is then generated from this small subset of the code. Because it significantly reduces the number of states in the verification model, the technique is suitable for use with production code that may contain hundreds of thousands of lines. Hitachi has started using the technique for model checking in the development of products with an automotive safety integrity level (ASIL) rating of C/D, the highest safety level defined in ISO 26262.

15 Passenger Flow Simulator

With railway infrastructure development plans in progress around the world with the aim of providing environmentally conscious transportation, recent years have seen growing demand for railway systems that deliver services that suit passenger needs. Unfortunately, in major cities where large numbers of passengers



15 Overview of passenger flow simulator

travel on complex railway networks, it can be difficult to determine what these passenger needs actually are.

To meet this challenge, Hitachi has developed a passenger flow simulator that models the interactions between train operations and passenger movements to predict the movements of 10,000,000 passengers and 10,000 trains on multiple lines, with a time-resolution of one second. In the simulation, the train operations are defined by their timetables and passenger movements are based on rational decisions about travel time, transfers, and other considerations. The simulator can perform a comprehensive evaluation of train occupancy rates and the number of passengers boarding or alighting from each train at each station. This can then be used to investigate the implications of changes in passenger travel demands. The simulator also has a function for balancing train occupancy rates to ease congestion by optimizing train departure times. This can help avoid long boarding and alighting times, which sometimes causes trains to be delayed.

16 Railway Traffic Management and Scheduling Techniques

Because recovering from train timetable disruptions in complex railway networks that operate over a wide area can take a long time, there is a concern that this will result in poorer passenger services.

Hitachi has developed a new technique for predicting future divergences from scheduled train operations from the current point in time. The technique calculates predictions at high speed using constraint programming, a method from a branch of mathematical programming. It mathematically models the constraints that ensure that trains do not get in each other's way at or between stations, while still keeping to timetables as far as possible even if a schedule disruption occurs. To make changes to train schedules, such as overtaking, to avoid major delays, Hitachi has also developed another technique using constraint programming that makes these changes in such a way that the number of trains running behind schedule is minimized. In simulation testing conducted on the world's largest railway network (1,100 km total length, 8,000 trains), the new method achieved a calculation time approximately one-tenth that of the previous method. The technique has also been incorporated into a prototype railway traffic management system ordered from the UK.

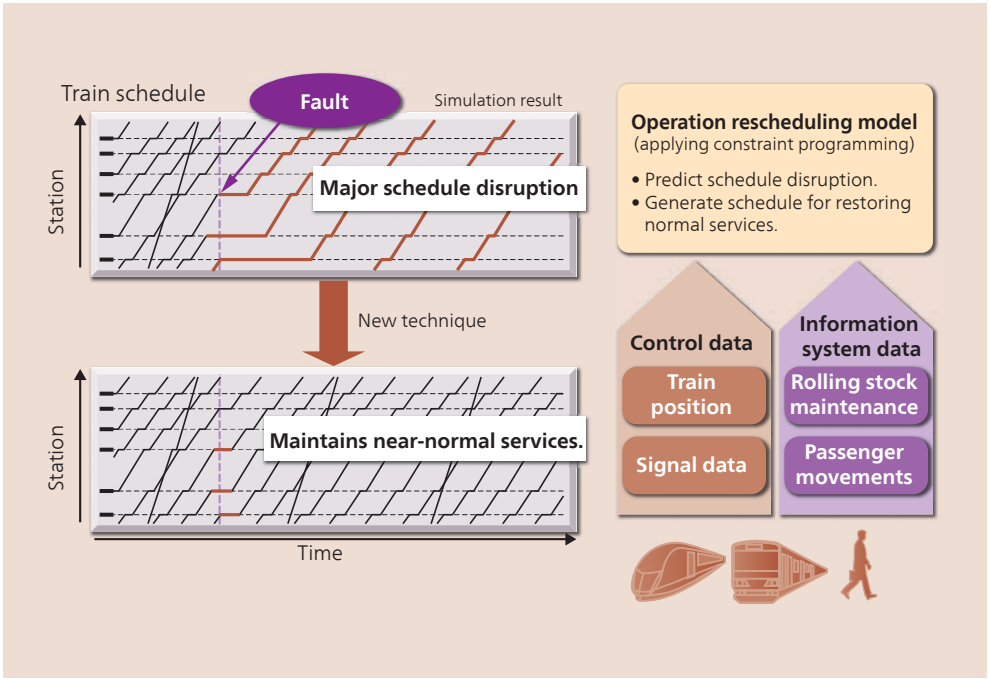
In the future, Hitachi plans to support high-density railway services by taking the traffic management and scheduling techniques it has developed through its experience with high-density railway operations in Japan and adapting them to better suit conditions in overseas railways.

17 Fault Recovery Navigation System Based on Autonomous IT Operation Technology

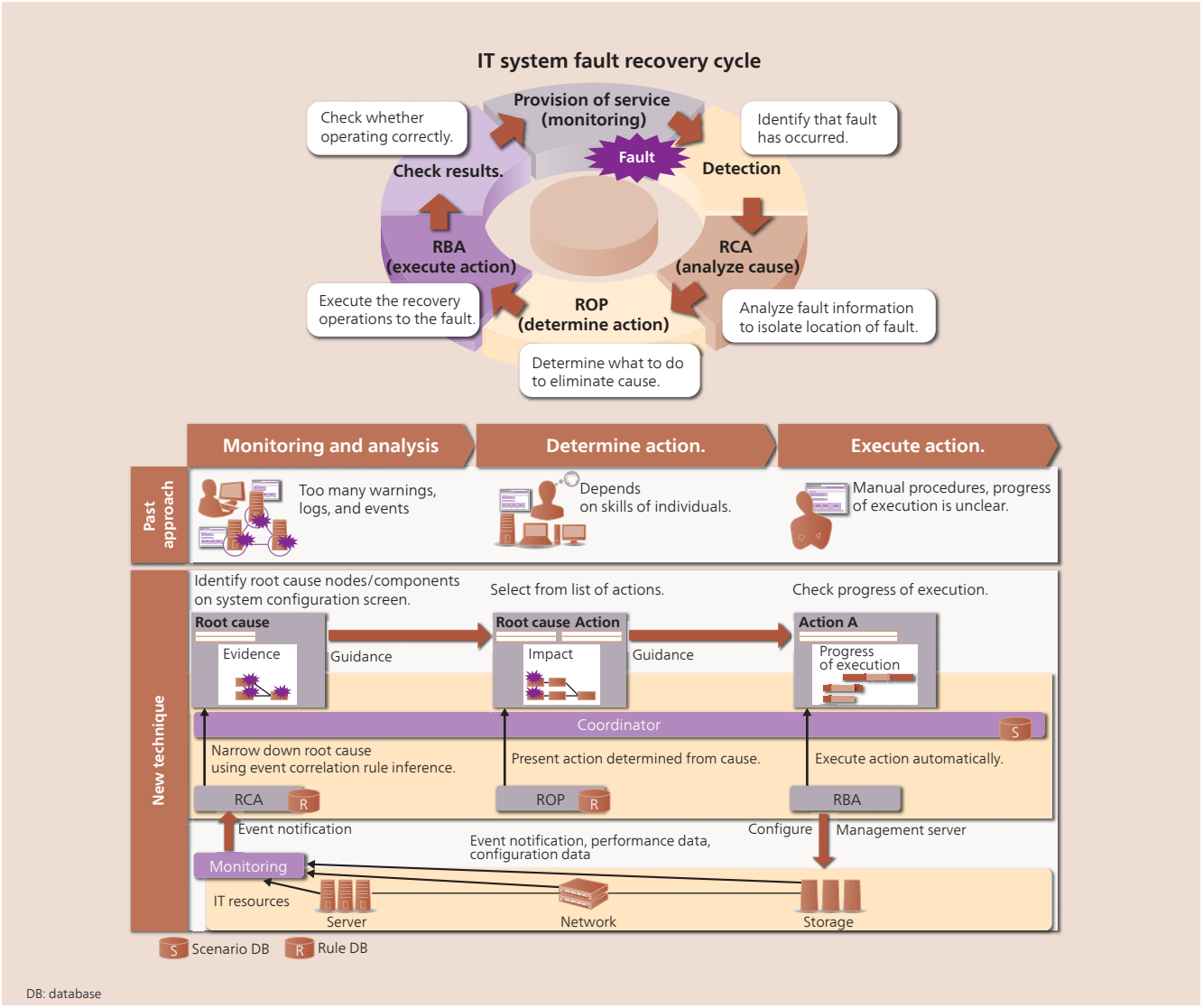
The "3R" autonomous IT operation technique automates the steps from information technology (IT) system monitoring and analysis to utilizing the analysis to decide on how to respond, and then executing that decision.

The three Rs that make up the 3R technique are root cause analysis (RCA), resource optimization planning (ROP), and run book automation (RBA). RCA determines the cause of an event from event messages sent by IT resources, ROP determines the actions to optimize system configuration and resource allocations needed to eliminate the cause, and RBA automatically executes the selected actions. By using 3R, the response to a fault in an IT system, which in the past may have taken several hours, can get underway in a matter of minutes based on pre-defined fault pattern scenarios. Even in situations that require high-level judgments and complex actions, administrators can be guided toward good decisions based on information provided by RCA and ROP.

In the future, Hitachi intends to extend the rules defined in RCA and ROP to cover both equipment and systems and fault patterns, and to incorporate the technology into its main hardware and middleware products.



16 Railway traffic management and scheduling techniques

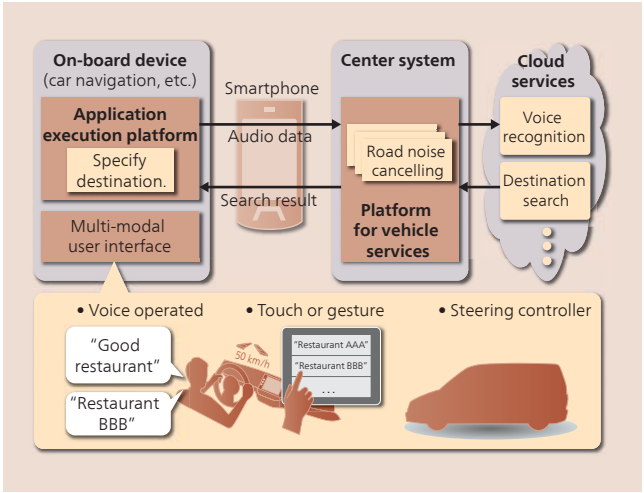


DB: database

17 Fault recovery navigation system based on autonomous IT operation technology

18 Multi-modal Technology for Next Generation of Car Navigation

Strict laws are being introduced, particularly in the USA, to ban the hand operation of car navigation systems, smartphones, and other digital devices while driving. On the other hand, the rapid spread of cloud services in recent years has led to growing demand for their use when driving.



18 Destination search system that uses cloud-based voice recognition

In response, Hitachi has developed a multi-modal user interface for vehicles based around the use of cloud-based voice recognition. To facilitate access to cloud services while driving, the interface incorporates features that act as a cloud service front end specifically designed for use in vehicles, including performing road noise cancelation prior to voice recognition. It also allows operation to be integrated with cloud services through an application execution platform for on-board devices. These features allow the use natural language commands such as "a good noodle bar" to specify a destination, for example, and some of them have been adopted in car navigation systems made by Clarion Co., Ltd.

To help make vehicles safer, Hitachi intends to focus on the user interfaces of on-board devices, and to combine a number of different modes of operation, such as gesture recognition or the use of an interactive interface to clarify the driver's intentions.

19 3D Fetal Imaging Technique for Diagnostic Ultrasound Systems

Volume rendering is used in obstetric ultrasound systems to generate 3D images of the fetus for the mother and family members to view.

The role of obstetrics equipment is not just to provide diag-

19 HI VISION series diagnostic ultrasound system (left) and three-dimensional fetal image produced using old and new techniques (right)

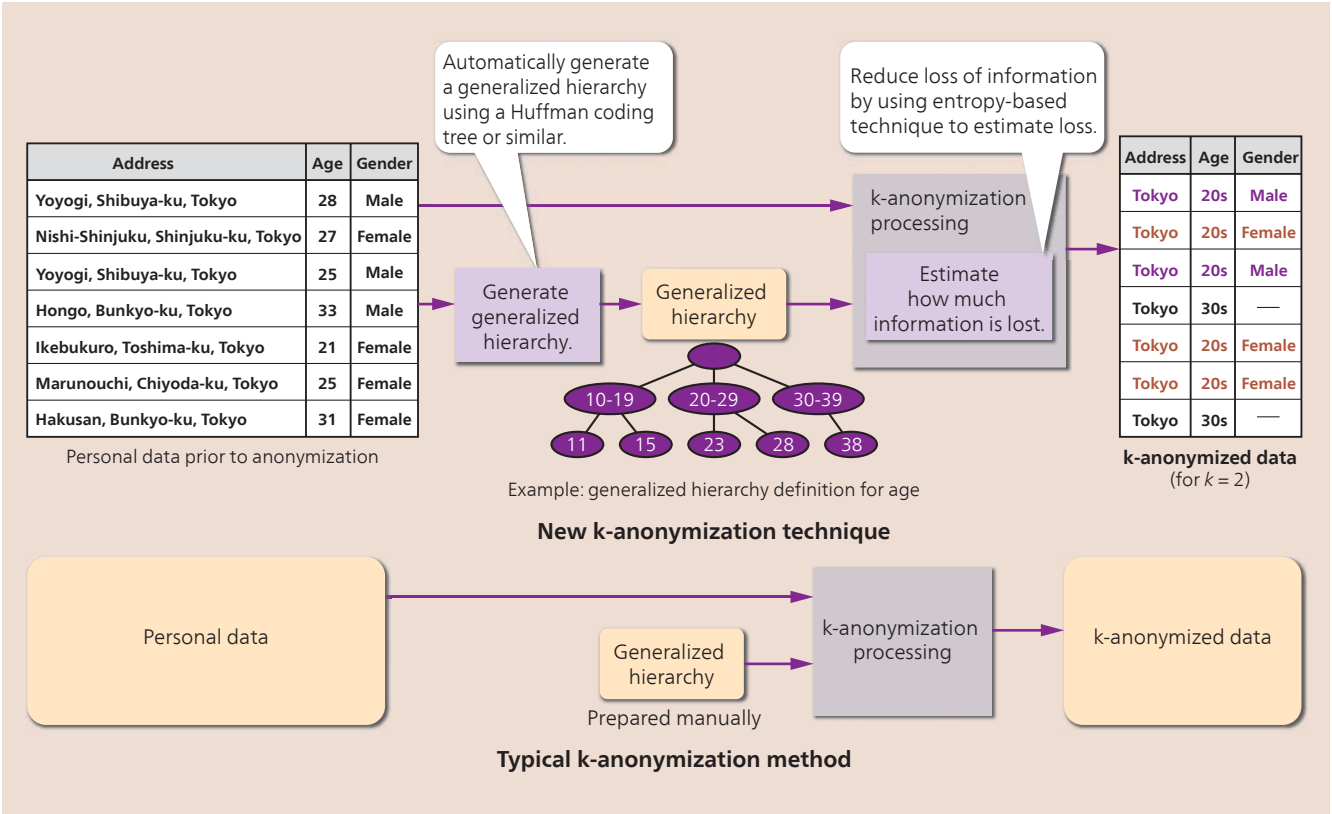
nostic functions for use by doctors and ultrasound operators. Rather, their functions intended for mothers are also important and represent added product value. There has also been the potential with existing technology for functions that are intended to invoke an emotional response or reassure the mother by providing more realistic images of the fetus to instead cause anxiety, because they lack an adequate ability to present features such as shape or skin color. In response, Hitachi has been able to generate three-dimensional fetal images that pregnant women find highly acceptable by utilizing a color map that invokes an emotional response and was produced using a subjective quantification technique based on machine learning, and a new rendering technique that reproduces shading and the dispersion and absorption of light. The technology has been incorporated into the HI VISION* series of diagnostic ultrasound systems made by Hitachi Aloka Medical, Ltd. (released in April 2013).

In the future, Hitachi intends to proceed with research aimed at making further improvements in image quality to facilitate diagnostic use, and at upgrading functions, including making the system easier to use.

* HI VISION is a registered trademark or trademark of Hitachi Medical Corporation in Japan and other countries.

20 Anonymization and Authentication Technology to Facilitate Use of Personal Data

k-anonymization is a technique for preventing people from being identified from their personal data when it is used for research or other purposes. The technique processes data to ensure that, for each data item that could be used for identification, at least *k* records will contain the same value. The problem with k-anonymization has been that it involves a loss of information. In response, Hitachi has developed a k-anonymization scheme that reduces information loss by approximately 25% compared to previous k-anonymization methods by automatically generating a generalized hierarchy for data processing, and by adding a technique that uses entropy to estimate how much information is lost when data is anonymized. The new scheme is to be evaluated as part of a proof of concept project regarding the use of healthcare information in the Manchester region of the UK.



20 Newly developed k-anonymization technique

Hitachi is also working on a technique for handling sensitive personal biometric information that makes this information available for personal authentication but still maintains a high level of protection. Currently, public key infrastructure (PKI) based on digital signature technology is widely used as a reliable means of personal authentication for e-government or e-commerce transactions. However, this relies on methods such as smartcards or passwords to safeguard the private key that certifies a user's identity, leaving open the risk of theft, loss, or forgetfulness. To eliminate these risks while also improving convenience, Hitachi has developed a new digital signature technique that uses biometric information such as a finger vein pattern as the private key. This establishes a safe, secure, and convenient infrastructure for personal authentication, which we call a public biometrics infrastructure (PBI).

21 Technology for Utilizing Unstructured Data

There is growing interest in business applications that use the unstructured data collected by companies, such as text, images, or audio. Hitachi is currently working on the research and development of platforms for utilizing unstructured data that can make this easier to achieve.

These platforms use media analysis technology to extract metadata from the content of unstructured data, and use it to create a database with a special type of structure called a "graph." This makes it possible to use the metadata to search or analyze the unstructured data. In the case of electronic healthcare records or medical images at a hospital, for example, this might involve extracting patients' names, diagnoses, and examination and treatment records and using a graph data structure to manage this information. This could then be used to extract similar cases by performing a search of the graph data structure to identify other patients with similar symptoms.

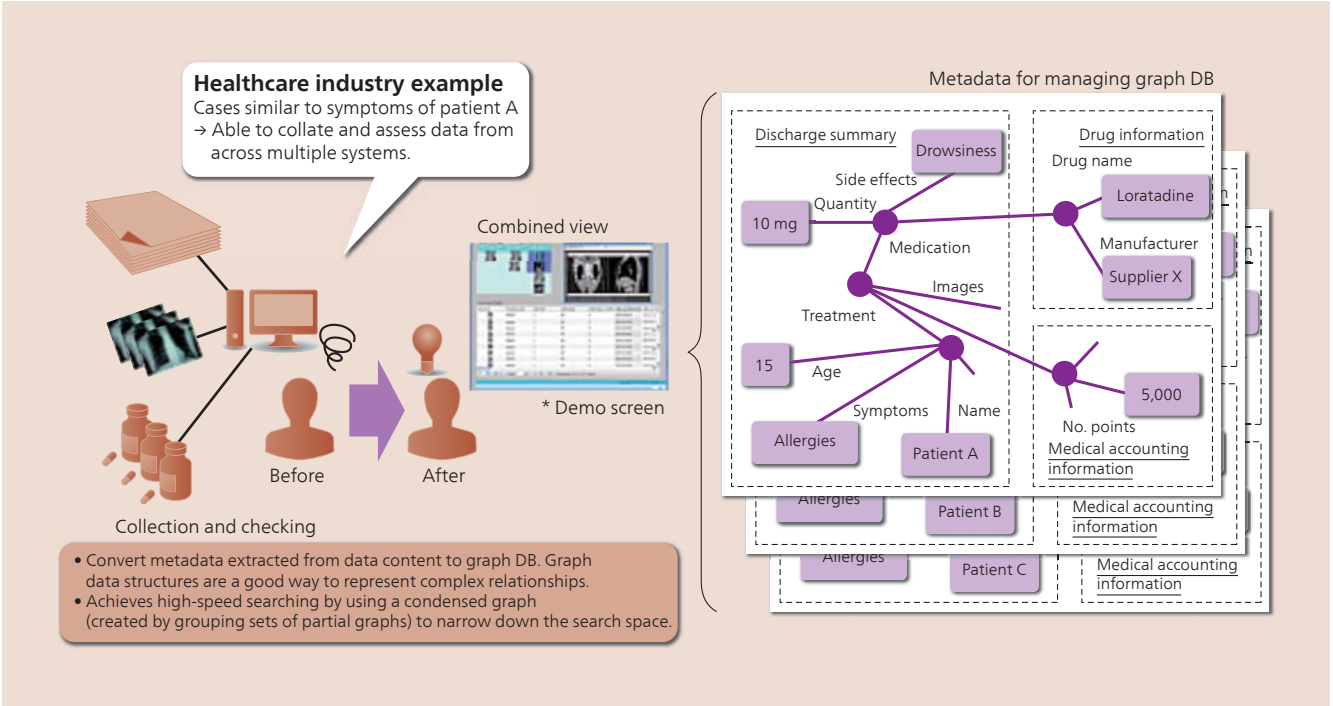
A problem with this, however, is that performing a search of information contained in a graph data structure typically requires a lot of computing time. To overcome this, Hitachi has developed a technique for speeding up searching by narrowing down the search space. To achieve this, it condenses the overall data structure by grouping sets of partial graphs made up of adjacent structures. When tested on medical data, the technique increased speed by a factor of 100 or more compared to previous methods.

In the future, Hitachi plans to develop applied technologies such as the use of graph data structures in knowledge processing for diagnostic support or other advanced analytical applications.

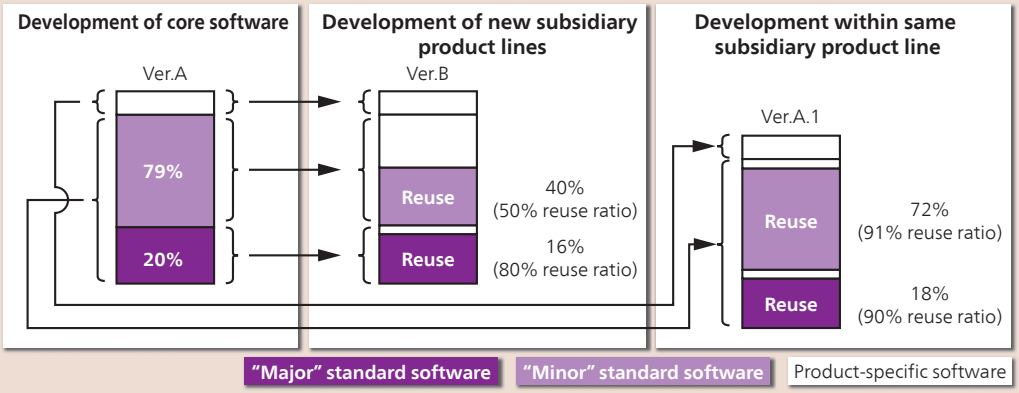
22 Cost Reduction in Network Switch Software Development by Software Product Line Engineering

In developing software for a network switch product series, Hitachi Metals, Ltd. is facing a proliferation in its product line as customer needs become more diverse, and a consequent increase in the volume of development work. In response, it has introduced software product line engineering that has allowed it to rationalize its software product line, with an emphasis on software modularization and reuse. This has resulted in greater development efficiency across its entire product line.

Hitachi has improved software reusability and development efficiency by integrating and rebuilding its source code, which in the past was developed and managed separately for each product, and by modularizing its core software into two classes, consisting of the "major" standard software that can be reused across all products (20%), and the "minor" standard software that can be reused within subsidiary product lines (79%). By improving the reusability of all different types of software assets, including establishing an environment for automating unit testing and consolidating similar documents, this has reduced software development costs by 68%. The first products developed under this regime were released in 2013.



21 Metadata management in a graph database



22 Software modularization and reuse achieved using product line engineering

In the future, Hitachi plans to release more series products, and expects to make ongoing cost savings.

23 Formal Methods for Highly Reliable System Development

Social infrastructure systems require efficient software development techniques that can cope with the increasing size and complexity of systems and still maintain a high level of reliability. One such technique that has attracted attention in recent years is the use of formal methods. While formal methods can ensure the high reliability of software, because verification is performed each time a formal model is created (to match the software design specification), they result in a longer development time due to the labor-intensive nature of verification.

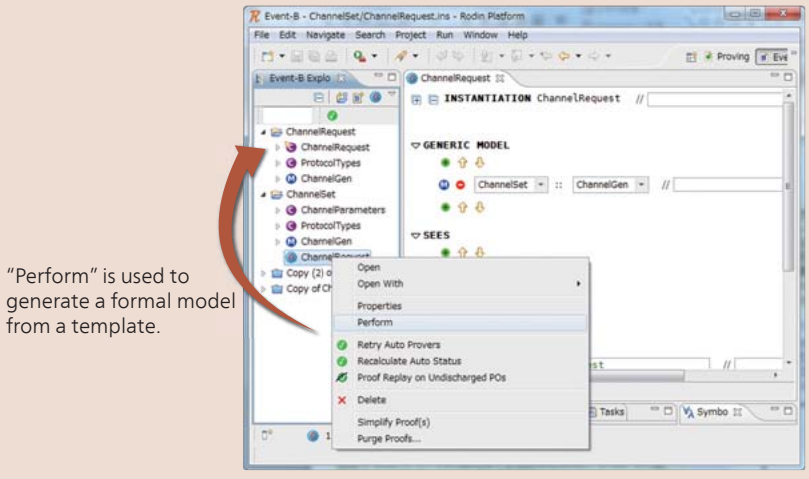
In response, a new technique developed by Hitachi generates a template from the formal model created to verify a particular system that keeps the states that have already been verified, and then makes this template available for reuse in the development of other similar systems. This shortens development times by reducing the amount of time taken to create and verify a model. When trialed on an in-house project, the amount of work required to create and verify formal models was reduced by about 80% compared to creating a new model each time.

Formal verification support software that incorporates this technique is currently being released as open source software. Hitachi plans to make further enhancements with the aim of introducing it in practice.

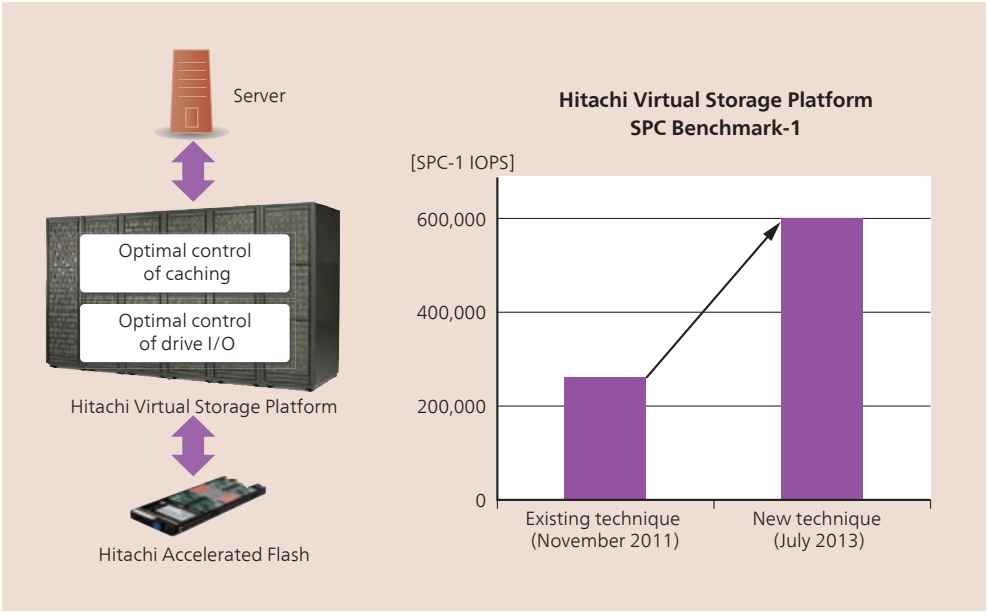
24 Flash Acceleration for High-end Storage

The explosive growth in corporate and other data and growing diversity of business applications are driving demand for storage systems that support high-speed processing of large amounts of different types of data. As a manufacturer of both storage controllers and flash drives, Hitachi develops and supplies storage systems that utilize flash drives for high-speed data processing.

This newly developed data processing acceleration technique uses interoperation with flash drives to achieve optimal control of caching and drive I/O by the storage controller. When incorporated into Hitachi Virtual Storage Platform, a high-end storage system that includes proprietary Hitachi Accelerated Flash drives, and benchmarked using SPC Benchmark-1, the new acceleration technique delivered world-leading*1 data processing performance (for a high-end storage system) of 602,019.47 SPC-1 IOPS*2.



23 Newly developed formal verification support software



24 Technique for accelerating data processing in high-end storage systems

In the future, Hitachi intends to take advantage of being a manufacturer of both types of devices to continue developing technology that uses flash drives to improve the performance of storage systems.

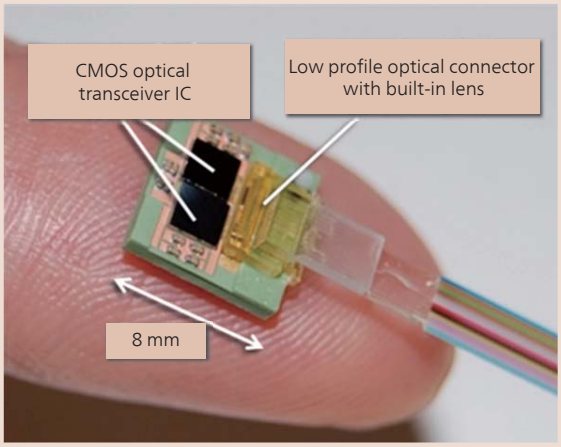
*1 As of July 11, 2013
*2 See "Trademarks" on page 142.

25 Optical Module with High Transmission Density and Low Power Consumption for Internal Communications in IT Devices

Hitachi Metals, Ltd. and Central Research Laboratory and Yokohama Research Laboratory of Hitachi, Ltd. have jointly developed an optical module with high transmission density and low power consumption with the aim of improving the performance of IT devices that use these modules.

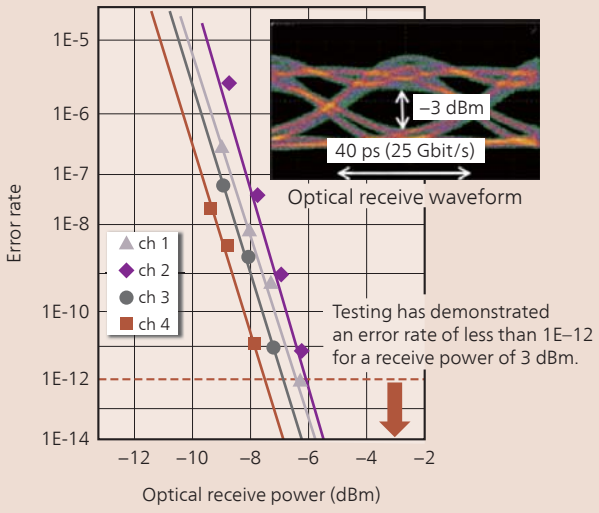
In the past, servers, routers, storage, and other IT systems have used electrical signals for internal communications. However, the higher level of signal distortion that accompanies the rising transmission speeds and wiring densities needed to provide greater capacity makes this communication more difficult. Optical transmission, on the other hand, although it has been used for longer transmission distances of tens of meters or more, faces problems such as module size and power consumption when used for internal communications in IT devices.

The new optical module developed by Hitachi makes it possible to incorporate optical transmission into IT devices. It achieves world-class transmission density and low power consumption using an optical transceiver integrated circuit (IC) that incorporates a low profile optical connector with a built-in lens and is manufactured using a complementary metal oxide semiconductor (CMOS) process. The 8 mm × 8 mm module has four input and output channels. Each channel is capable of 25 Gbit/s of error-free transmission (error rate < 1E–12), providing a total capacity of 100 Gbit/s. The 1.2-W power consumption is approxi-



Small size and low power consumption are achieved by use of a low profile optical connector with a built-in lens and an optical transceiver IC manufactured using a CMOS process.

New optical module



Measurement results

25 Optical module with high transmission density and low power consumption

mately half that of previous modules, and suitable for commercial use.

In the future, Hitachi intends to contribute to increases in capacity through the use of optical transmission for internal communications in IT devices.

26 Pb-free Zn/Al Clad Metal with Cu Coating for Heat-tolerant Soldering

Hitachi Metals, Ltd. and Yokohama Research Laboratory of Hitachi, Ltd. have jointly developed a copper- (Cu) coated zinc/aluminum (Zn/Al) clad metal for use as a heat-tolerant solder for power semiconductors.

Most materials used for soldering power semiconductors are made primarily of lead (Pb) and tin (Sn). In recent years, however, there has been demand for more reliable solders that, for reasons of environmental protection, do not use Pb. While this has directed attention toward Zn-Al solders, these materials are easily oxidized and there are problems with their wetting and soldering characteristics.

This new Cu-coated Zn/Al clad solder uses a roll cladding technique in which the solder is built up in layers of different materials in the sequence: Cu, Al, Zn, Al, and Cu. When heated to 382°C, the five layers melt together and function as a Zn-Al-Cu solder. The Cu surface layer prevents oxidization of the interior Zn and Al. Meanwhile, a problem when Cu and Zn are in contact is that they react over time resulting in the loss of the Cu surface layer. In this material, the Al layer ensures the long-term stability of the Cu layer by preventing the Cu and Zn from coming into contact and reacting. These effects provide the solder with good storage characteristics and good wetting and soldering characteristics in standard soldering machines.

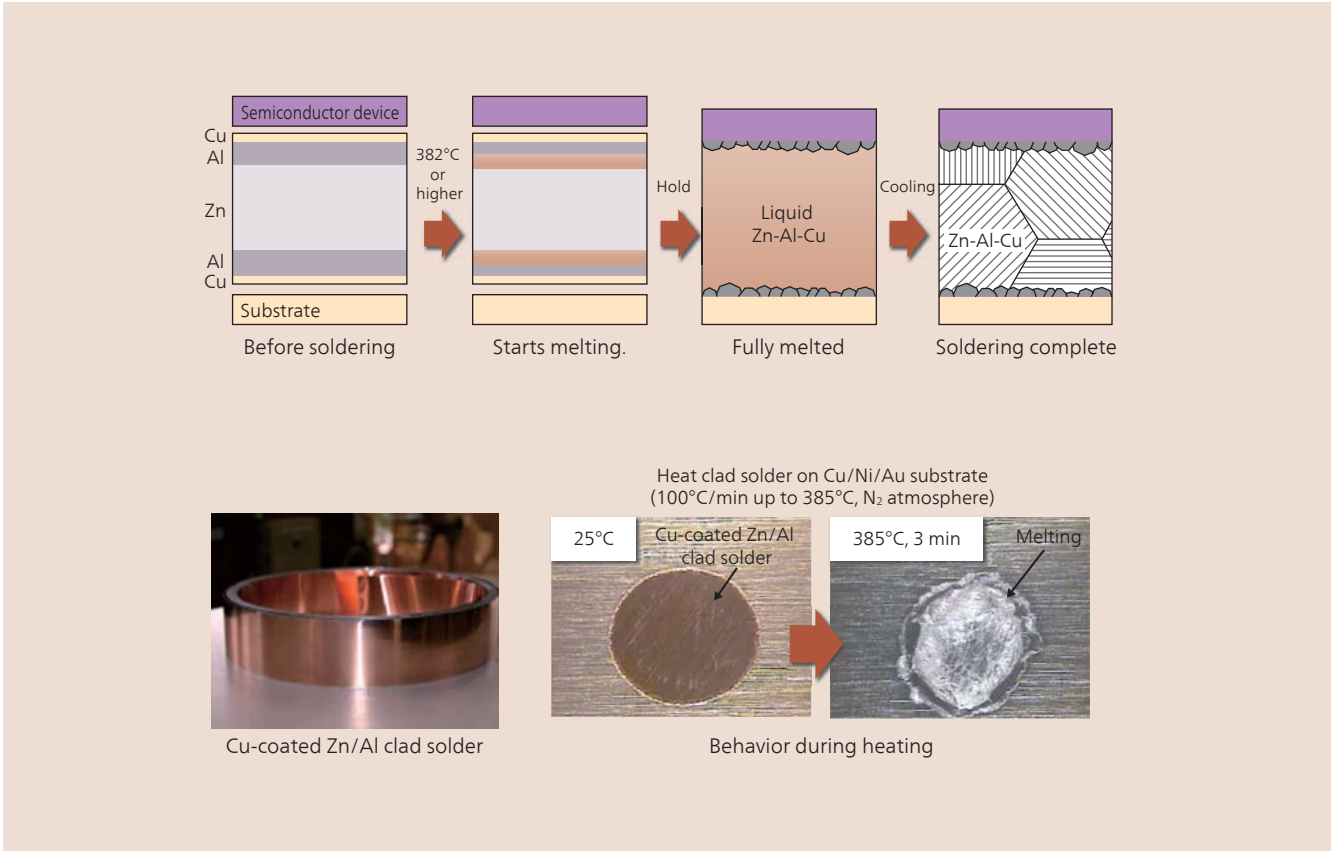
When a semiconductor device was soldered using the new solder, it demonstrated a longer temperature cycle life than Pb solder and maintained the integrity of the joint interface when kept in a 250°C environment. The new material has the potential to provide an alternative to Pb solder and to find uses as a solder for silicon carbide (SiC) devices that operate at high temperatures.

27 Flow Control Technique for Messaging Systems

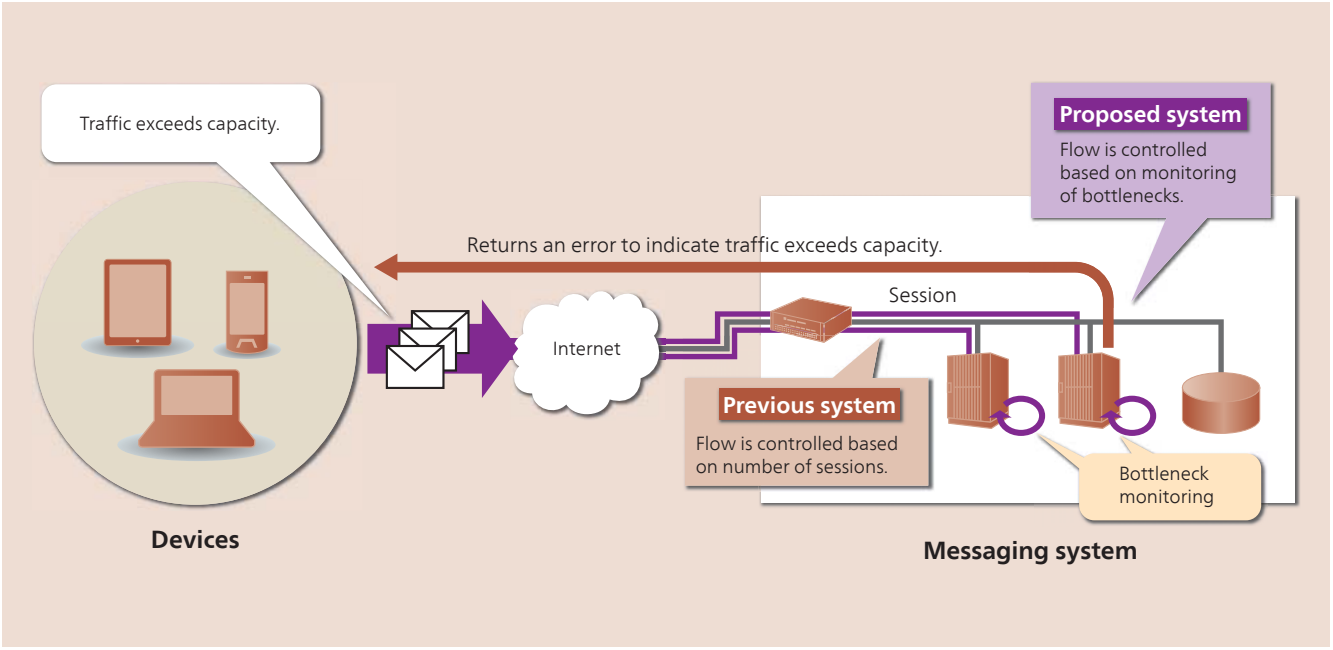
This era of big data is likely to involve large numbers of devices sending large volumes of message traffic. This makes it essential that the messaging systems that relay these messages be able to continue to operate reliably even under conditions of overloading due to heavy traffic. Past systems have used a predefined limit on the number of sessions to regulate message flow when traffic exceeds their capacity. A problem with these systems, however, is that they have not been able to make effective use of resources because messaging systems that place a priority on reliable operation have needed to control flows by building enough of a margin into their limits to prevent congestion from occurring.

Hitachi's newly developed technique includes a function that monitors bottlenecks in the messaging system and regulates message flow accordingly. Because flow control is based on realtime monitoring results, the technique ensures reliable operation while also making effective use of system resources.

In the future, Hitachi intends to use this technique as a base for further improving the availability of messaging systems.



26 Diagram of joint cross-section and soldering mechanism of Cu-coated Zn/Al clad solder



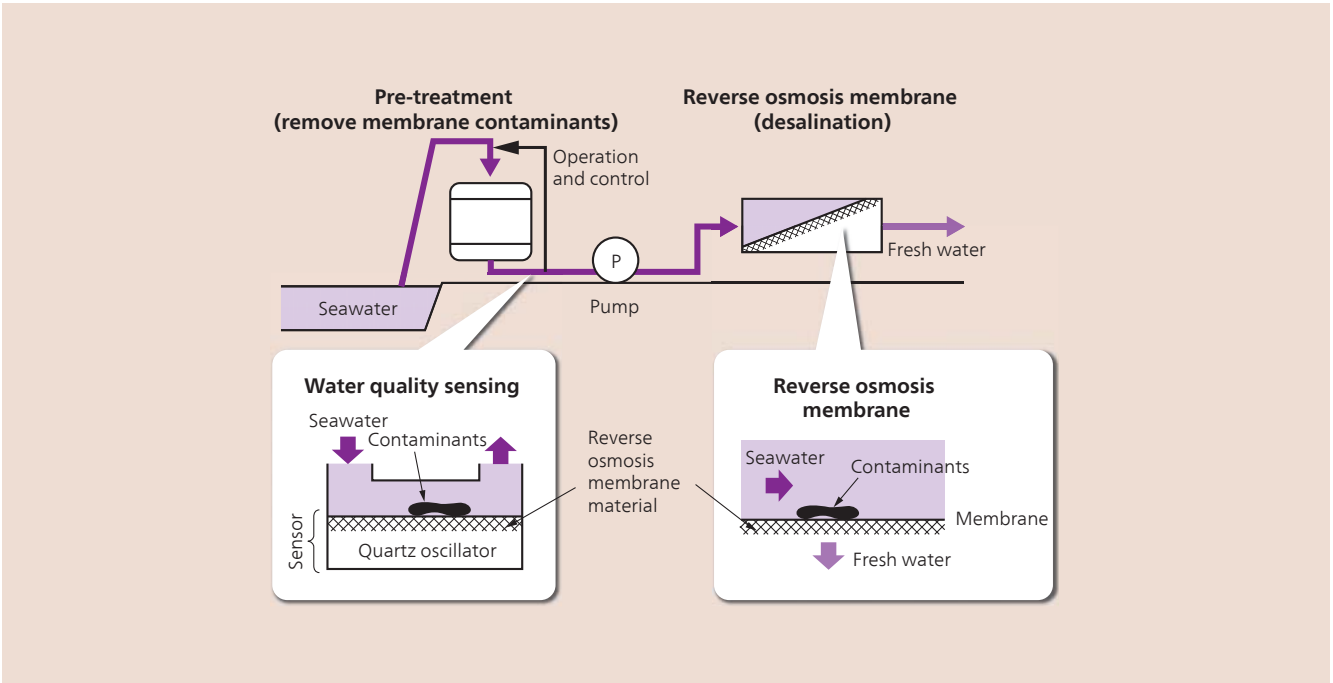
27 Flow control technique for messaging systems

28 Water Quality Sensing Technique for Seawater Desalination Plants

Seawater desalination plants use reverse osmosis membranes to remove the salt from seawater. Preventing the clogging of the membrane by organic contaminants in the seawater is an important requirement for ensuring efficient operation. In the past, the lack of a direct means of detecting organic contaminants in the seawater has meant that clogging has instead been identified from increases in pressure at the pumps that supply the seawater to the reverse osmosis membranes.

A new technique developed by Hitachi can sense the presence of organic contaminants quickly and with high sensitivity. Given that clogging is caused by these organic contaminants being sucked into the surface of the membrane, organic contaminants can be selectively captured by a reverse osmosis membrane material coated on a highly sensitive quartz oscillating sensor. The new sensing technique has a strong correlation with pressure increase (0.95) but takes less than one-twentieth of the time required to detect clogging from an increase in pressure (less than two hours compared to several days). It is anticipated that the technique will facilitate highly efficient operation by detecting the presence of organic contaminants in advance so that they can be removed by chemical or other means before they reach the membranes.

In the future, Hitachi intends to improve detection accuracy and establish automatic measurement methods, and to apply this technology to the operation and control of seawater desalination plants.



28 Diagram of seawater desalination plant and sensor features