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Industrial Information Technology Edition

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Industrial Information Technology Edition

CONTENTS

Our front cover shows major examples illustrating the Industrial Information Technology theme of this special issue of Advance. The interactive multi-user information system (upper center) uses eight, 70" displays for ITV supervision and control of multiple sites. The realtime MR3300 computer and system console (lower right) offer extremely high reliability and open (UNIX "MI-RT") system architecture. The MR2000 (lower left) is a desktop-sized realtime computer.

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Overview

Industrial Information Technology

*by Muneo Kawasaki**

The move to digital communications and the astonishing advances being made in information technology constitute nothing less than a new, worldwide industrial revolution. Mitsubishi Electric is engaged in research and development at the heart of this revolution, seeking to create uniquely innovative products and systems. These include information systems for business, industry and the home, next-generation communications and broadcasting technologies, and advanced LSIs. In all fields, we seek to perform R&D and implement products in a thoroughly market-oriented paradigm.

This issue of *Advance* is devoted to industrial information technology, a field in which intense competition makes it absolutely essential to conform to international standards and adopt open architectures, while the systems themselves must use information technology to provide ever more sophisticated functions.

It is in such an environment that Mitsubishi Electric is implementing conformity to international standards and working to further enhance the performance and reliability of the industrial computers, controllers, man-machine interfaces, networks, etc. that constitute its industrial information and control systems. We are also developing revolutionary industrial control systems that make active use of advanced multimedia, Internet and intranet information technologies.

In the following articles, we introduce some recent examples of our successes in these areas, from individual products to entire systems.

**Muneo Kawasaki is General Manager of the Energy & Industrial Systems Center.*

Industrial Information Systems Technology, Present and Future

*by Kazuyuki Katori and Tadashi Matsuzaki**

Advances in computer, communications and software technologies are driving the development of information systems for electric power, gas and water utilities, manufacturing plants, intelligent transportation systems and buildings. These systems implement supervision, control and data acquisition functions, and provide operation and maintenance support. Ongoing concern for rationalization, energy savings and other improvements in target systems is being satisfied through synergetic solutions incorporating new concepts and functions and networking improvements. Mitsubishi Electric has long experience in developing industrial information systems, with expertise in supervisory control systems for plants and wide-area networks, and technologies spanning computers and microprocessors, communication, multimedia, and information management. This articles describes trends in information systems for industrial sys-

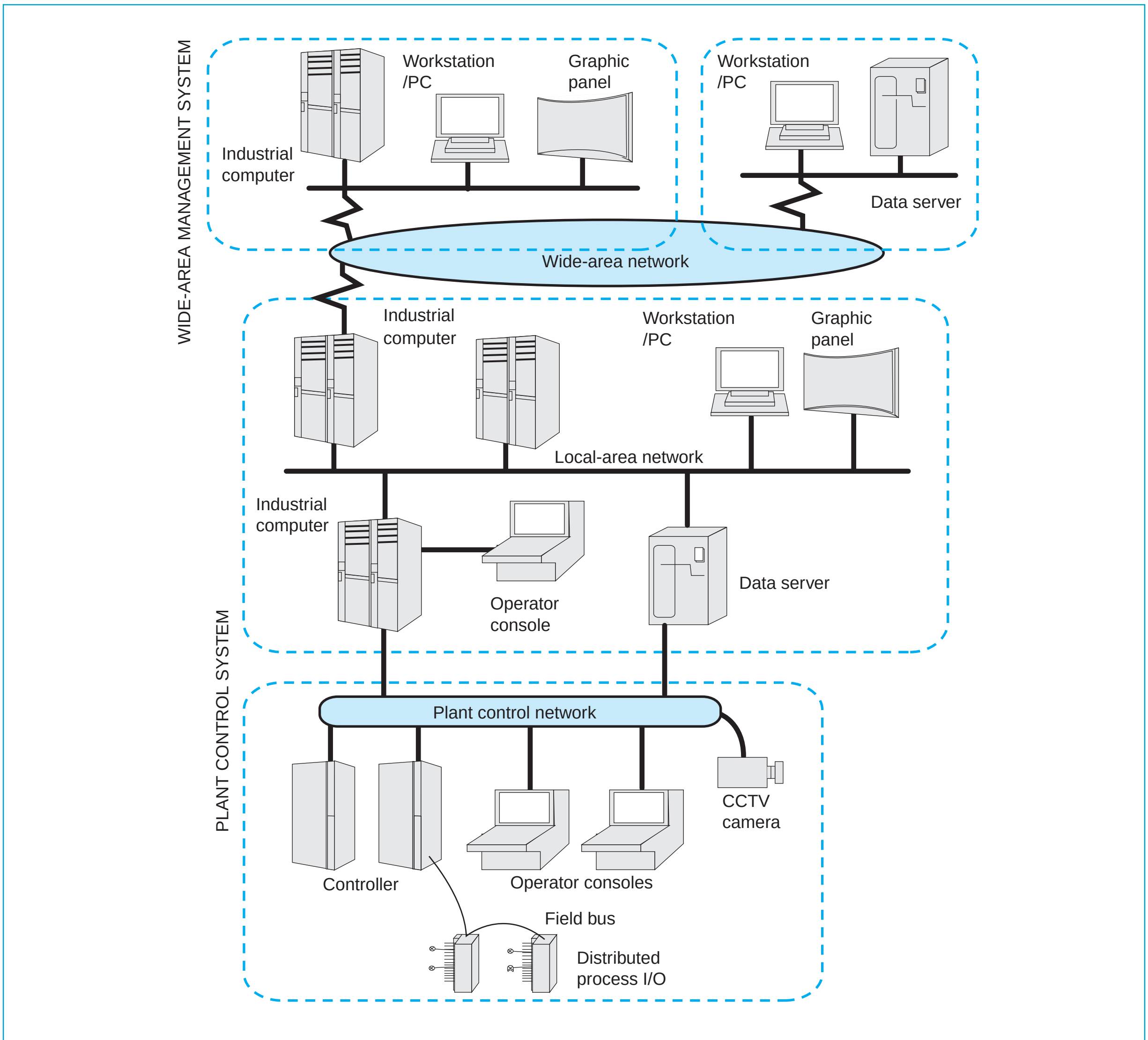


Fig. 1 Overall structure of industrial information and control systems.

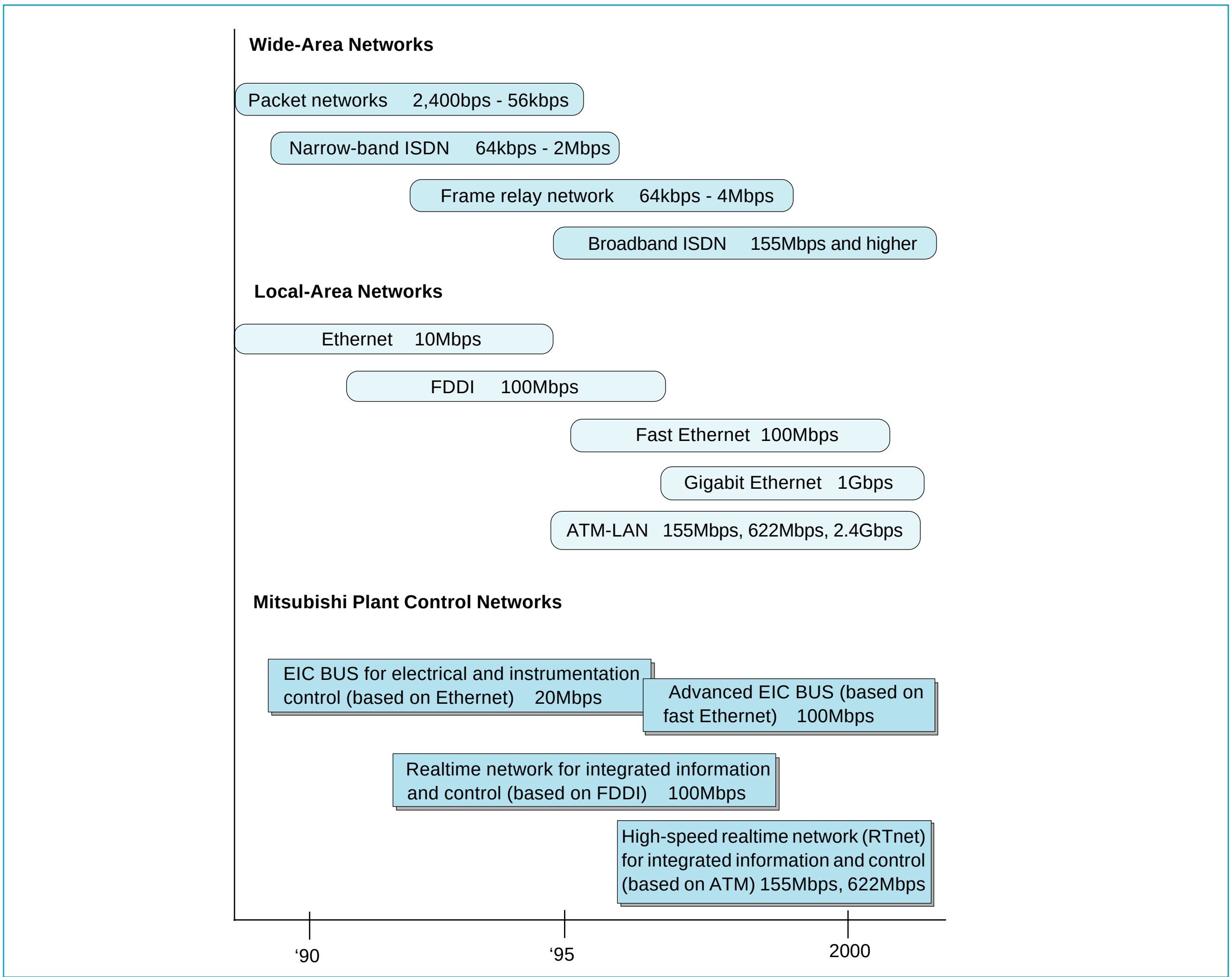
Kazuyuki Katori and Tadashi Matsuzaki are with the Energy & Industrial Systems Center.

tems and introduces solutions from the company.

Technology Trends in Industrial Information Systems

Connectivity and interoperability requirements in current industrial systems now require network-based information systems linking computers, controllers, operator consoles, networks, field buses, CCTV cameras and other equipment as illustrated in Fig. 1. Target systems include: information systems for power distribution mapping and facility design, intelligent transportation systems and disaster information services; wide-area supervisory control systems for power transmission, water distribution control and management, and building automation; plant management systems for power plant management, plant maintenance support and facility information management; and plant supervisory control systems for nuclear and thermal power plants, steel plants, and wastewater treatment plants. These information systems need to provide security functions to protect sensitive information, and effective user-friendly ways to communicate information to system operating staff. Finally, information systems developed for worldwide application need to adhere to estab-

Table 1 Key Networking Technologies



lished and de facto international standards.

Operating System and Basic Software Technology Trends

Improvements are being seen in a variety of operating system platforms which are the foundation for information systems. Overall the trend is toward general-purpose operating systems: enhanced versions of Unix and Windows 95/NT running on general-purpose workstations, servers and personal computers. Industrial systems employing direct digital control and other online instrumentation require computers capable of realtime processing. At the same time, software portability requirements demand use of open system architectures. Mitsubishi Electric meets these dual requirements with MI-RT, the corporation's realtime Unix operating system. MI-RT can easily network with general-purpose computers in distributed systems.

To support network computing technologies in industrial applications, we are integrating realtime processing capabilities with object-oriented network technologies such as ActiveX and Java.

Network Technology

Table 1 lists key networking technologies. Ethernet and ATM form the basis for low-cost high-speed LANs. Control networks previously based on proprietary technology must now meet pressures for interoperability. The company is developing realtime ATM technology that offers open-system benefits alongside realtime performance for high-speed and multimedia applications. Explosive development of Internet technologies and the emergence of the Java language have driven development of enterprise intranets and are encouraging the development of wide-area wideband networks. Wide-area supervisory control systems are a major development aim at Mitsubishi Electric.

In field bus technology, we are seeing advanced information and control capabilities in low-level systems through the use of intelligent field devices. Emerging field-bus standards include Foundation Fieldbus, CC-LINK, Lonworks,

Table 2 Mitsubishi Electric Industrial Information System Components

Name	Technology
HOPE[1] engineering tool	High-level engineering environment based on international standard IEC1131-3
GRASS[2] configurator	Application software configurator based on an object-oriented framework
MR2000 Series industrial computer and HOPE controller	Common architecture CPU systems based on PC-AT architecture, PCI bus and compact PCI
Scalable realtime OS for MR2000 Series and HOPE	Consistent OS-based micro-kernel technology for industrial computer systems and distributed controllers under HOPE
Mitsubishi industrial ATM, 100Mbps Ethernet, FDDI	Control network based on de facto standards
HOPE operator station	Operator console based on personal computer architecture, OLE and OPC
Mitsubishi interactive multiuser information system with large multiple screen	Multimedia functions; Modular-X, Shared-X and DLP
Mitsubishi FIS[3] field bus	De facto standard field buses such as CC-LINK, Lonworks and Foundation Fieldbus
Mitsubishi FIS process I/O	Distributed I/O system
Mitsubishi FIS sensors and controllers	Intelligent field devices

1.HOPE: human-oriented open control system.
2.GRASS: generation-based reconfigurable tool for SCADA systems.
3. FIS: field intelligent solution.

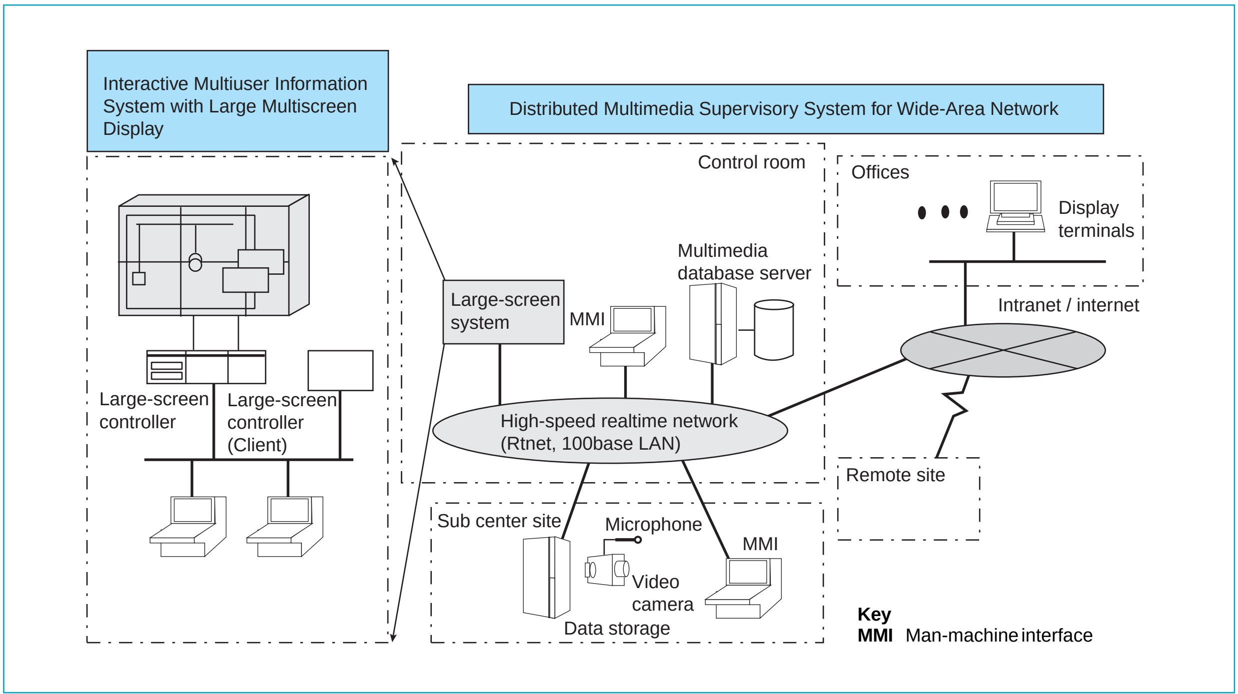


Fig. 2 Information and control system using multimedia and intranet technology.

Profibus and Device Net, with Mitsubishi Electric engaged in active technology development.

Intranet and Internet Trends and their Impact on Industrial Systems

New business fields are forming as a result of advances in Internet and intranet technologies, and other new network-oriented technologies. In the industrial field, key applications are multimedia-on-demand, virtual reality operator consoles, business process reengineering, electric commerce and continuous acquisition and life-cycle support (CALS). Corresponding industrial applications under R&D at Mitsubishi Electric include: intelligent transport systems with advanced road navigation, wide-area monitoring and control systems; distributed computer supported cooperative work (CSCW) systems for remote plant equipment maintenance; operator support systems; industrial decision support systems in which plant data is integrated with a management information system by SAP; CALS systems for steelmaking, electric power, etc.; virtual corporation services; and network-based enterprise activity.

Multimedia System Technology

Advances in video image and still-image compression technology, and the ability to integrate text, graphic and video data to create an ambient environment for operating staff are enabling the integration of multimedia capabilities into monitoring and control systems. An important step in this evolution is the development of CSCW systems that allow multiple operators to share and manipulate information. Key technologies for this capability include DLP using digital mirror devices (DMD), bright, large-screen display units, and Shared-X Windows and Modular-X Windows software.

Mitsubishi Industrial Information System Components

The company is developing industrial information systems and components based on the above technologies. Table 2 lists the components, and

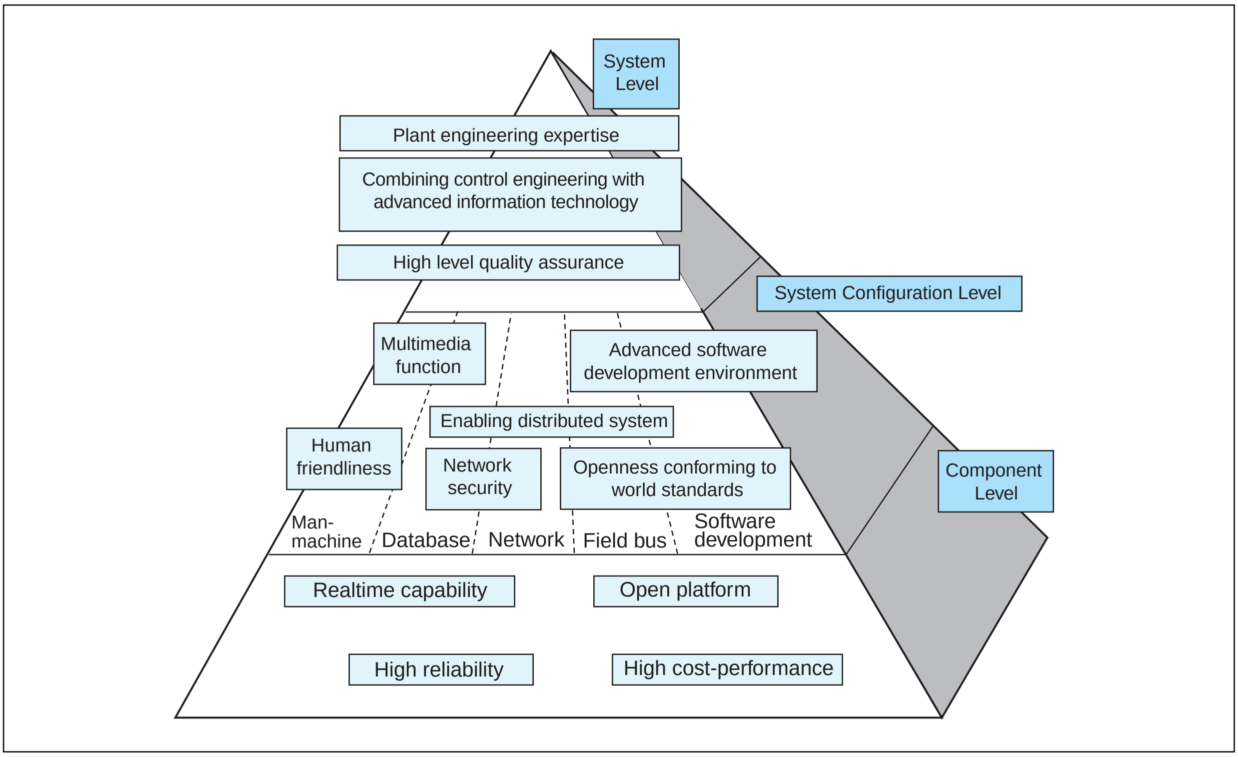


Fig. 3 Concept of industrial information system.

details can be found in subsequent articles.

Multimedia and intranet technology are also being incorporated into industrial information systems. Monitoring and control systems for wide-area applications such as road facility and traffic management systems benefit from allowing operators access from multiple remote sites. These systems need to process live and stored video and sound information, binary data and text. Fig. 2 shows two information and control system products using multimedia and intranet technologies: a distributed wide-area multimedia supervisory system, and an interactive multiuser information system with a large multiscreen display. Fig. 3 shows the key concepts for industrial information systems and their mutual relationships at the component, system configuration and overall system levels.

Mitsubishi Electric is committed to the conception and implementation of industrial information systems that embody all these key concepts, and the development of key components that will contribute to their overall effectiveness and flexibility. ❑

Note

- Unix is a registered trademark in the United States and other countries, licensed exclusively through X/Open Corporation.
- Windows, Windows NT, Active X, OLE and MS-DOS are registered trademarks of Microsoft Corporation in the United States and other countries.
- Java is a registered trademark of Sun Microsystems, Inc. in the United States and other countries.
- DMD and DLP are registered trademarks of Texas Instruments, Inc.
- X Windows is a registered trademark of X Consortium, Inc.
- SAP is a registered trademark of SAP AG.

MR Series Realtime Computers

*by Tadashi Matsuzaki**

Computer technology trends such as downsizing and open architecture are influencing designs of information and control systems, where industrial computer systems—often realtime systems—are used to serve the needs of power plants, power transmission systems, steel and chemical plants, public transportation systems and buildings. Realtime computer systems need to provide guaranteed response times for periodic tasks, non-proprietary operating system design similar to off-the-shelf computer systems, performance sufficient for large-scale applications, and continuous, reliable operation for long periods.

Fig. 1 Model MR3300 realtime computer.

System Configuration

Mitsubishi Electric has developed MR Series realtime computers to meet these requirements. The MR Series employs the MI-RT operating system, which features a realtime response of 0.1ms, POSIX[1] compliance and Mitsubishi-developed high-reliability hardware design.

It also employs precision architecture (PA) -RISC[2] processors from Hewlett Packard, and to ensure reliable operation, redundant hardware systems and a system that automatically reconfigures the hardware in the event of a malfunction. A suite of software system analysis tools is also available.

MR3000 Series computers are intended for server applications, while MR2000 Series computers have a form factor for desktop use. Customers can choose feature sets to suit the application. Fig. 1 shows Model MR3300 and Fig. 2 Model MR2000. Table 1 lists major hardware specifications.

Fig. 2 Model MR2000 realtime computer.

Table 1 MR Series Hardware Specifications

Model	MR3300	MR3200	MR3100	MR2200	MR2000
Performance	100MIPS	100MIPS	100MIPS	200MIPS	100MIPS
Cache	512KB	512KB	512KB	1MB	256KB
Max. main memory	512MB	256MB	256MB	1GB	512MB
Max. disk size	28GB	28GB	14GB	12GB	4GB
I/O bus	Futurebus+			PCI bus	
No. of I/O slots	10	6	2	5 + 6**	3

** Using I/O expansion unit

**Tadashi Matsuzaki is with the Energy & Industrial Systems Center.*

Hardware Architecture

The PA-RISC processor with superscalar processing capabilities and large cache memory gives the MR Series industry-leading performance. The main logic circuits such as processor control, memory control and I/O bus control are implemented in ASICs, enhancing hardware-level reliability.

The hardware includes error detection logic that corrects main memory errors and performs cache parity checking. It also detects clock loss, power failure and excessive temperature. Information on these errors is displayed on a hardware status panel and the system console. A separate memory unit with battery backup logs hardware status data to facilitate fault analysis.

MR3000 Series computers offer hot-plug capabilities through use of a Futurebus+ I/O bus conforming to IEEE 896.1 and 896.2 Profile B. MR2000 Series computers employ a Rev. 2.0-compliant PCI bus, allowing use of cost-effective third-party I/O boards. Figs. 3 and 4 show the hardware configurations of MR3000 and MR2000 computers, respectively.

Realtime Operating System

The corporation has developed a realtime operating system for MR Series computers to meet the strict scheduling and response requirements of high-speed communication control and DDC applications. MI-RT employs a realtime UNIX architecture conforming to IEEE POSIX standards 1003.1, 1003.1b and 1003.1c. Fig. 5 shows the difference in response times between MI-RT and off-the-shelf Unix[3].

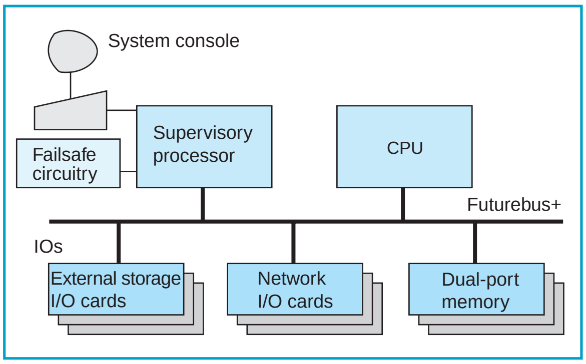


Fig. 3 Hardware configuration of MR3000 Series computers.

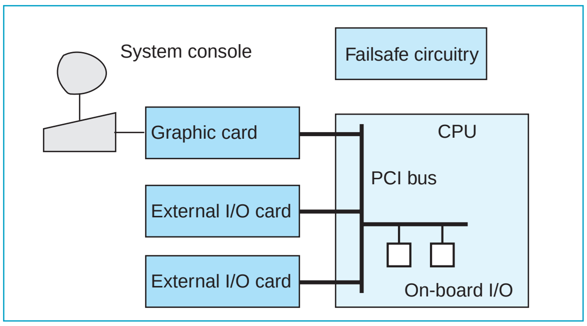


Fig. 4 Hardware configuration of MR2000 Series computers.

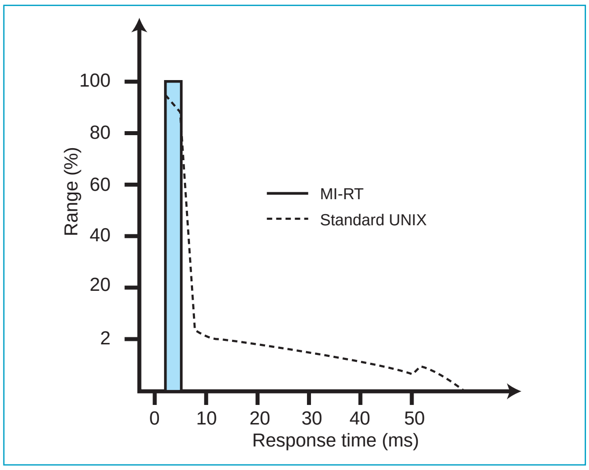


Fig. 5 Response times of MI-RT and off-the-shelf Unix.

RAS System

Fig. 6 shows reliability, availability and serviceability (RAS) design features. Each hardware assembly has built-in diagnostic circuits that enable failures to be localized and isolated. These circuits detect errors and report them via interrupts to error handling routines in the processor. Error conditions are displayed on the system console. If continued operation is possible, error information is passed to middleware which reconfigures the system to adjust to currently available functionality. The RAS system also provides for shutting down in the event of an unrecoverable hardware failure, such as loss of power. Type of error, time of occurrence and fault location data are logged in a separate memory device with a battery backup to assist in error analysis.

Middleware

The MR Series has a rich set of middleware supporting an open, reliable software system. The middleware also raises software productivity by simplifying the task of configuring software for industrial control applications. The middleware provides a feature set sufficient for most industrial application fields, including a distributed realtime file system, high-reliability software design, and realtime middleware functions. Incorporating a graphic user interface, the middleware package supports multiple plat-

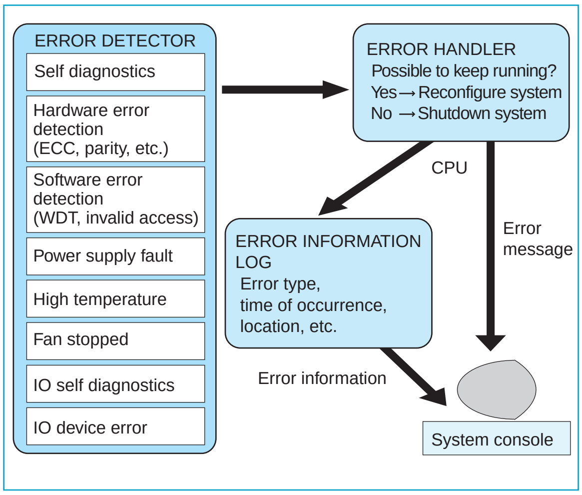


Fig. 6 The RAS system.

software errors, performance degradation or a combination of factors. Errors in large-scale realtime systems can be difficult to trace due to the high complexity involved. The MR Series software system analysis tools, listed in Table 2, assist in these environments, performing such functions as predicting software response behavior, system tuning, verification and error analysis.

Table 2 Software System Analysis Tools

Tool	Analysis
Sylvia	Internal status information from OS and tasks
Sbtracer	Event information from OS and tasks
Syloc	Internal resource information

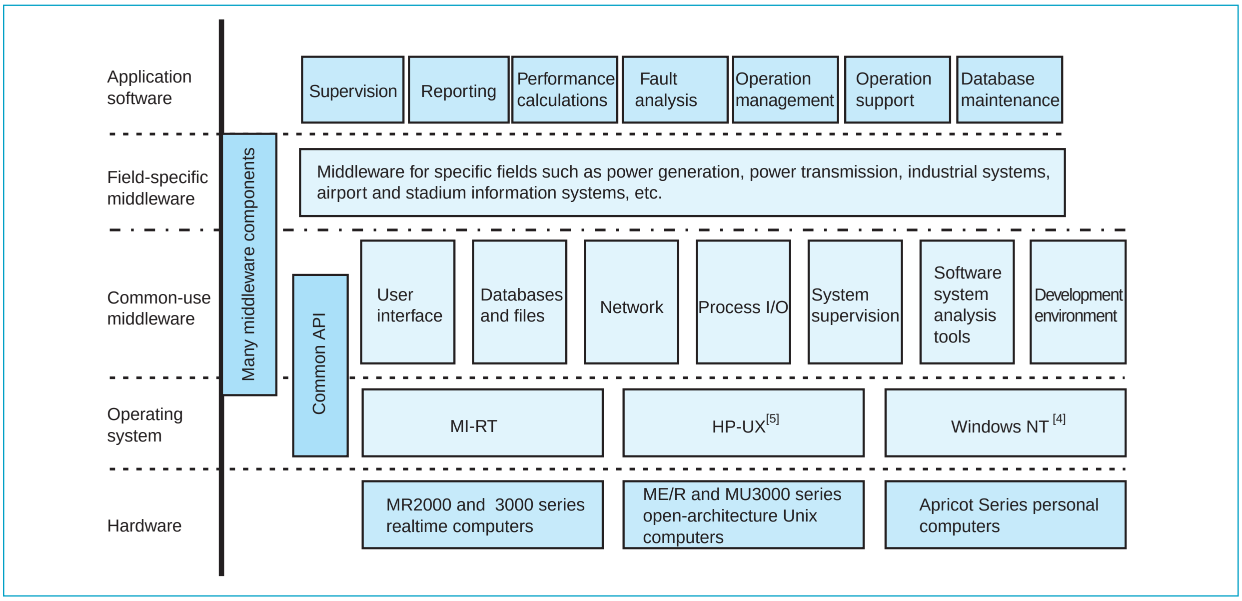


Fig. 7 Applications and platforms for realtime middleware.

forms, including Unix, Windows NT[4] and Mitsubishi's MI-RI (Fig. 7). Preconfigured middleware incorporating de facto middleware standards is available for a variety of application fields.

Software System Analysis Tools

System analysis tools are required to design tasks with guaranteed response times and to perform error analysis.

Realtime software design is difficult because a large-scale realtime system may involve hundreds of tasks in complicated relationships, and each task must be designed to guarantee the specified response time in the context of the entire environment.

Errors may develop due to hardware failures,

Realtime computers are essential to controlling industrial systems because unlike conventional computers, their response is predictable—applications can conduct event-processing within guaranteed time constraints. Wider availability of realtime computer systems and middleware with fault-tolerant designs promises increasing use of realtime capabilities for controlling mission-critical industrial systems. ❑

References

1. POSIX is a trademark of The Institute of Electrical and Electronics Engineers in the United States and other countries.
2. PA-RISC is a registered trademark of Hewlett-Packard Company.
3. Unix is a registered trademark in the United States and other countries, licensed exclusively through X/Open Corporation.
4. Windows NT is a registered trademark of Microsoft Corporation.
5. HP-UX is a registered trademark of Hewlett-Packard Company.

A Plant Supervision and Control Network

*by Yasunori Nemoto**

Recent plant supervision and control network designs are dominated by distributed configurations employing a network of small high-performance controllers. Networks for this application need to be capable of realtime response with sufficient bandwidth and support for video and audio data streams. The efficiency of the field networks handling remote I/O at the lowest level is being enhanced through distributed designs using intelligent remote I/O units.

This report introduces leading-edge asynchronous transfer mode (ATM)-based network technology for plant supervision and control, describing its application and work in progress on intelligent field equipment.

Network Configuration

Fig. 1 shows the network model used for the plant supervision and control system. The top level of the hierarchical LAN, used for information management, requires open specification networking for connectivity with a variety of computer equipment. The middle level control LAN, which transmits plant supervision and control data, requires realtime performance and high reliability. The field network, which handles low-level process I/O data, needs to provide an efficient non-proprietary standard for linking intelligent digitally controlled sensors and actuators. The network model also needs to support connectivity to a wide-area network for remote plant management and maintenance.

Features of ATM-Based Networks

ATM networks transmit data as 53-byte cells, which are assembled at the receiving node to reconstitute the original message, video or audio information. Parameters controlling transmission priority maintain the quality of service required by particular data sources, allowing a single network to handle data and multimedia streams with varying delay constraints. ATM cell routing is executed in hardware to support gigabit-per-second bandwidths with minimum transmission delays. Standards organizations are continuing to work to standardize ATM network specifications to support multivendor connectivity. ATM technology has already been adapted

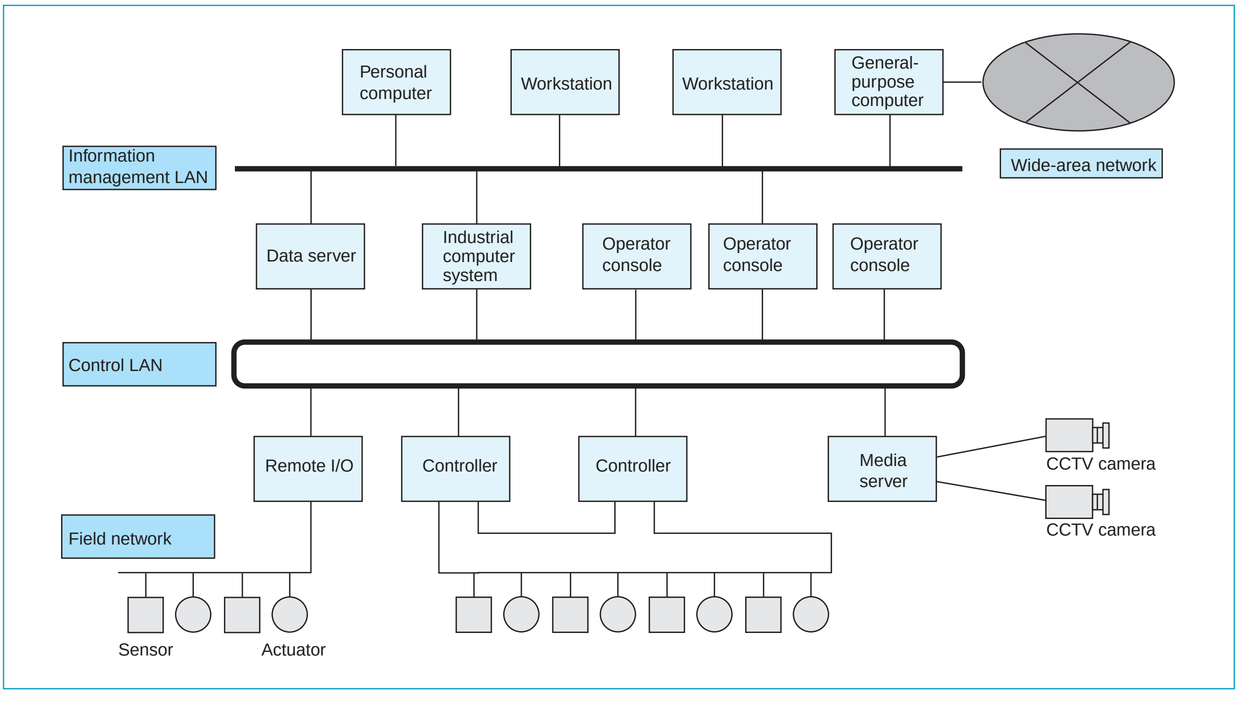


Fig. 1 Layers of the plant supervision and control network.

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to B-ISDN transmission, and it is only a matter of time before ATM-based wide-area networks and plant network systems are connected seamlessly.

High-Speed Realtime Network

The high-speed realtime portion of the network is ATM based, providing 155Mbps and 622Mbps speeds, long transmission distances over optical fiber, and multivendor compatibility based on open standards. This network is used for various networking layers: private wide-area networks installed along railroad, highway and sewage system right-of-ways, TCP/IP-based information management LANs, and the plant control LANs for handling process I/O. These networks can also be used to handle audio and video data streams. Fig. 2 shows a photograph of a node unit for this network, and Fig. 3 the net-

Fig. 2 Node unit for the high-speed realtime network.

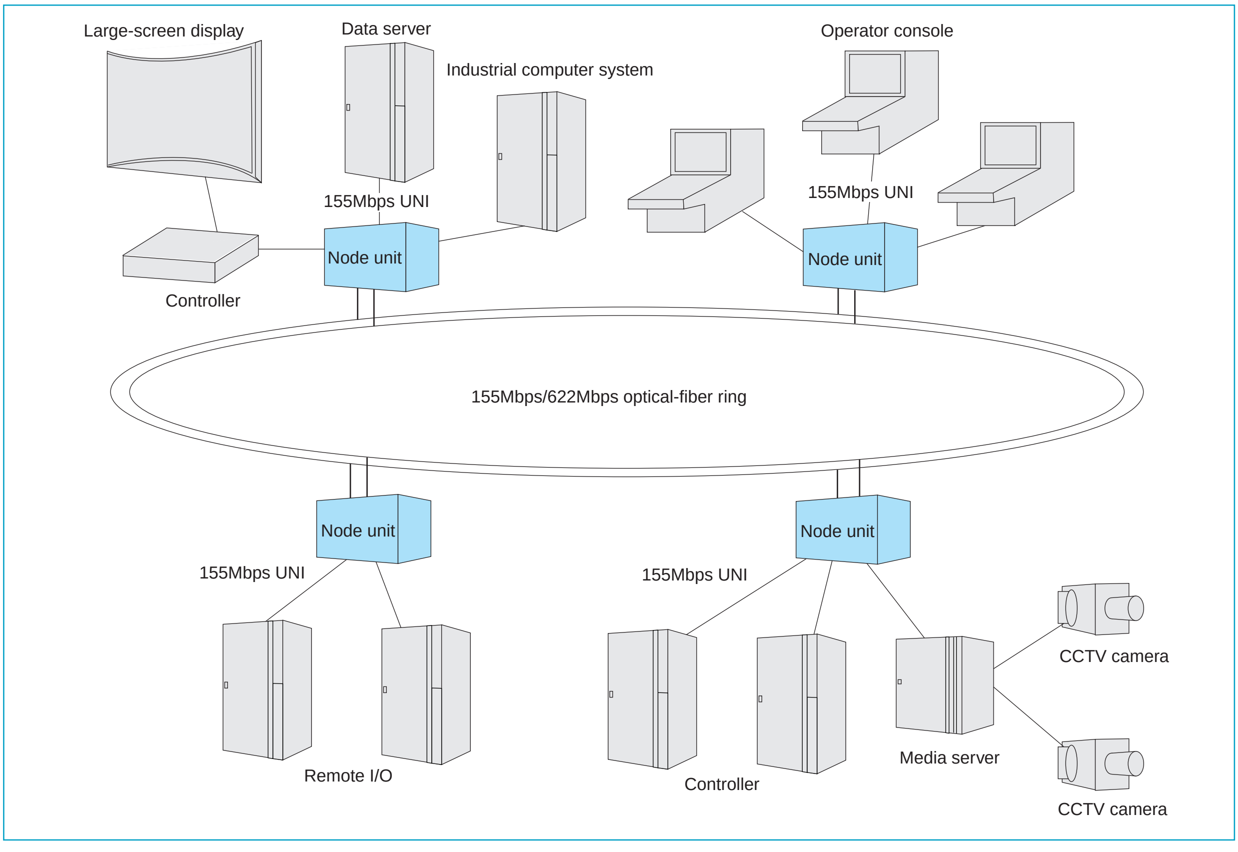


Fig. 3 Configuration of the high-speed realtime network.

work architecture. Table 1 lists the major specifications. We have added several functions that support plant control applications without sacrificing interoperability with other ATM networks.

PRIORITY CONTROL. The extremely small size of the ATM data cells lends itself to multiplexing of data with varying transmission delay constraints, including varying degrees of realtime performance. Our realtime network supports four levels of priority for realtime data, corresponding to different allowable delay windows—the higher priorities for process data and multimedia data.

CYCLIC DATA TRANSMISSION. Realtime transmission of process data is guaranteed by broadcasting the contents of process-related shared memory locations over the network at regular intervals. These memory locations may be distributed throughout the network.

RELIABILITY ENHANCENENT. Redundant design and an original dual-ring topography for ATM switching dramatically enhance network reliability. Redundant network switches, network management modules and power supplies are used, with failure of one unit automatically triggering a switch to a healthy unit. The network's ring topography is monitored by continuous loopback testing, and cell transmission is automatically routed around network faults. An optical bypass for each ATM switch isolates faults, allowing the unaffected portions of the network to remain functional.

SIMPLIFIED CONNECTION SETTINGS. Specialized knowledge of ATM technology is generally required to change connection identifiers when setting up a permanent virtual circuit (PVC) connection. To lower the skills required of plant network support and maintenance personnel and reduce the likelihood of network configuration errors, we have implemented a maintenance console that automatically generates connection and cell transmission control specifications from manually entered ATM node and terminal connection data.

Table 1 Specifications of the High-Speed Realtime Network

Switching capacity	4.5Gbps (non-blocking)
Connection type	PVC
ATM interface	155Mbps (ATM Forum UNI version 3.1)
Max. interface ports	24
Max. distance	2km
Network interface	Ring-node interface 622Mbps Star-node interface 155Mbps
Max. distance between nodes	Star nodes 2 - 20km Ring nodes 4km 20km using optical repeater
Max. no. of nodes	Star nodes 32 Ring nodes 64
Priority controls	Cell loss priority 4 levels Cell delay priority 4 levels
Protocols	Cyclic transmission (periods of 100ms - 5s), TCP/IP
RAS functions	Redundant ATM switch modules, redundant power modules, dual-ring operation

Field Equipment Trends

Field equipment networks for operating sensors, actuators and other instrumentation are rapidly transitioning to intelligent designs that allow functionality to be distributed over a network, with benefits of lower network traffic and simpler system design. Standards organizations, industry associations and individual manufacturers are working to establish common standards for the field networks linking these intelligent instruments. The corporation is developing distributed process I/O equipment and CC-LINK networking technology optimized for field equipment networks.

DISTRIBUTED PROCESS I/O. By incorporating intelligent functions into sensors, actuators and other on-site process I/O equipment, these instrumentation functions can be integrated seamlessly into a plant control network, allowing the use of common procedures for networking main equipment, controllers and other field equipment.

By incorporating intelligent sensors into the design of target equipment, control functional-

Table 2 CC-LINK Specifications

Transmission rate	Up to 10Mbps
Access control	Polling
Topology	Bus
Synchronization	Frame synchronization
Coding	NRZI
Transmission format	HDLC frames
Max. total distance	100m
Transmission medium	Shielded twisted-pair cable (3P)
Error control	CRC ($X^{16} + X^{12} + X^5 + 1$)
Transmission data capacity	Bit data 2,048 points Word data 256 points
Max. remote I/O stations	64
RAS functions	Line test, self diagnostics, automatic station insertion/ deinsertion, dual master stations, dual bus

ity can be enhanced and equipment costs lowered. The emergence of non-proprietary field networks will facilitate the implementation of total plant solutions integrating field equipment from multiple vendors.

CC-LINK NETWORK TECHNOLOGY. We have developed CC-LINK network technology to support intelligent distributed process I/O technology. CC-LINK was created specifically for factory automation with the cooperation of field equipment manufacturers. CC-LINK is a bus-topology network offering a 10Mbps bandwidth with a 5ms scanning cycle. Table 2 lists the major specifications. The system uses shielded twisted-pair cables as the transmission medium, and maintains high reliability through automatic deinsertion and reinsertion of faulty stations, and redundant master network controllers and transmission paths.

We have discussed the application of ATM technology to high-speed realtime networks for plant supervision, control and information management. While ATM solutions are being developed to support multivendor and multimedia capabilities at the top and middle levels of plant networks and at the wide-area network level, non-proprietary distributed control technologies are being developed to simplify the design of low-level field networks. Here, too, optical fiber and wireless technologies for harsh environments and simplified configuration technologies are continuing to advance.❑

A Multimedia System for Industrial Applications

*by Mitsuo Asano**

Mitsubishi Electric has developed a user-friendly multimedia-capable information control and management system for industrial applications. The system is designed to support efficient management of industrial plant equipment and provides tools to quickly apprehend and respond to equipment malfunctions.

Multimedia Requirements of Industrial Systems

The scale of industrial systems for manufacturing, electric power generation and distribution, transportation, traffic management, water treatment and building management is continuing to grow. Supervisory and control systems for these applications are expanding from single-facility scale to larger networks spanning cities or even larger geographical regions.

To handle this vastly increased complexity, system operators need information-processing equipment that provides information in readily accessible form, supports quick, accurate response to emergency conditions, enables operation staff distributed over a wide geographical area to work cooperatively, and facilitates operator education and training (Fig. 1).

Trends in Multimedia Technology

System operators managing large-scale and wide-area systems require a sophisticated multimedia-capable information system. Mitsubishi Electric is developing information technologies for this purpose. These technologies enhance conventional monitoring and control capabilities with large-size multiscreen display units, enable the recording and transmission of multimedia information across large geographical areas, provide image processing for detecting alarm conditions, and support mobile computing.

Several trends can be seen in multimedia technology for industrial applications. Monitors of 50 ~ 70 inches with multiwindow displays are entering wide use. These projection-type monitors use CRT and LCD technology, with potentially sharper digital micro-mirror projection technology approaching practical application.

Wide-area video transmission is increasingly practical with the advance of video-compression technologies such as M-JPEG, JPEG, MPEG2 and MPEG4. Within the next 2 - 3 years, advancing networking and video-compression technologies will enable operators of industrial monitoring and control systems to view CCTV signals from remote sites on demand. The high-quality video required for industrial applications will be increasingly available as the prices of MPEG2 encoders and decoders continue to drop, and as corporations introduce high-speed networks with intranet and Internet capabilities. Fig. 2 illustrates the capabilities targeted for future multimedia information systems.

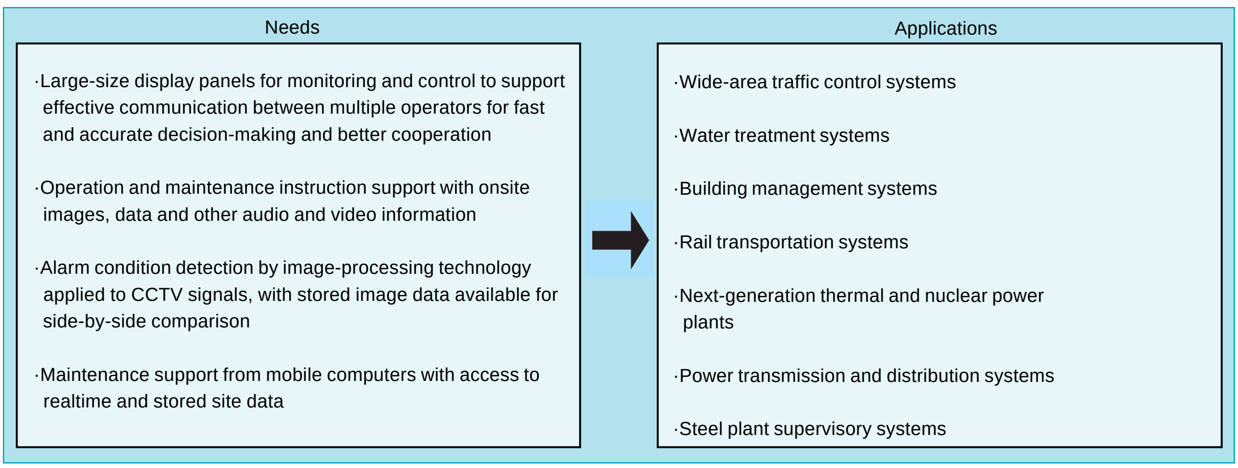


Fig. 1 Needs for multimedia capabilities in industrial systems.

**Mitsuo Asano is with the Energy & Industrial Systems Center.*

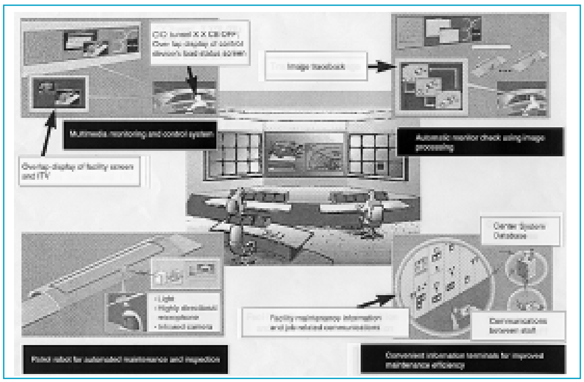


Fig. 2 Illustration of a multimedia system for a road management and control system.

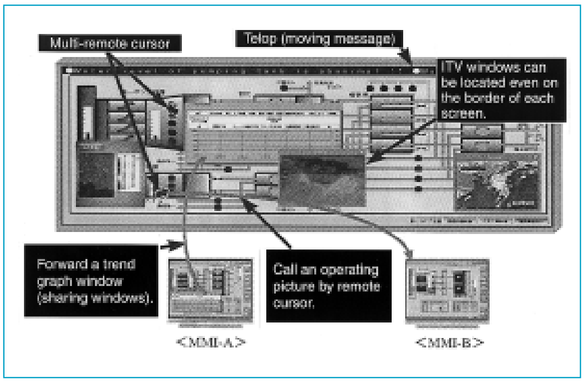


Fig. 4 Typical images on a large-size multiscreen display.

System Products Under Development

Multimedia technology that organically combines voice, audio and data handling capabilities is approaching commercial implementation. This technology offers realistic presentation, simple operation procedures, remote operation capabilities and support for fast, accurate response to unanticipated conditions. Fig. 3 shows two multimedia system products under development at the company: an interactive multiuser information system with a large multiscreen display, and a distributed multimedia supervisory system for wide-area applications.

INTERACTIVE MULTIUSER INFORMATION SYSTEM WITH MULTISCREEN DISPLAY. Central control rooms have employed graphic panels and central control boards, with large-screen displays used primarily for plant monitoring. We have developed large multiscreen displays with sophisticated functions that dramatically facilitate the tasks of plant operation and maintenance. While the multiscreen display can function as a single large monitor, it can also simultaneously show multiple CCTV images from remote sites along with other video images, maps, radar raingauge data, and other monitoring and control data. The display system supports cooperative plant operation and decision-making by allowing multiple operators to manipulate plant control screens using multiple remote cursors. The display is also capable of window sharing with an operation console. Fig. 4 shows a typical screen display.

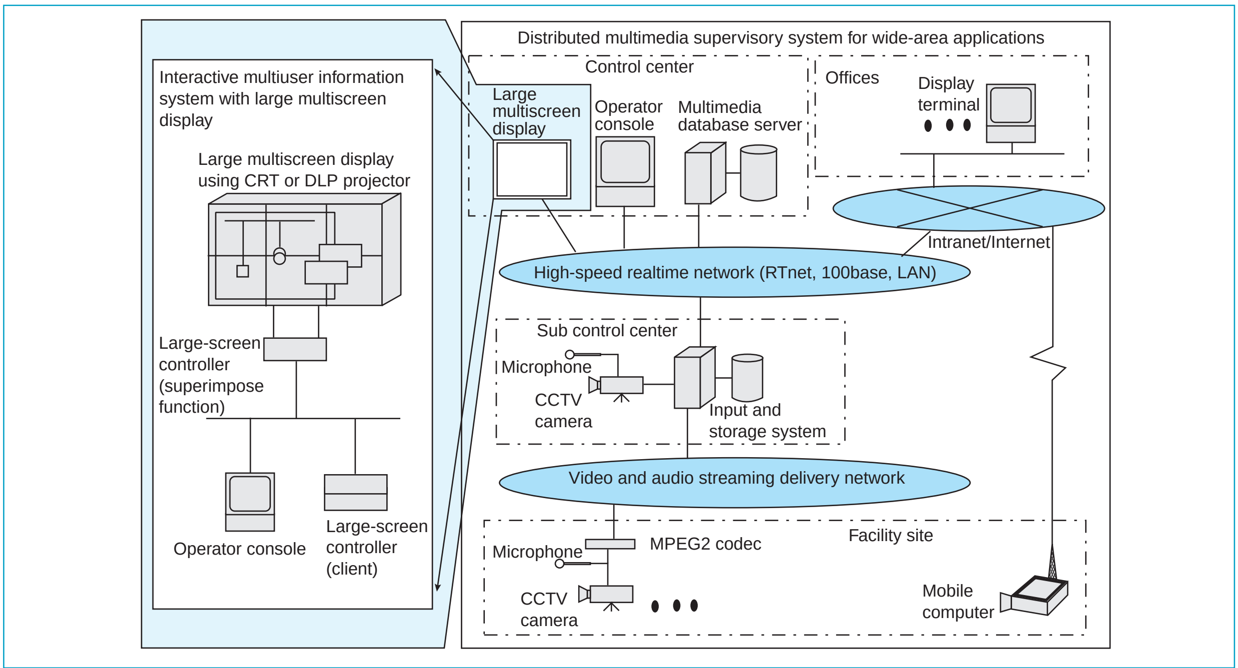


Fig. 3 Multimedia system products under development at Mitsubishi Electric.

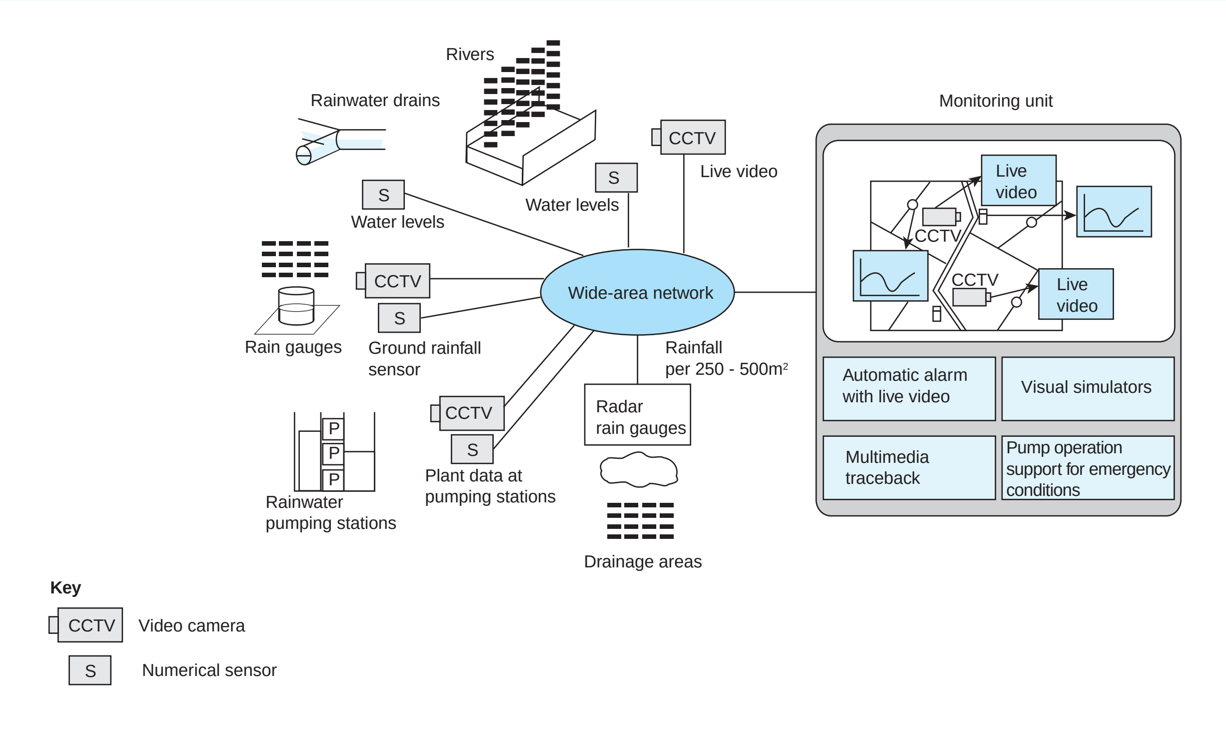


Fig. 5 A multimedia rainwater management monitoring system.

DISTRIBUTED MULTIMEDIA SUPERVISORY SYSTEM FOR WIDE-AREA APPLICATIONS. Previous wide-area CCTV systems were monodirectional systems feeding multiple video signals to a remote monitoring center. We are developing bidirectional monitoring functionality using high-speed network technology, digitally encoded CCTV signals and Internet/intranet technology. These technologies support bidirectional video and audio communications between the plant and control center, sensor-triggered emergency video monitoring and recording, direct control of CCTV cameras from operator consoles or multiscreen display units, and use of image processing to detect abnormal conditions. Benefits of the system include better cooperation between remote monitoring and local supervisory staff, with reduced need for local inspection. Realtime CCTV images can be compared side-by-side with previously recorded images, and the video record during plant function abnormalities can be readily called up for detailed inspection. The system supports rapid response to emergency conditions, and a single monitoring center can efficiently manage facilities spread over a wide geographic area, reducing staff requirements. Fig. 5 illustrates a typical application system for a rainwater management network.

Rapid advances in multimedia plant monitoring technologies are expected to continue, with mobile computing and intranet technologies providing a foundation with Mitsubishi Electric's scalable platform for large interactive networked environments (Spline) technology for cooperative system operation within distributed virtual environments. Future multimedia information systems will enable operating staff in a central facility to select and view three-dimensional computer graphics and data from widely distributed monitoring targets. ❑

An Intranet System for Industrial and Public-Use Applications

*by Takaaki Maekawa and Akira Horiguchi**

The dramatic growth and development of Internet/intranet technologies has had a powerful impact on industrial information systems, with many enterprises actively introducing intranet capabilities. This article reviews trends in intranets for industrial and public-use applications and introduces developments at Mitsubishi Electric.

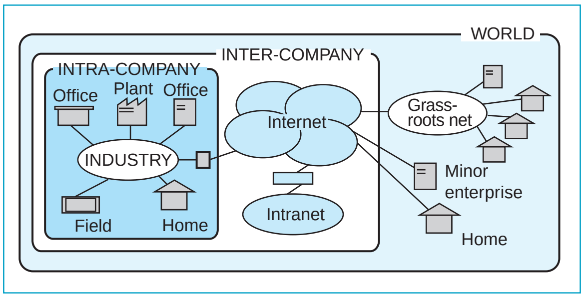


Fig. 1 Connectivity potential of industrial intranet-based information systems.

Background

Intranet technology applications are growing rapidly in the industrial sector due to several advantages of this technology: reduction in time required for system configuration and lower cost resulting from the use of general-purpose software, support for multimedia capabilities, and finally, lower system maintenance costs through having key software reside on a central web server. To satisfy security and performance requirements, enterprises have typically established their own high-speed networks protected by firewalls. Recent improvements in security and the increasing bandwidth of Internet back-

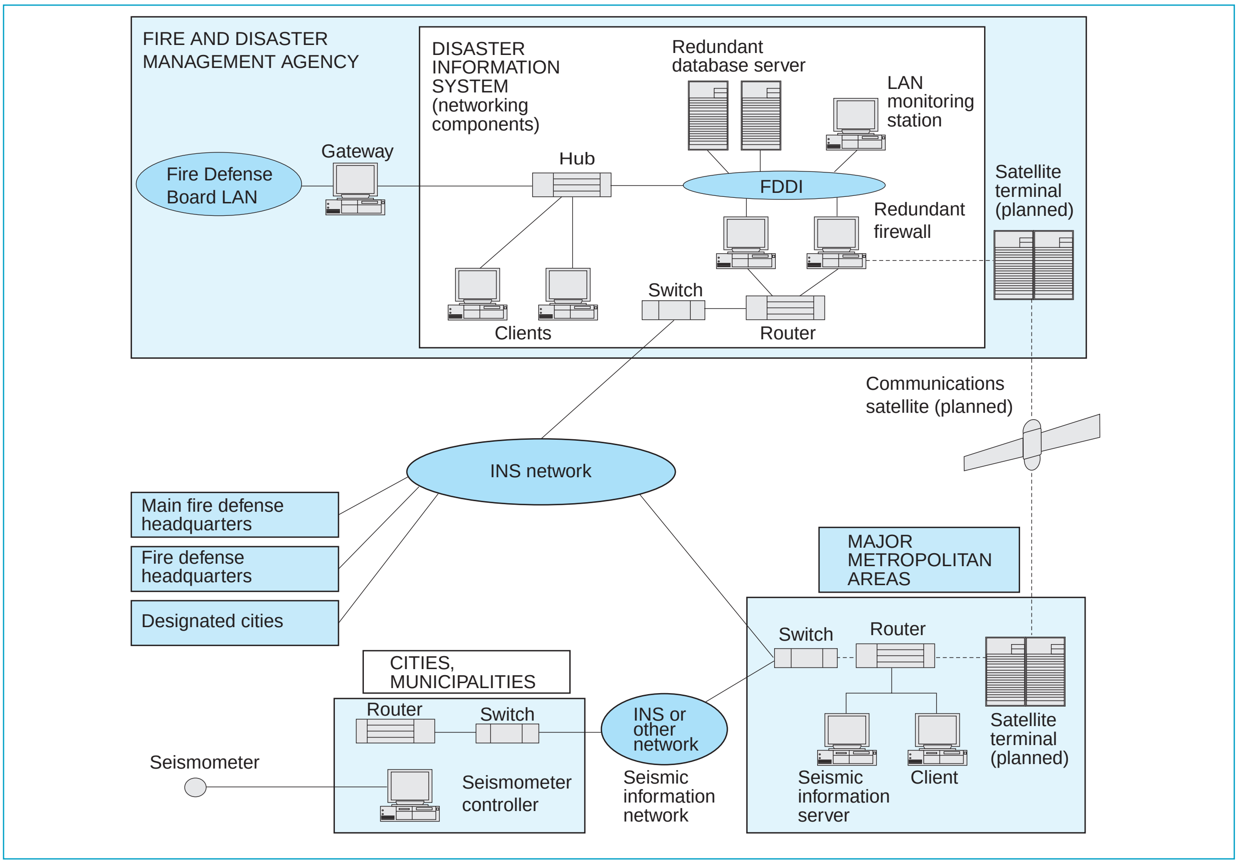


Fig. 2 A disaster information system for the Fire and Disaster Management Agency of Japan. The shaded area indicates portions of the system provided by Mitsubishi Electric.

*Takaaki Maekawa and Akira Horiguchi are with the Energy & Industrial Systems Center.

bones are encouraging the wider connectivity illustrated in Fig. 1, in which an enterprise is connected through the Internet to other companies and society at large. Adoption of this technology is being driven by four major application areas: multimedia on demand, virtual reality-based user interface systems, continuous acquisition and life-cycle support (CALS), and business process reengineering. We will examine the first three of these services.

Multimedia on Demand

Industrial and public-use communications use a variety of media including text, diagrams, photographs and video; workers need to be able to share these many kinds of information through the enterprise network. Organizations like police and fire departments may need to share information across an entire state or nation.

Intranet System for the Fire and Disaster Management Agency

Fig. 2 shows the configuration of an intranet system applied to a national disaster information system for the Fire and Disaster Management Agency of Japan. The system uses a wide-area network to allow municipal and regional government offices and the agency to share information, rapidly disseminate disaster reports and relay instructions for field workers. These capabilities derive from three major intranet functions.

The first is shared databases. Seismic measurements, disaster reports, regional response plans and other data can be managed centrally and made available at terminals throughout the nation.

The second is guaranteed reliability. Reliability of data resources is guaranteed by the use of redundant disk storage devices and servers. Reliable network connectivity is ensured by providing alternative communications links to backup links when main links experience trouble.

The third is a full complement of security functions. A firewall prevents unauthorized external access, while internal security is maintained through user passwords.

Realtime Monitoring

For industrial and public-use applications, World Wide Web technology is required for the realtime monitoring of facilities distributed over wide geographic areas and provides ready access to information resources on demand.

Fig. 3 shows a screen of a weather information system supporting roadway safety monitoring. The system gives its administrators access via browsers to continuously updated rainfall tables, trend graphs and other data at will. Display speed is accelerated by the use of Java applets, with high-productivity WYSIWYG

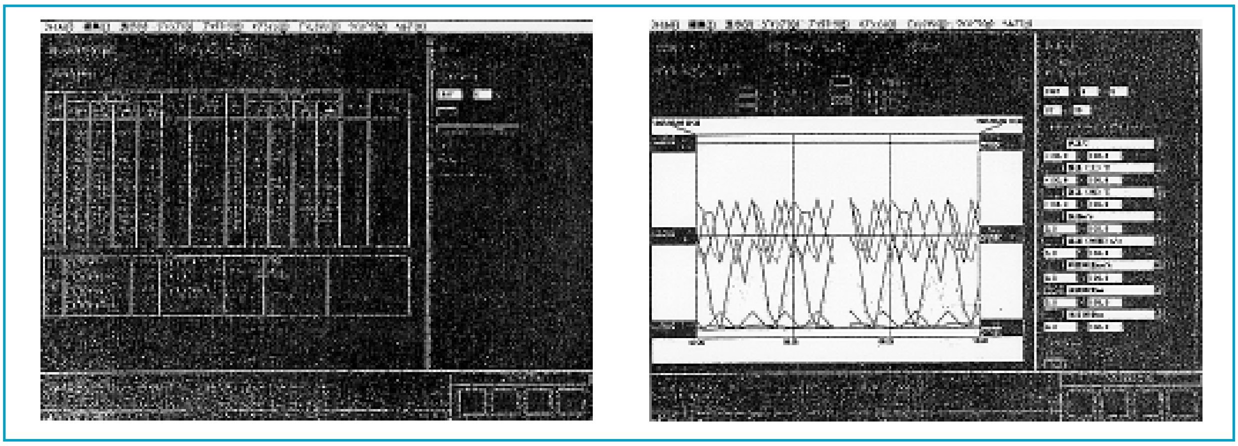


Fig. 3 Sample screens from a weather information system used for roadway management.

tools for screen creation from a Java software component library.

The corporation has also developed original push technology for distributing alarm displays and other unscheduled information to browsers in real time.

A Virtual Reality Control Console

Virtual reality technology using three-dimensional computer graphics is being applied to support efficient maintenance of geographically distributed roadway facilities. Fig. 4 shows the concept for a roadway facility operation and management system. Local personnel investigating emergencies or equipment failures need to coordinate their actions with staff at central roadway management offices. This system uses three-dimensional computer graphics technology to enable central office staff to view on-site graphic images taken from the patrol vehicle and transmitted via an intranet. Unlike CCTV images, use of graphic images allows viewing from any desired perspective. This gives the office staff an ambient sense that facilitates communication. The local workers can communicate with the central office using voice and video.

Continuous Acquisition and Life-Cycle Support

CALS is a digital network infrastructure supporting equipment procurement, configuration and maintenance. CALS supports shared databases, reengineering and concurrent engineering processes, and is expected to dramatically boost management efficiency of industrial systems. The corporation is focusing on the following two major CALS applications.

CALS FOR ELECTRIC POWER UTILITIES. This system will enable equipment manufacturers and thermal power plant engineering staff to share documents, supporting more efficient work flow. Currently CALS standards are being evaluated in a prototype engineering corresponding sheet

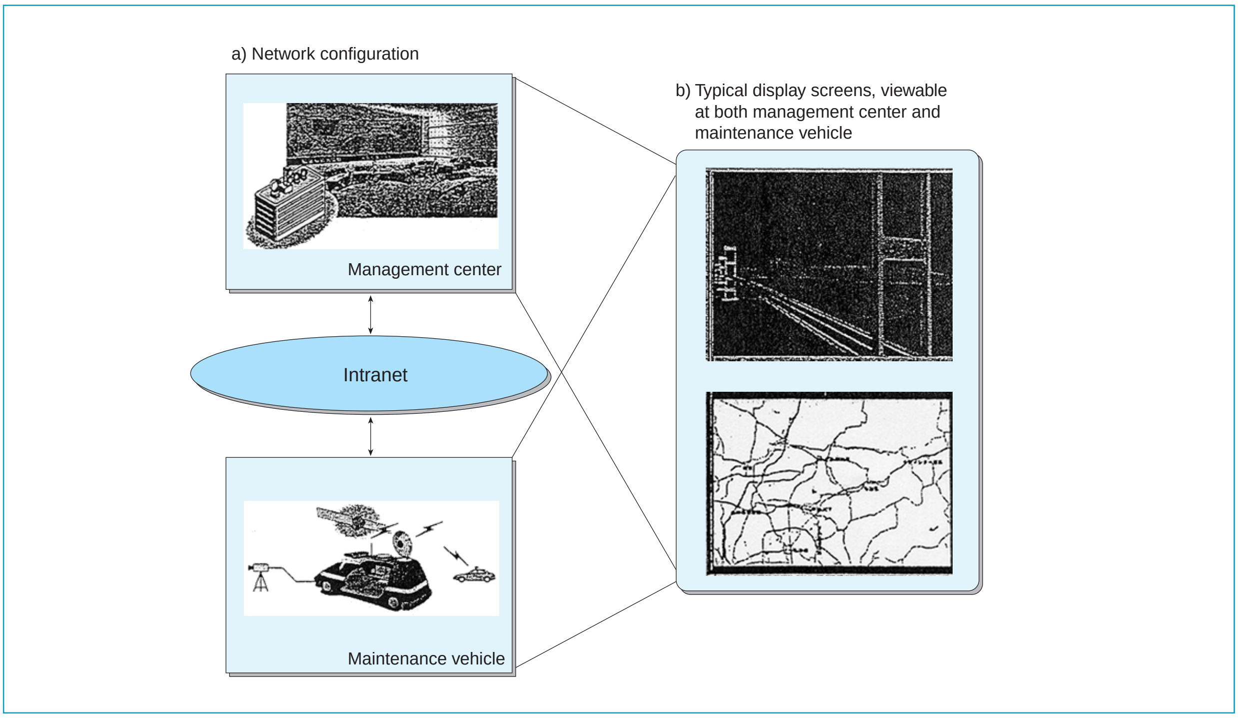


Fig. 4 Basic concept of a virtual reality system for roadway facility management support.

(ECS) system for the sharing of engineering documents. We have developed MELECS, an ECS document generation support system using World Wide Web technology (Fig. 5).

CALS FOR STEEL MANUFACTURERS. Similarly there is a strong need for more efficient communication between steel plant engineering staff and equipment vendors. We are currently participating with other vendors and steel manufacturers in qualification testing of a prototype CALS system for improving rolling mill management and administration efficiency. A database of the mill equipment is being built with vendors sharing access. Our current work involves developing production-quality implementations of selected functionality relating to accessing and responding to database contents and database configuration management.

Future Developments in Network Computing

In the near future, we expect Internet/intranet computing paradigms and technologies to increasingly dominate the architecture of industrial information systems. Network computing technology allowing mobile terminals to rove freely over large distributed environments is fast approaching commercial implementation.

Mitsubishi Electric is committed to developing advanced information systems incorporating intranet technologies, distributed object technologies, agent technologies, and other innovations in information science. ❑

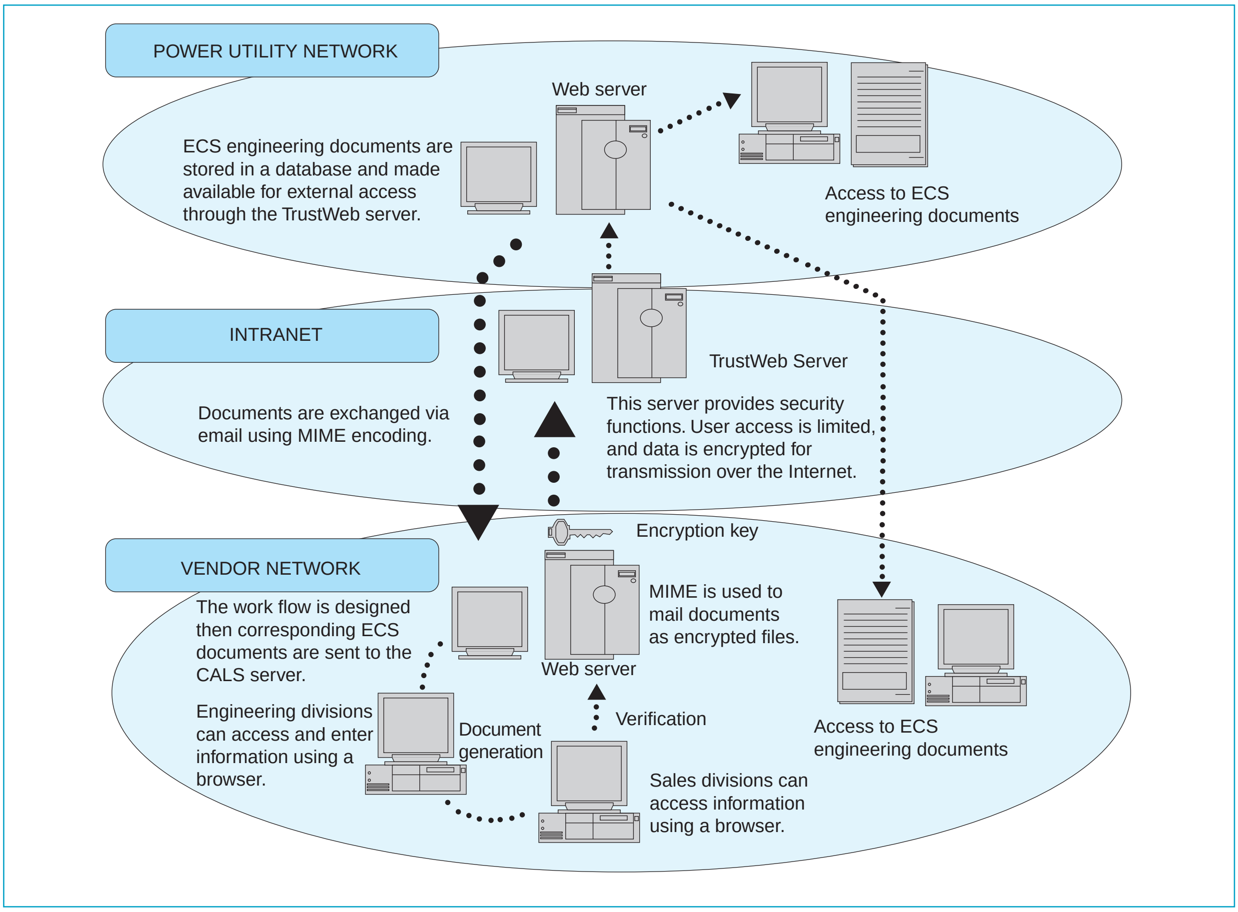


Fig. 5 Basic configuration of a CALS system.

Information Systems for Iron and Steel Plants

*by Kazuo Sena and Keijiro Takeda**

Iron and steel plants began introducing computers for process control in the 1970s. Having delivered computers for a variety of industrial control applications, Mitsubishi Electric is now designing network based information and control systems for iron and steel plants of a dramatically larger scale.

Current steel plants typically run 24 hours a day, 365 days a year with steel moving continuously through production processes. Information systems supporting these processes must offer rapid, sophisticated realtime processing capabilities combined with long-term reliability and maintenance support features. Current trends toward open-architecture computers and right-sizing are reflected in increasing use of high-performance workstations and personal computers with general-purpose open-architecture computer systems, all linked by LANs into a single integrated network. System developers are moving away from proprietary technology toward use of common standards for hardware and software components. Mitsubishi Electric has accumulated extensive experience with steel plant computer systems since the 1970s, with numerous systems delivered in Japan and abroad.

This article reports on requirements of information systems for iron and steel plants, introduces Mitsubishi Electric MR series industrial computer systems and their applications, and examines future trends.

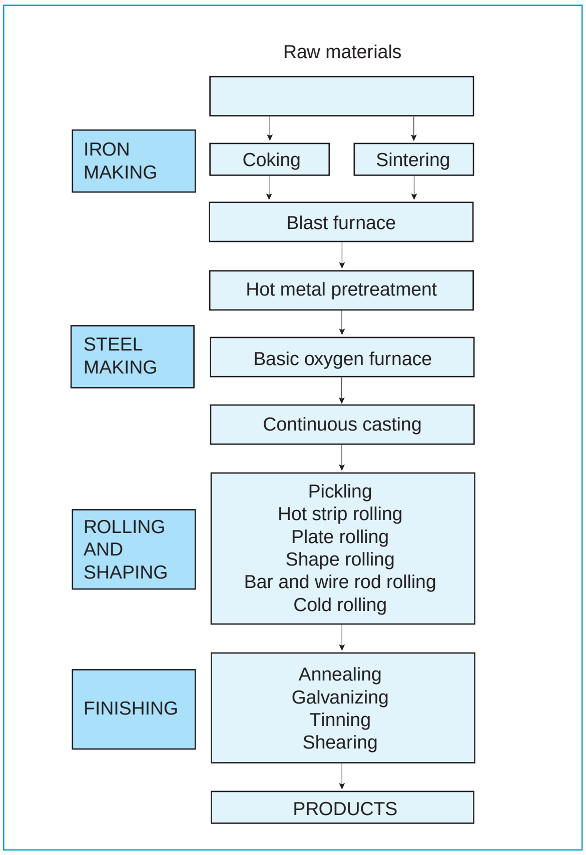


Fig 1. Flow of iron and steel manufacturing processes.

Needs and Trends in Computer Systems for Iron and Steel Plants

Fig. 1 shows the process flow in a steel plant. It is divided into three sections, with work moving continuously through the entire system. A separate control system is implemented for each process, and these systems are linked together by a LAN. Each process benefits from the use of process automation technology and a hierarchical system architecture with separate control layers implementing high- and low-level process-control functions. Table 1 lists the characteristics of major iron and steelmaking processes, including realtime and reliability requirements. Individual process control systems are engineered to match these requirements. Table 2 lists levels of control in a hierarchical process control system.

Plant control systems are evolving towards single, integrated systems handling electrical, instrumentation and computation tasks. New systems are being organized around information as much as control tasks, with applications to supprot engineering, operation, diagnosis, maintenance and software development incorporated into large-scale total plant information and control system. Workstations and personal computers, long used to implement these support services, are increasingly popular due to their greater versatility and cost-effective computing power, and are being integrated with process control computers into seamless networks. They are also moving into small-sale control

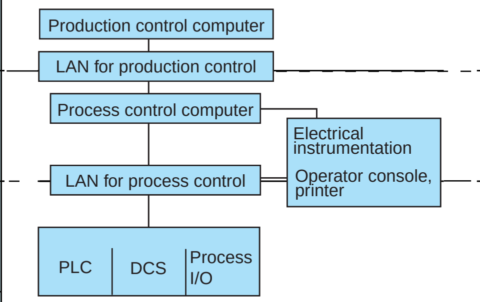
**Naoki Shimoda and Yoshinori Wakamiya are with the Power & Industrial Systems Center.*

Table 1 Computation Requirements of Iron and Steel Manufacturing Processes

Area of application	Characteristics	Reliability	Realtime requirements
Blast furnaces, batch steelmaking, continuous casting processes, management of energy, powder and fluids for continuous processes	Large-scale process automation High volume data storage Extensive instrumentation	Non-stop operation	Response of seconds to minutes
Hot strip, plate and cold rolling mills	Large-scale process automation with high-speed control, mathematical calculations for control model	Non-stop operation, 1:N backup with configuration control	Interrupt response within several hundred µs, realtime file system
Continuous annealing line, continuous glavanizing line, cold rolling mills, continuous processing lines for cold-rolled steel	Medium-scale, medium-speed process automation	Non-stop operation, 1:N backup with configuration control	Interrupt response within several hundred ms, realtime file system
Finishing, shearing and plating lines, material handling, yard control	Small- to medium-scale	Non-stop operation, 1:N backup with configuration control	Interrupt response within several hundred ms, realtime file system
Support systems for engineering, operation and maintenance	Online data acquisition, storage and analysis, simulations using realtime operation data, maintenance and diagnostics support	Non-critical	Non-critical

Table 2 Hierarchy of Information and Control System for Iron and Steel Plants

Level	Characteristics	
Level 3: Enterprise computer	Production control Response: seconds to minutes Message driven Cobol, C	
Level 2: Process computer	Process control Response: 10ms to seconds Event driven, polling C, Fortran	
Level 1: Instrumentation control	PLC Mechanical drive control Response: 1ms Sequence control Ladder diagram language	DCS Fluid control Response: 1s PID control Tag language
Electrical instrumentation		



Key
DCS Distributed control system **PID** Proportional integral differential **PLC** Programmable logic controller

applications where realtime requirements are less demanding.

System Development Concepts

When a system is developed, the design is tailored and optimized to specific application requirements. We offer a wide range of solutions for clients, from basic control functionality only to any number of the support systems mentioned. Combination of our MR2000 and MR3000 series realtime computers, MU Series Unix servers, ME/R Series Unix Workstations, programmable controllers and personal computers offer seamless splutions to system needs. LAN capabilities are available in bandwidth increments from general-purpose Ethernet to ATM high-speed realtime LANs. This approach is summarized in Fig. 2.

MR Series Computers

MR Series computers offer realtime capabilities incorporating the corporation's expertise in realtime operating systems and analytic tools while maintaining the benefits of open-architecture systems—a combination of features unavailable in previous workstation and process computer solutions. MR Series computers run MI-RT, a POSIX-compliant version of Unix enhanced with high reliability, realtime features, and a complete software development environment. The MR2000 and 3000 Series computers offer improvements over the realtime performance of M50 and M60 computers—vastly better than workstations—with superior computational performance and most of the open system benefits that a workstation offers.

Computation performance is achieved through the use of high-speed RISC processors. RAS and maintenance support features include enhanced reliability through the use of LSIs, disk mirroring and error retry functionality for peripheral devices. Hardware initialization functions support restart capability, allowing continuous operation. Diagnostic and error logging functions assist maintenance.

Networking capabilities include Ethernet, RS232C, ATM, as well as Mitsubishi-developed MDWS-600S1 and MDWS-700 control LANs. A line manager handles RS232C connections between general-purpose computers and specialized control equipment.

Fig. 3 shows an example of an information system for a cold rolling mill based on the MDWS-600S1 LAN.

Software System

Portability of application programs is highly desirable. We uses middleware that eliminates hardware dependence in the application program code, resulting in excellent application portability among MR and ME/R series computers, both of which run Unix-based operating systems. Fig. 4 lists these middleware capabilities. The middleware for iron and steel plants supports application programming in both C and Fortran by providing a simple API for accessing common library routines.

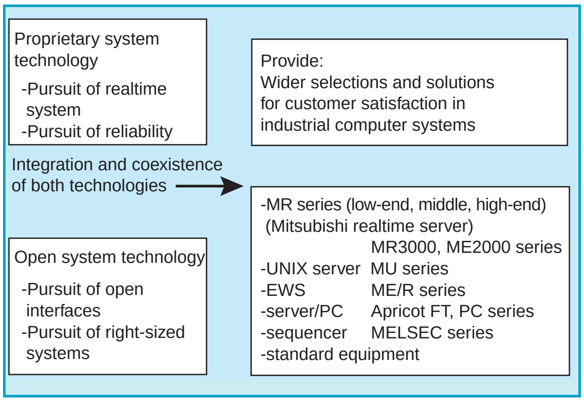


Fig. 2 Approach of MELCO for industrial computer systems in steel plants.

Future System Trends

Fig. 5 illustrates the extent and capabilities of future information systems for iron and steel plants.

LARGE-SCALE SYSTEMS. Major control systems for hot strip, continuous cold rolling and plate mills will continue to benefit from improvements in realtime capabilities, reliability and maintenance support. High-performance speciality computers will continue to emphasize open-system design using standard interfaces and software.

OPEN SYSTEMS. The trend toward use of open interface specifications will continue, with workstations, personal computers and other general-purpose technologies growing increasingly popular. Industrial personal computers designed for harsh environments will also benefit by adhering to industry standards. These standards will facilitate integration of general-purpose and special-purpose computers into a single seamless network.

SYSTEM MODERNIZATION. Many of the information systems delivered to steel mills in the 1970s and early 1980s are still in service, both in Japan and abroad. They will eventually be replaced by new systems. Hardware, software and development tools will need to be engineered to sup-

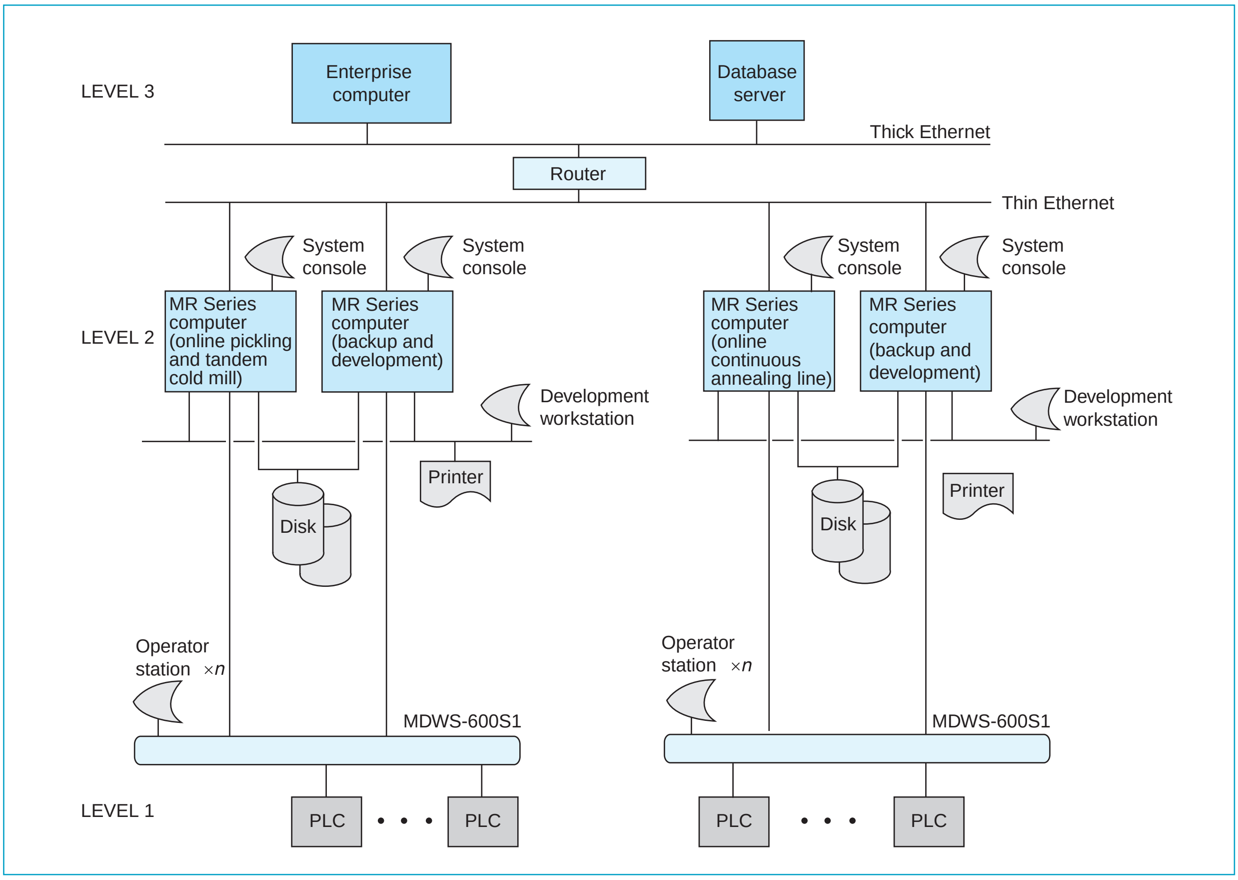


Fig 3. System configuration for cold rolling mill.

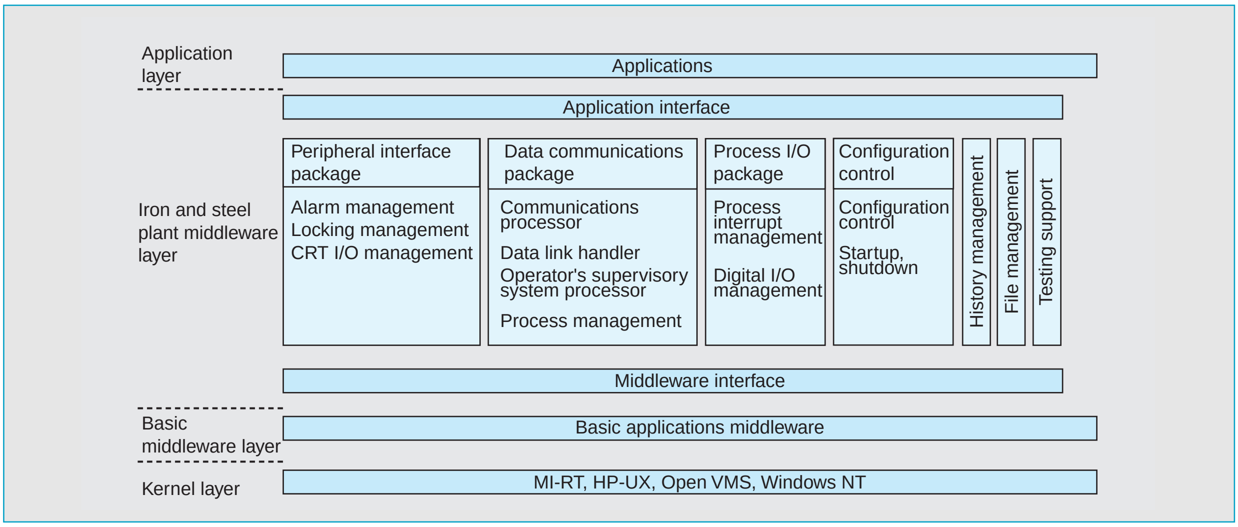


Fig 4. System software configuration.

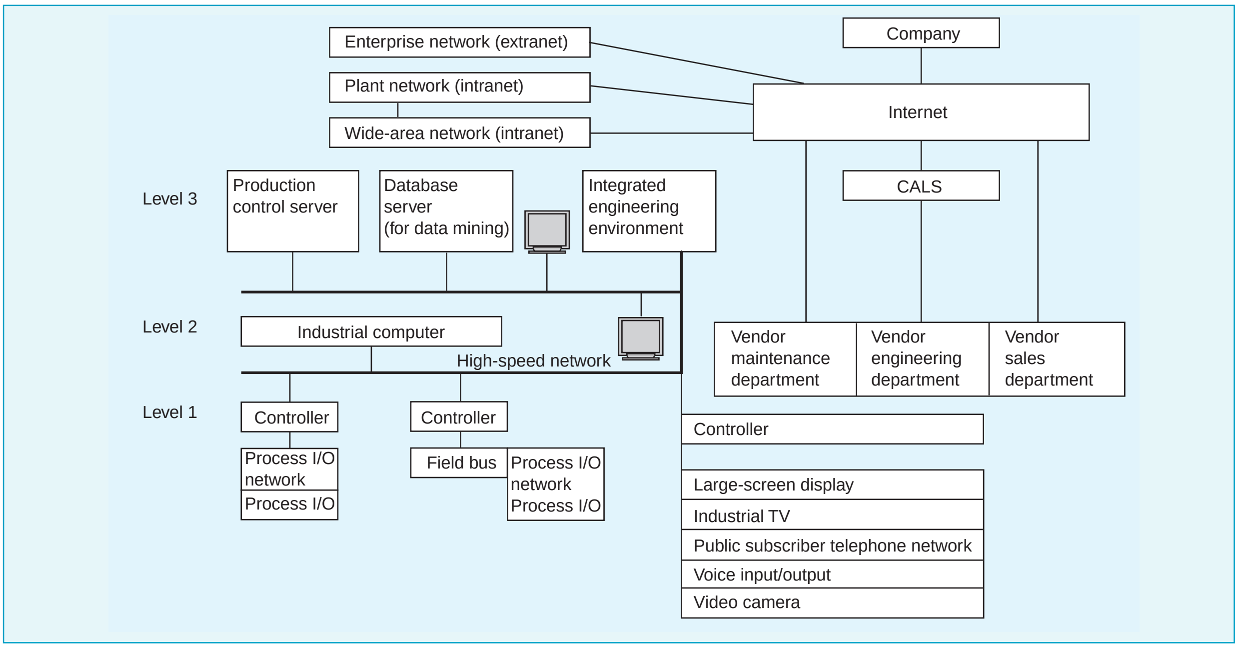


Fig. 5 Total network configuration for iron and steel plants involving Internet and intranet technology.

port this changeover. Special considerations will be needed to support the use of existing LANs and process I/O equipment. Dual signal inputs will be needed to support the transition process, and source code conversion utilities will also be required.

MULTIMEDIA. Multimedia technologies will facilitate the work of system operation and maintenance staff by enabling them to visually assess system status. Still images, moving pictures and audio information will supplement the numerical control data provided by previous systems. Operator consoles will enable control data to be superimposed over moving pictures or for moving pictures to be displayed in windows within control data displays.

NETWORKING. Advances in networking technology will enable system data resources to be accessed and manipulated from remote sites, with connectivity eventually extending to mobile computers. Internet connectivity and on-site intranets will improve communication between plant control systems and accommodate a variety of support systems. Various CALS systems will enable online management of tasks ranging from order placement to maintenance support, and will be closely linked to other plant information systems.

DATA WAREHOUSING. Development of high-speed servers capable of archiving and referencing manufacturing, quality and other plant operating data will enable data warehousing and data mining, and this functionality will be used to enhance the capabilities of plant information and control systems.

The ongoing evolution in information and networking equipment for iron and steel plants and the move toward open systems will open the door to data warehousing, data mining and multimedia technologies, leading to continued improvements in plant control. ❏

An Integrated Digital Control & Protection System for Substation Automation

*by Kenji Ohgaki and Seiji Kaneko**

In recent years, power-system networks have grown in complexity in order to extend the supply of electrical power to wider network areas. Energy control centers must therefore retain highly skilled operators to provide power-system control and timely analysis of power-system phenomena.

Power systems have also become more reliable, with the result that operators have fewer opportunities to respond to faults or other contingent failures. This can make it more difficult for operators to respond correctly when a fault or other emergency does occur.

To resolve the problems of operator error, Mitsubishi Electric has developed a fully integrated digital control and protection system for substation automation. This article describes that system.

Power Utilities' Needs

Power utilities' systems require the following five features; high reliability, low-cost system configuration, easy operation, easy expansion and simplified maintenance.

High reliability, with multi-level backup of control operations, is essential to avoid maloperation. Built-in self-check and diagnostic functions and automatic testing facilities are also required.

"Starting small" is a very important factor in control and monitoring system development, because it lowers initial system costs. However, this necessarily implies a configuration that accommodates multi-vendor support to facilitate system upgrades for the addition of new equipment—such as feeders—and new, useful functions, without having to change or replace the entire system. Reducing the number of cables is also an effective way of saving space and lowering substation costs.

The ease and efficiency of overall system operation is critically important in view of increasing system complexity and minimizing operator error. Useful functions include an easy-to-learn, easy-to-use human-friendly interface, automated operation, and support facilities for operations, protective relay settings and maintenance (including preventive maintenance). These should be provided in modular packages so that power utilities can select which packages and when to install them, depending upon their needs and budgets. A multi-level access key-code option is also necessary for maximum security.

Easy system expansion has two aspects. First, it means the ability to keep pace with the expansion of the power system (i.e., with increases in the number of inputs and outputs, processing units and databases). Second, it means the ability to add new, useful functions for easier operation (see above). This also calls for open-architecture and distributed configurations, conformity with formal and *de facto* standards, and a multi-vendor approach.

Simplified maintenance is very important if the availability of power is to be essentially uninterrupted. Here, support functions for maintenance (including preventive maintenance) can play a useful role. When a failure does occur, easy location of the failure, readily replaceable modules, and easily tested equipment all become important. Operational support functions that guide the operator in the proper procedures for maintaining power supplies to customers are also important. Fault location should be displayable and self-checking and diagnostic functions are necessary.

Modern Automatic Substation System Concept

We have developed an integrated digital control and protection system for substation automation embodying the corporation's latest technologies and extensive experience in automation and control. Its main features are as follows:

- Open-architecture and distributed configurations,
- Integrated protection and control using digital technology,
- Object-oriented software design,
- Conformity to formal and *de facto* standards,
- Consistent architecture to facilitate flexible configuration (from simple to complex),
- User-friendly interface for ease of learning and operation,
- Multi-level backups for control operations,
- Automatic test facilities that ensure high reliability,
- Built-in self-check and diagnostic functions for ease of maintenance,

**Kenji Ohgaki and Seiji Kaneko are with the Transmission & Distribution, Transportation Systems Center.*

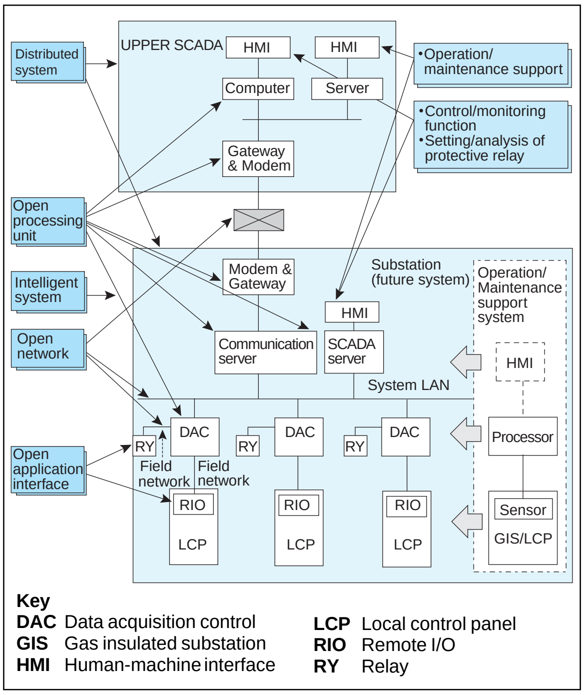


Fig.1 A typical modern substation system configuration.

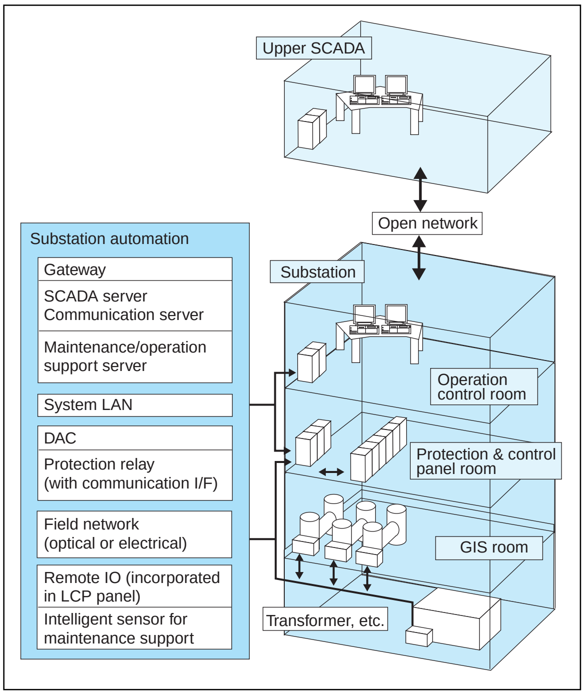


Fig. 2 A typical indoor-type substation.

- A multi-vendor approach that facilitates expansion, and
- A multi-level access key code for maximum security.

System Configuration

Our modern substation automation system satisfies the needs identified above, in line with the concepts described, by using fully digital open-architecture and distributed configurations. A typical configuration is shown in Fig. 1, and an indoor-type substation is shown in Fig. 2.

THE MASTER CONTROL STATION. This is based on a client-server model with UNIX servers and engineering workstations as human-machine interfaces. Its main features are as follows:

- Flexibility in adopting single or duplex configurations,
- A specialized software package for handling data and fault analysis, while data reporting assumes end-user computation (functions additional to supervisory control and data acquisition (SCADA)),
- A user-friendly graphic interface that supports data visualization, and
- Communication with upper EMS/SCADA systems supported through a variety of standard protocols.

DATA ACQUISITION CONTROL (DAC) SUBSYSTEM. This is based on microprocessors using the UNIX operating system. Its main features are as follows:

- Compact, space-saving design,
- Optical-fiber communications that save cable space inside the substation,
- Communication with relays and remote I/O devices supported through communication protocols, and
- Remote I/O flexibility (local control panel in switchgear cubicles, etc).

THE PROTECTION SUBSYSTEM. This adopts digital technology for high reliability and performance. The main features of the digital protection relays are as follows:

- Consistent design concepts applied to hardware and software for different relays,
- Modular software,
- Standardization,
- Tools for analysis and coordination,
- User-friendly interface,
- Relay parameters set remotely and/or locally,
- Data backup and storage for later analysis,
- Standard communication protocols supported for communication with the DAC subsystem, and
- A serial interface for connection to personal computers.

The modern digital system for substation automation described above is based on open-architecture and distributed configurations. It embodies new technologies, developed by Mitsubishi Electric, that allow it to play an essential role in meeting the actual needs of power utilities in the area of automatic substation operation. ❏

A Realtime Personal Computer

*by Hitoshi Ito**

Personal computers are becoming an increasingly popular platform for implementing control systems due to the high performance and low cost of today's models. Mitsubishi Electric has developed a realtime control mechanism for Microsoft Windows NT platforms that meets needs for millisecond-class response times for starting periodic tasks.

Background

Personal computers are now being utilized to implement operator consoles and information managers for supervisory, control and data acquisition (SCADA) systems, however the realtime performance of the widely used Windows NT operating system is inadequate for controller applications. We have developed a device driver for Windows NT that supports realtime program execution in a multitasking environment, expanding the realtime application possibilities of standard-architecture personal computers.

The Windows NT operating system supports security, fault-tolerant file systems and fixed-priority scheduling, and application programs are readily available. Its greatest weakness is the relatively poor realtime response of the system as supplied.

Fig. 1 illustrates three possible approaches for developing Windows NT compatible realtime systems. Implementing the Win32 API under a realtime operating system (Fig. 1a) suffers the drawback of limited applications compatibility and the inability to make use of new operating system features. The hardware abstraction layer required for Windows NT and a realtime operating system to share a single processor (Fig. 1b) requires changes to the standard personal computer architecture. Executing Windows NT and the realtime operating system on separate processors linked by a common bus (Fig. 1c) involves the higher hardware cost of multiple processors. The second and third solutions have the added drawback of requiring software development under multiple operating systems.

Realtime Performance of Standard Windows NT

Fig. 2 shows measurements of the realtime performance of Windows NT running on a 120MHz Pentium processor. Low-priority tasks affect the execution of even the highest-priority applications, resulting in execution delays ranging from tens to hundreds of milliseconds. Device drivers, however, are executed within 0.2ms, regardless of the number of applications running or the presence of other device drivers. This suggests that a device driver could be used to implement millisecond-class realtime controllers under standard-architecture personal computers using the

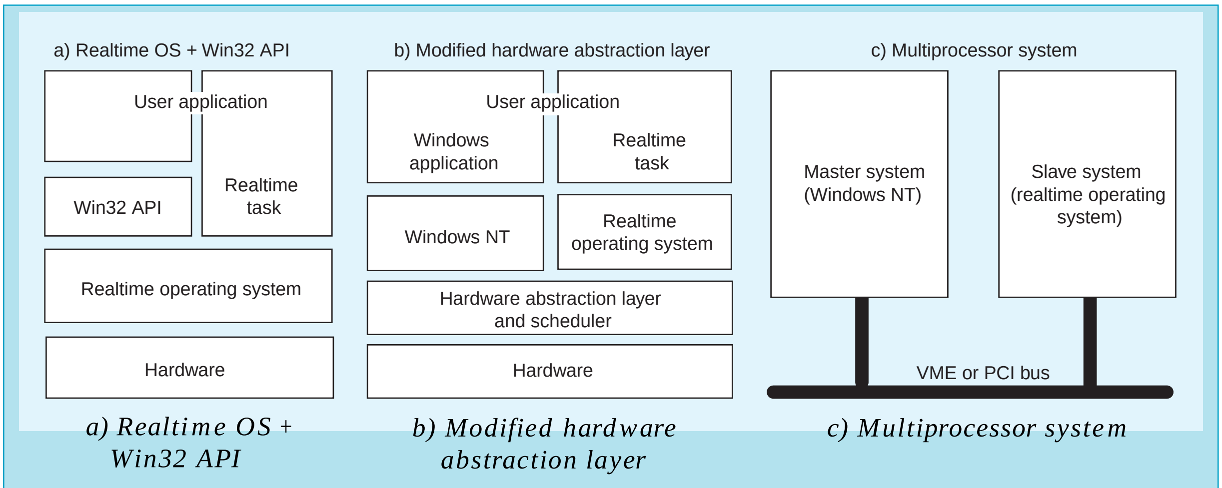
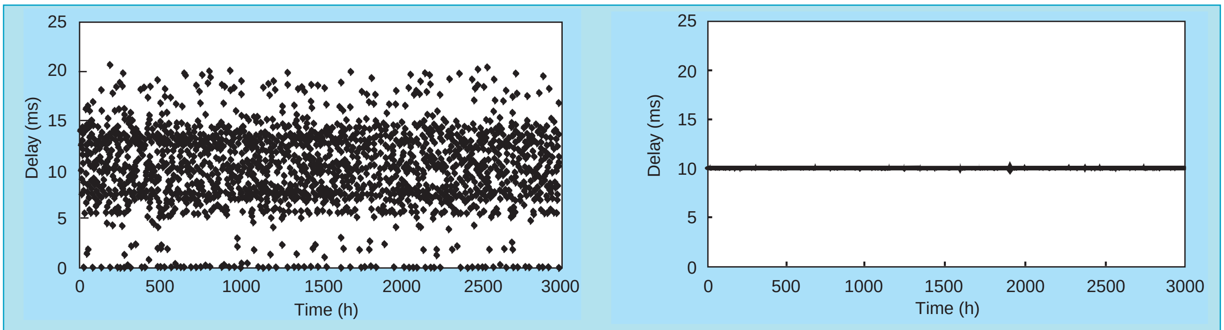


Fig. 1 Various approaches for running a realtime job under Windows NT.

**Hitoshi Ito is with the Information & Technology R&D Center.*



a) Application execution delay *b) Driver execution delay*

Fig. 2 Realtime performance of Windows NT for a 10ms periodic task.

standard Windows NT kernel, allowing easy integration with other software applications.

Realtime Control Mechanism

A control system can be divided into functions requiring realtime response such as data acquisition and control outputs, and other support functions such as monitoring and logging that do not require realtime response. Fig. 3 shows how these functions map to software under Windows NT. The realtime control capabilities are implemented through a Windows NT device driver, the nonrealtime portion by Windows NT application programs. Fig. 4 shows the structure of the device driver that implements the realtime control mechanism. The mechanism supports multiple realtime tasks, allowing realtime functions for data acquisition, computation and equipment control to be implemented separately.

Realtime tasks are implemented as coroutines under the realtime control mechanism. Each task has its own name, priority and period. The mechanism offers 31 priority levels to control scheduling when multiple realtime tasks are queued for execution. Interprocess communication is implemented using a mailbox approach.

The realtime control mechanism has a timeout manager triggered by interrupts from an external clock, allowing it to provide periodic task execution. On initialization, each task is registered in the timeout manager, and when the time for execution arrives, the timeout manager sends a dispatch request signal to the task manager.

Windows NT applications can communicate with the realtime control mechanism using the normal Windows NT logical devices for reading and writing files. Realtime tasks communicate with applications using an interface equivalent to interprocess communication.

A task tracer is provided to analyze task operation. The tracer logs messages, task scheduling, system calls, errors, internal function calls and other data, and provides services for referencing logged data.

Windows NT performs two levels of interrupt processing. The first is by interrupt service routines (ISRs), and the second is by deferred procedure calls (DPCs). ISRs are executed by the interrupt handler and generally involve processing of very short duration. DPCs are executed in kernel mode at a higher

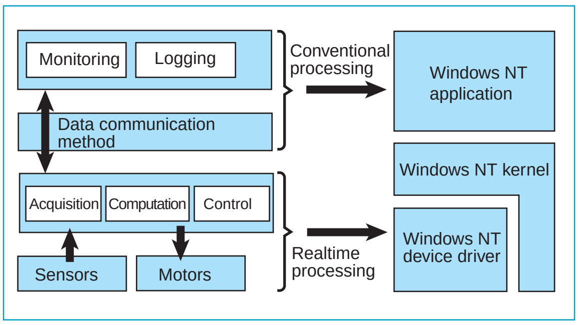


Fig. 3 Simple control system model and its implementation under Windows NT.

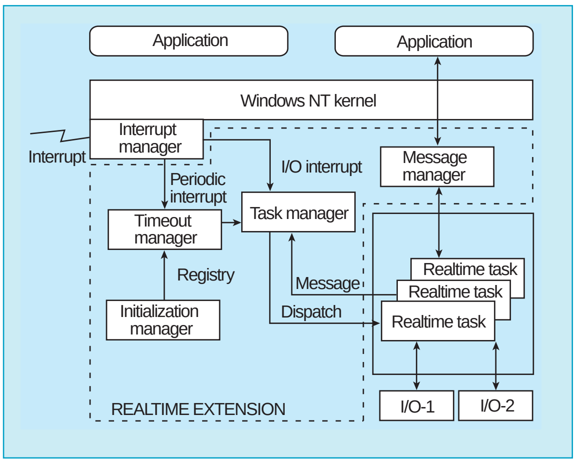


Fig. 4 Structure of realtime control mechanism.

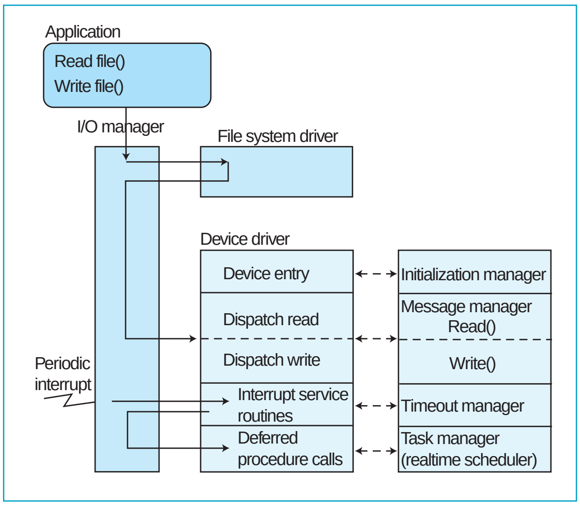


Fig. 5 Realtime control mechanism implemented as Windows NT device driver.

priority than application programs and a lower priority than ISRs.

The realtime control mechanism has its own timer for generating periodic interrupts, which call its own ISRs via the timeout manager. The ISRs call the realtime scheduler as a DPC routine, which performs task scheduling and dispatching (Fig. 5). As a result, event handling (ISRs) associated with periodic tasks is not affected by the execution of other drivers, and tasks (DPCs) are not affected by the execution state and loading of applications.

Because realtime tasks are executed as internal functions of the device driver, a program error in a realtime task will stop the system—just as would happen due to a flawed device driver. To facilitate realtime program development and testing, we therefore developed a Windows NT application that emulates the realtime control mechanism. This allows testing to be conducted without bringing the entire system down.

We developed an evaluation tool that monitors the per cycle execution time of periodic tasks, permitting measurements of how the realtime control mechanism interacts with the kernel and with the network, disk and other drivers.

Through the realtime device driver presented here, a standard-architecture personal computer running Windows NT can be used to implement periodic processing at intervals as short as several milliseconds. Applications can range from minimal monitoring and control systems to sophisticated data logging systems (Fig. 6). Weaknesses include slow recovery from errors (due to Windows NT's long startup time) and vulnerability of the system to disk drive errors, which affects its ability to support long-term continuous-running applications. As countermeasures for these issues are developed, Mitsubishi Electric plans to offer open, low-cost control systems based on Windows NT. ❑

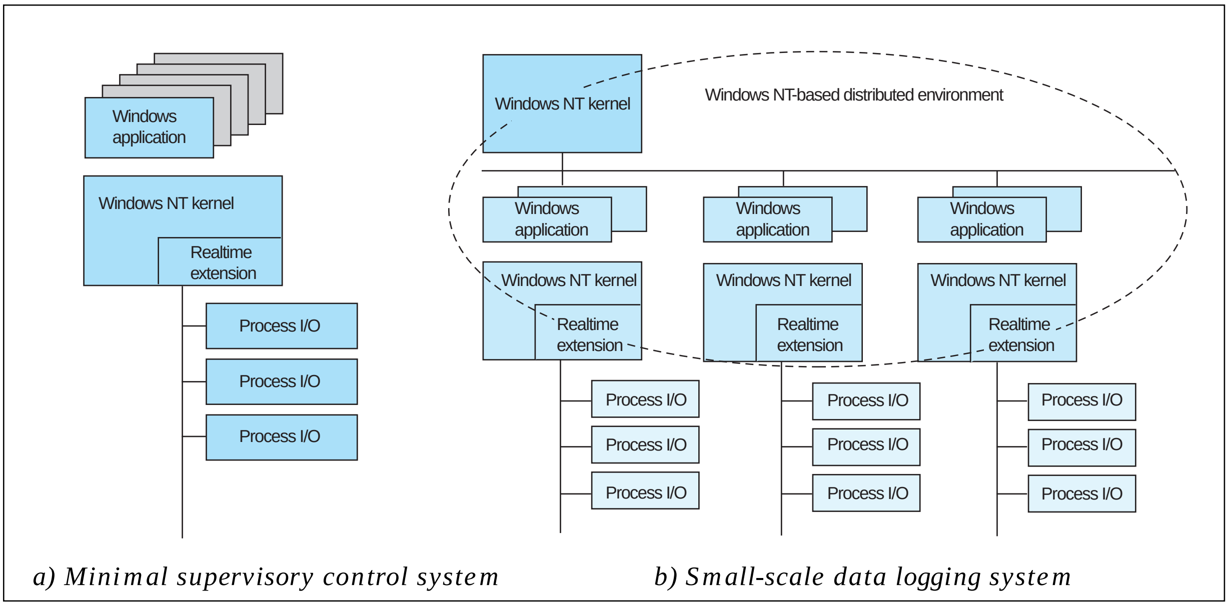


Fig. 6 PC-based realtime applications.

Realtime Software Technology

by Morikazu Takegaki*

Realtime systems for controlling industrial plants or factory automation equipment are difficult to design because they must not only arrive at the correct responses, but also generate these responses within a constrained period of time. In the past, realtime system developers achieved realtime response, reliability and hardware redundancy through project and field-specific development. Recently, the increasing scale and complexity of realtime industrial control systems is leading the industry toward general-purpose realtime solutions such as Mitsubishi Electric's PRTLIB realtime task management middleware. This report summarizes trends in realtime software technology and describes recent industrial applications.

Trends in Realtime Software Technology

Fig. 1 shows key elements in realtime software architectures. Scheduling algorithms take on heightened importance in realtime systems because effective task scheduling is essential to predictable system response. Other requirements are priority inversion, deadlock avoidance, guaranteed maximum blocking time and exception processing for errors and hardware failures.

REALTIME SCHEDULING THEORY. We say that a group of tasks is "schedulable" if a schedule exists under which all of the tasks can be completed by their respective deadlines. Preemptive fixed-priority scheduling algorithms are one set of widely studied solutions. Rate monotonic scheduling is a fixed-priority algorithm used for managing periodic tasks that assigns a higher priority to tasks with a shorter period. Schedulability of this algorithm can be evaluated from current processor utilization and the worst-case blocking time for a task can be determined by examining higher priority tasks in the scheduling queue.

REALTIME SYNCHRONIZATION PROTOCOL. Rate monotonic scheduling algorithms are being enhanced to handle synchronization needs of interactive tasks. When semaphores are used to manage shared resources, a low-priority task waiting on a resource may be preempted by a medium-priority task at any time, making it impossible to calculate the worst-case blocking time. This problem is resolved by introducing a priority inheritance protocol under which an attempt by a high-priority task to acquire a resource held by a low-priority task bumps up the priority of the low-priority task, preventing interruption by an intermediate-priority task. Priority scheduling protocols extend priority inheritance capability to allow contention for multiple resources.

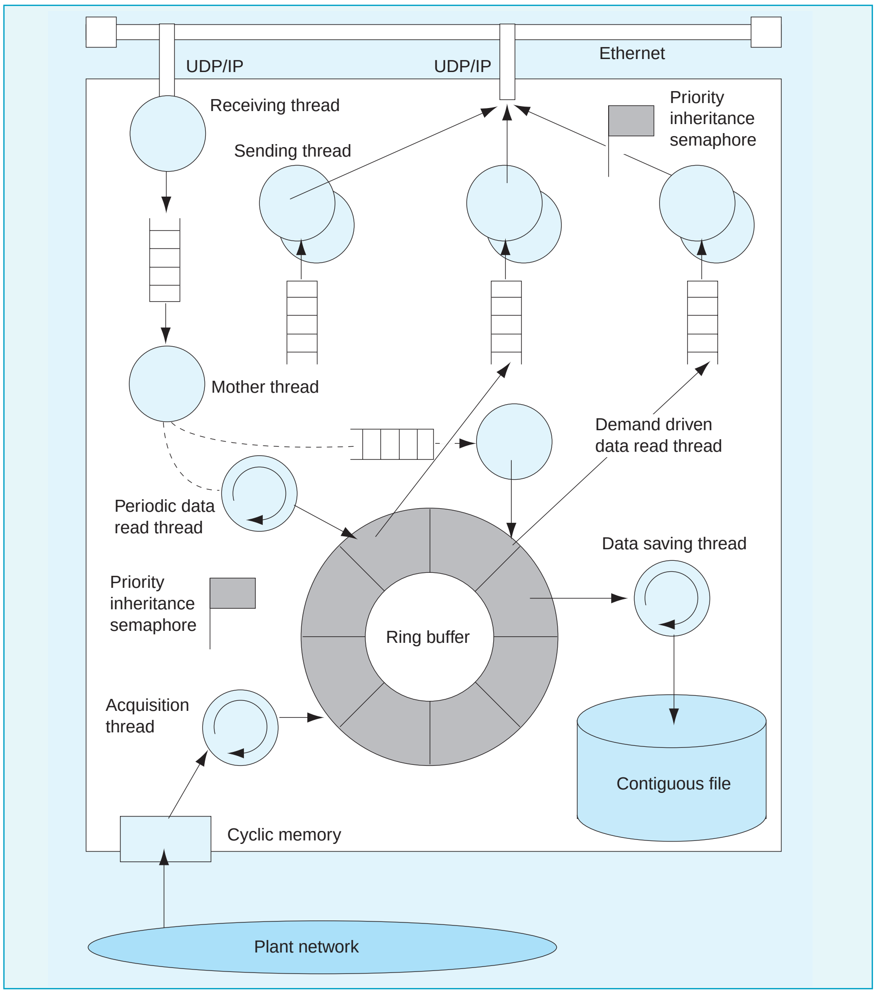


Fig. 1 Software architecture of the realtime data server.

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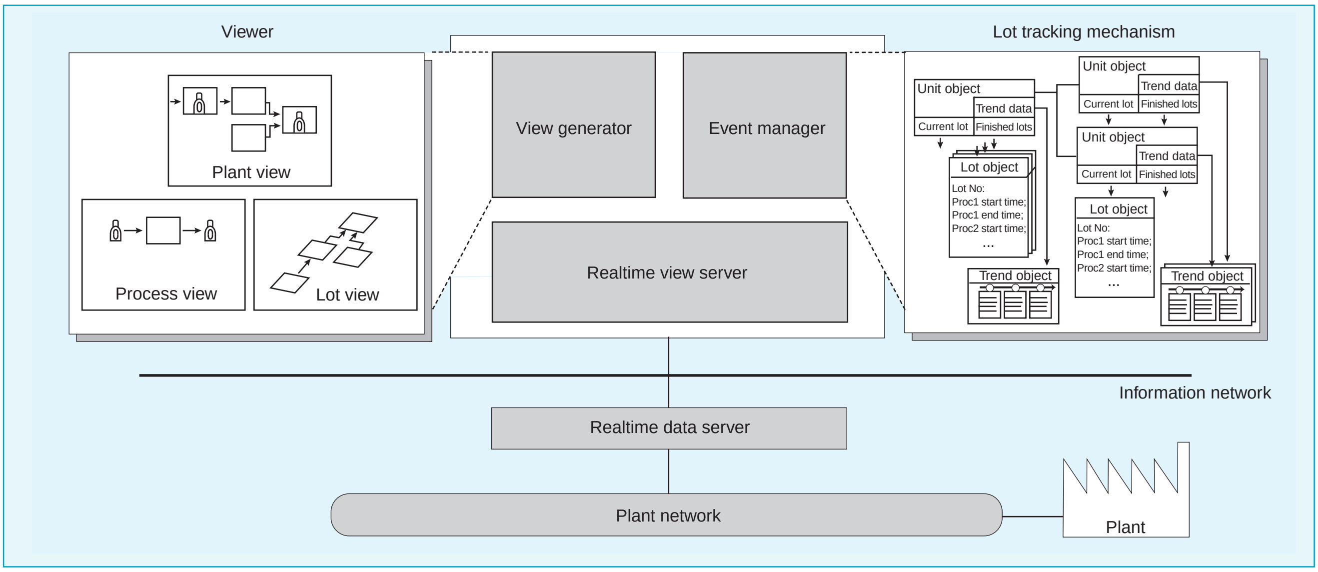

Fig. 2 Architecture of the realtime view server.

REALTIME COMMUNICATION. For realtime software to function in a distributed computing environment requires that the network deliver messages within specified time constraints. Schedulability of the set of message streams subject to transmission delays needs to be determined from worst-case transmission delay characteristics specified at the media access protocol level. FDDI employs an extended rate monotonic scheduling (RMS) algorithm. Additionally, implementation of a realtime channel for generalized network media is under way.

REALTIME DATABASES. Transaction processing with concurrency control and other scheduling problems associated with realtime constraints have been thoroughly studied. While a general-purpose solution is yet to be implemented, specialized solutions for industrial plant control applications have been developed by limiting realtime processing to transactions associated with plant data requests and machinery activation.

Standardization of Realtime Systems

POSIX specifications for realtime operating systems (sections 1003.1b and 1003.1c) define an interface that supports predictable realtime software programming. With OS-level standards already converging, the next level of standards is expected to extend to middleware-based services. Although realtime services are potentially useful in distributed computing environments, the DCE, OLE and CORBA distributed object frameworks are not easily adapted to meeting the time constraints and reliability requirements of realtime systems. We believe that the problem of providing realtime communication services will need to be solved at the network level before distributed computing environments for realtime systems can be constructed.

Realtime Middleware for Industrial Applications

We have developed realtime middleware that supports realtime applications under the company's industrial computer systems.

A POSIX-BASED REALTIME TASK LIBRARY. Our PRTLIB realtime task management middleware uses RMS analysis to provide predictability for realtime applications under POSIX-compliant operating systems. The realtime library manages periodic and message-driven tasks, performing starts, time-outs, normal and abnormal termination, and controlling redundant system hardware.

A REALTIME DATA SERVER. In manufacturing plants, realtime data servers help ensure that production process data is acquired without loss and provide history logging with all events recorded in correct time sequence including commands executed by the control systems as well as change-of-state events detected by the information system. The realtime data server consists of a set of periodic tasks. RMS is used to ensure a precise invocation interval. Fig. 2 shows the configuration of the realtime data server.

A REALTIME VIEW SERVER. Plant administration requires the ability to search for information keyed on such data as product, process and lot number. We have developed a realtime view server with a object data model allowing data referencing on a variety of keys.

By providing a foundation for realtime functionality in industrial monitoring and control applications, Mitsubishi Electric realtime middleware and server software offer application developers excellent tools to satisfy the realtime requirements of industrial control applications. ❑

GRASS: An Object-Oriented Framework for SCADA Systems

*by Taizo Kojima and Akira Sugimoto**

Mitsubishi Electric has developed an object-oriented framework in C++ programming language for implementing supervisory, control and data acquisition (SCADA) systems. This article introduces the new framework (generation-based reconfigurable architecture for SCADA systems, GRASS) and a typical GRASS application.

Background

We developed GRASS to provide high software productivity for SCADA systems. The framework consists of class library routines and tools that support development of online system software by automatically generating system description data and providing editing tools for subsequent customization. GRASS operation is based on two main parts; online system software that runs on a workstation and data acquisition control units (DACs), and an offline system configurator that generates the system description data used by the online system.

The basic functional requirements of SCADA systems are similar, regardless of the particular application field, so substantial software sharing is possible. Nevertheless, productivity of SCADA software is impeded by dependence on details of the target system. The task of configuring the SCADA software for each target system is complex, typically involving manual input of extensive system description data. GRASS simplifies this task while reducing opportunities for manual introduction of errors.

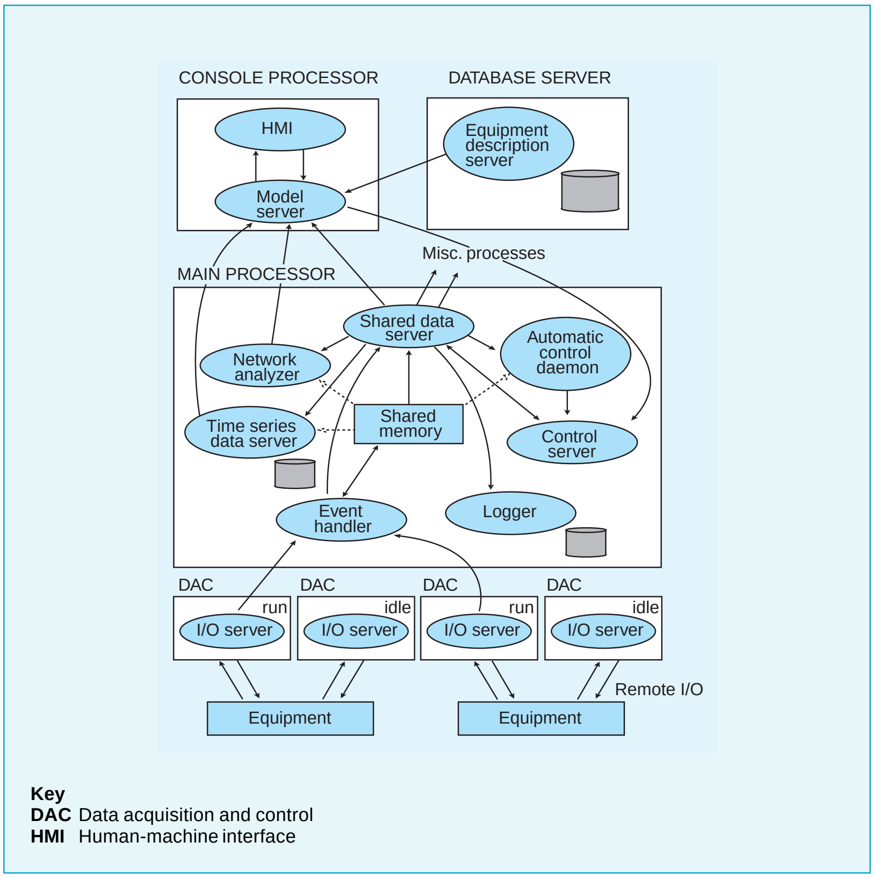

Fig. 1 Architecture of the GRASS online system.

Applications

A substation automation system is currently being developed using GRASS. The system uses a field bus to link remote I/O cards and DACs to the main processor and uses a workstation as the console.

Fig. 1 shows the organization of processes under the system. Plant data is supplied through an I/O server to the event handler of the main processor. The event handler conducts range checks and sets fault status bits. This information is passed to human-machine interface (HMI) processes and application programs via interprocess communication protocols based on object and attribute IDs.

Generation and Customization

Fig. 2 shows the relationship between the system description and the corresponding online system. In the first stage, the system configurator automatically generates the description data used by the online system software. Second-stage customization is performed manually using an editor for description data and scripts. The event handler employs a script language interpreter that provides ample latitude to implement domain-specific processing.

The equipment description data is derived from circuit, equipment and system diagrams, and is used to generate default monitoring screen and I/O descriptions. Supple-

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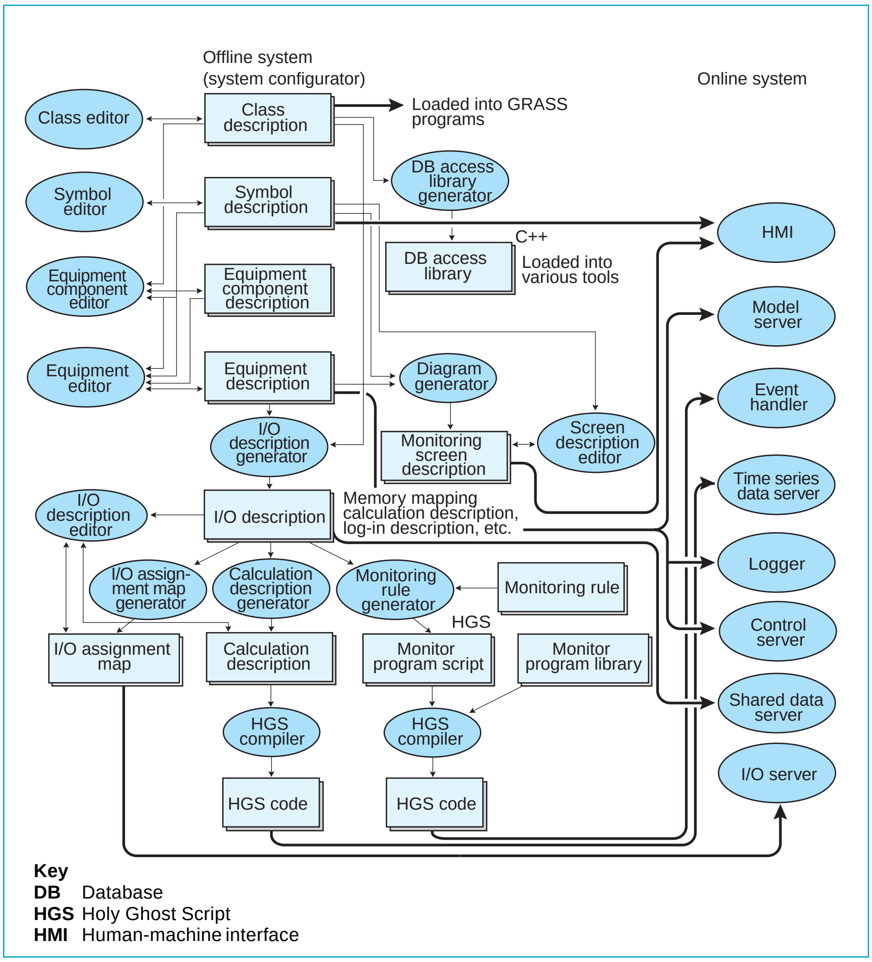


Fig. 2 Organization of GRASS framework.

mental manual modifications made with the editor result in the final description. The I/O data from this description is also used to generate assignment maps for the I/O signals, calculation descriptions and to set alarm conditions for input monitoring routines. This centralized object-oriented configuration management reduces the labor involved in configuring and customizing SCADA system software, and reduces the risk of introducing configuration errors.

The system configurator is especially productive when several systems of the same type are to be developed, and boosts productivity in applications where manual customization is required as well. The system configurator for a power network monitoring system would automatically generate monitoring screen descriptions from circuit diagrams for an electric power network, after which the default descriptions would be edited. The procedure is much easier than constructing descriptions from scratch, with the added benefit that icons for equipment and their bindings are assigned automatically.

Extensibility

Extensibility is a major design goal of GRASS. An application developed using GRASS is provided as package-based software with customization services available. This excellent support for extension sets GRASS apart from other packages. Control servers, automatic control daemons, network analyzers and other servers are generated from GRASS's server construction libraries, and tools are available that reduce the programming requirements associated with system extension. The GRASS object-oriented framework also simplifies custom programming, although skills in using object-oriented language and an understanding of the GRASS framework design are necessary.

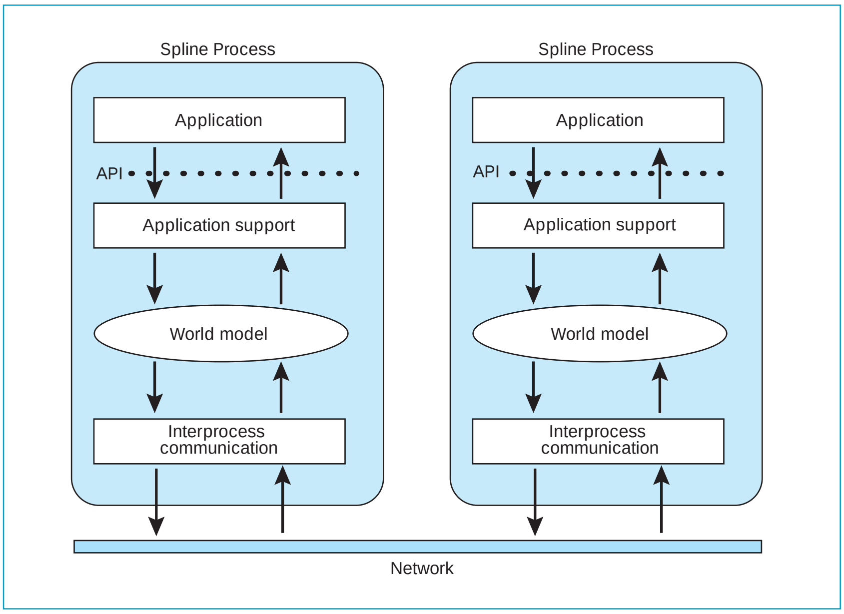
Future Prospects

GRASS currently runs on Unix-based systems with considerations made for porting to Windows NT and other operating systems. The addition of Internet-working functionality is also under study, including security mechanisms, use of Java applets for access to online data and equipment descriptions, and the provision of porting to multiple platforms. Already offering a dramatic boost to SCADA software productivity, future provision of Internet-working capabilities will offer added connectivity options.❑

Technologies for Shared Virtual Environments

Distributed virtual environments (DVEs) are a promising new computing architecture under which geographically distributed users can interact in realtime within a shared virtual world. Mitsubishi Electric has developed Spline (an acronym for "scalable platform for large interactive network environments") as a foundation for building DVEs. Spline supports interactions among multiple users using a shared world model, which is a type of distributed database. Each object within a virtual world is packaged with related information such as position, appearance and sound, as well as methods that applications may use to modify the object. Application programs in this environment can function interactively, modifying the world model and observing modifications made by other applications.

The information constituting the world model is distributed. Each application maintains its own partial copy of the world model containing information the application needs to operate. The copy is associated with a point of view, and includes data for objects used by the application. Changes in object state are communicated to all applications in the system by an exchange of update messages, maintaining a dynamic state we define as "approximate consistency." The computing and communications loads are reduced by dividing the world model into small regions called "locales." Change-of-state information from each locale is transmitted over a separate multicast transmission channel. Fig. 1 shows how two processes operate under Spline. When one Spline process modifies its copy of the world model, it sends update messages that other processes use to update their world model copies.



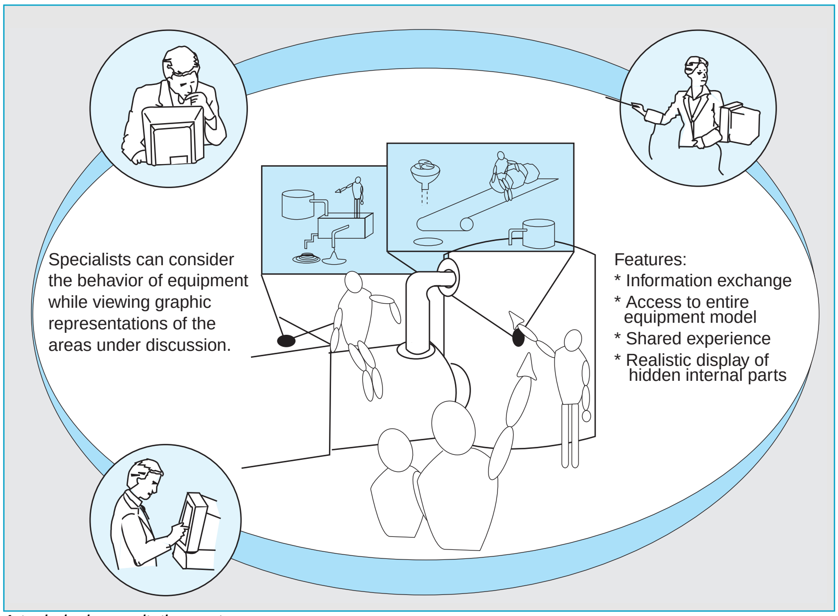
Process configuration under Spline.

The Spline applications programming interface (API) serves mainly to create and destroy objects in the world model, and to read and write object data fields. The application support modules are a library implementing this API. Visual and audio processes, which share the structure shown in Fig. 1, offer expanded I/O capabilities to interactive applications.

Potential industrial applications for Spline include technical consultation systems and simulators for training in remote monitoring and maintenance procedures.

Fig. 2 illustrates the concept of a technical consultation system in which equipment is represented as three-dimensional graphic models within a virtual world. Multiple users would share access to these virtual objects over a network and exchange information so that each user observes the same representation of the equipment under study, providing a focus for technical discussion. The 3D representations can include cross sections and other views not available to direct observation.

A virtual training system would give geographically distributed trainees hands-on practice in monitoring and maintenance procedures in a virtual plant (world model) shared with the educational staff and other trainees. ❑



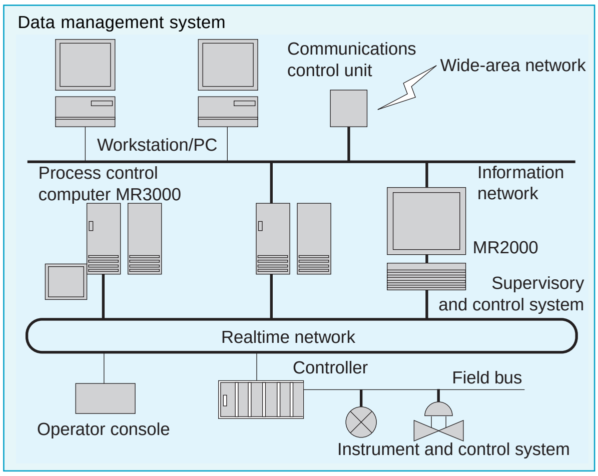
A technical consultation system.

Spline was originally developed by Mitsubishi Electric Research Laboratory, and is currently being enhanced and promoted by Mitsubishi Electric Information Technology Center America and Mitsubishi Electric Corporation.

The MELCOM350-MR2000 Series Industrial Computer

The MELCOM350-MR2000.

The MELCOM350-MR2000 Series is a compact industrial computer system meeting needs for downsizing and network connectivity. The computer runs under a realtime enhanced Unix operating system, and is suited for plant monitoring, control and management applications using distributed computing architectures. MR2000 Series computers employ PA-RISC processors. The high-end model, MR2200, accommodates up to 1GB of RAM, an 8GB disk and PCI slots for additional I/O cards. The MI-RT operating system provides fast, deterministic realtime response and the functionality of a "hard" realtime operating system, with full preemptive multitasking, and high-speed program loading functions. Replete error logging functions track system and application errors, and system analysis tools are provided. Hardware-level reliability support features include an error-correcting main memory, cache memory error detection, and power supply and temperature monitoring. The industry standard PCI interface provides a fat pipeline for I/O intensive applications. ❑



Typical system configuration.

Hardware Specifications

Model	MR2000	MR2200
Processor	PA-RISC	PA-RISC
Performance	100MIPS	200MIPS
Max. memory	512MB	1GB
Internal disk storage	4GB	8GB
External storage	2GB DAT	2GB DAT
I/O interface	Ethernet (2 channels), Fast SCSI-2, RS232C, UPS, multipurpose digital interface	
PCI slots	3	5 (expandable to 11)
Optional devices	Graphic CRT, touch panel, printer, MO disk drive	
Dimensions (W × D × H) (mm)	480 × 452 × 175	480 × 452 × 200

Software Specifications

Operating system	MI-RT	
Networking	TCP/IP	
GUI	X-Windows X11R6	
Analysis tools	System information viewer, system load collector, system tracer	
Software development environment workstation	Languages	C, FORTRAN 77
	Tools	Source debugger, graphic data builder

Note:

Unix is a registered trademark in the United States and other countries, licensed exclusively through X/Open Inc.

PA-RISC is the precision architecture reduced instruction set computer developed by Hewlett-Packard Company.

X-Windows is a registered trademark of X Consortium, Inc.

Super-Distributed Intelligent Process I/O

Intelligent systems continue to evolve. Mitsubishi Electric has developed a super-distributed intelligent process I/O (PIO) combining compactness, excellent durability to harsh environments and fast communication functions, intended for use in super-distributed supervisory and process control on location in the field. Now slimmer, smarter, more cost-effective plant-field PIO systems are available.

In plant systems where high-speed control is required, normally sensors, actuators and other field instrumentation devices are hard-wired to controllers. The cable wiring requires considerable resources, both material and labor, and maintenance following startup is also expensive and troublesome.

The super-distributed intelligent PIO newly developed by Mitsubishi Electric injects intelligence into plant site control and monitoring, thereby facilitating more effective use of global and human resources, while at the same time enabling a system which is fast yet simple. The Mitsubishi Super-Distributed Intelligent PIO System incorporates a 32-bit RISC processor in a 3.5"-size body (see photo) along with an open-specification high-speed field bus (10Mbps, conforming to Control & Communication Link). The system can be provided with functions for scanning at a fixed interval (approx. 10ms) and for tracing events at 1ms, making possible fine-tuned plant control. In addition to twisted-pair cable, the product also supports fiber-optic cable in lengths up to 2km. The product also benefits from technology for resistance to harsh environments amassed by the corporation over the years as well as original redundancy and RAS engineering for enhanced reliability and low-burden maintenance. Compact and with an attractive external appearance which belies its advanced intelligence and immunity to punishing environments, the intelligent PIO is ready to be used in a wide range of power generation, manufacturing and other plants.

Distributed Intelligent PIO

Providing close overall supervision, monitoring and appropriate advice, Mitsubishi's Super-Distributed Intelligent PIO is an indispensable element for any plant.

In aiming at future expanded applications, the product will continue to undergo refinements, among them more sophisticated intelligence and a more durable housing. ❑

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	Mitsubishi Semiconductor America, Inc.	Three Diamond Lane, Durham, North Carolina 27704	919-479-3333
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