Computer gateways for distributed control systems

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As more applications are automated, future gateway designs will offer still higher throughput and more control and communications functions.

The increasingly competitive and diverse markets for the products of continuous and batch processing plants demand significantly more flexibility with regard to types of products, product mixes, and sources of raw materials. As a result, integrated process control systems have had to provide new areawide process control functions and capacities that require the sharing of large volumes of data among distributed control systems. Moreover, as process control systems become part of Computer Integrated Manufacturing (CIM) networks, they must share data with other computer systems.

There have been major changes and substantial upgrades in the capabilities available from computer gateways. Whether installed for new processes or modifying existing control systems, the more powerful second-generation gateways are providing more user-friendly (programmer) functions than first-generation gateways. The newer gateways are also capable of higher data throughput between processing facilities. Most second-generation gateways support distributed control systems with multiple control functions that demand increased capabilities.

An integrated process control system

Figure 1 shows part of a millwide manufacturing network that includes many of the integrated process control functions of a state-of-the-art paper mill. In addition to unitwide control systems and area control computers (ACCs), such a network could include other areawide computer systems and connections for exchanging data with other sites.

This network includes two generations of gateways, as might be the case when a network is expanded over time. Two first-generation gateways (lower left) provide point-to-point connections between small distributed control systems (DCSs) and ACCs linked to the network. The difference between the two gateways is that one ACC is dedicated to a single DCS, while the other handles three. The specialized functions provided by the control computer can include material balance, energy balances around specific equipment, advanced control algorithms, and short data historians. The computers execute all the unique control algorithms beyond the capabilities of the distributed control systems.

Two second-generation gateways (lower right) link DCSs to the network. Many of the special-purpose control functions performed by ACCs for small DCSs are now built into the DCSs themselves. In a paper mill, a single DCS could be responsible for such major entities as pulp mills, paper machines, steam plants, waste treatment facilities, and recycled chemical recovery units.

Value of accessible process data

Many benefits can be obtained by making process data accessible to plantwide application programs and by speedily returning results back to the processes. Process and laboratory data can be combined into a single database for closer examination of cause-and-effect relationships. The effects of changes in processes and materials can be more quickly understood. Yield, efficiency, and cost models are easier to develop. With information available from all parts of the mill, more complex material and energy balances can be achieved. Material and energy savings can be realized when signals from areawide computers that trigger setpoint changes reach processes faster.

When managers have access to more complete and timely energy and materials use data in mill processes, they can focus on reducing total mill operating cost rather than the operating cost of individual units. Scheduling computations can be more accurate when they are based on realtime process data. Upstream and downstream effects can be predicted more accurately, and necessary adjustments can be made in advance.

Many of these process engineering functions are being done today but not as quickly as required. In addition, many process and product engineering activities are not performed frequently enough because of slow access to

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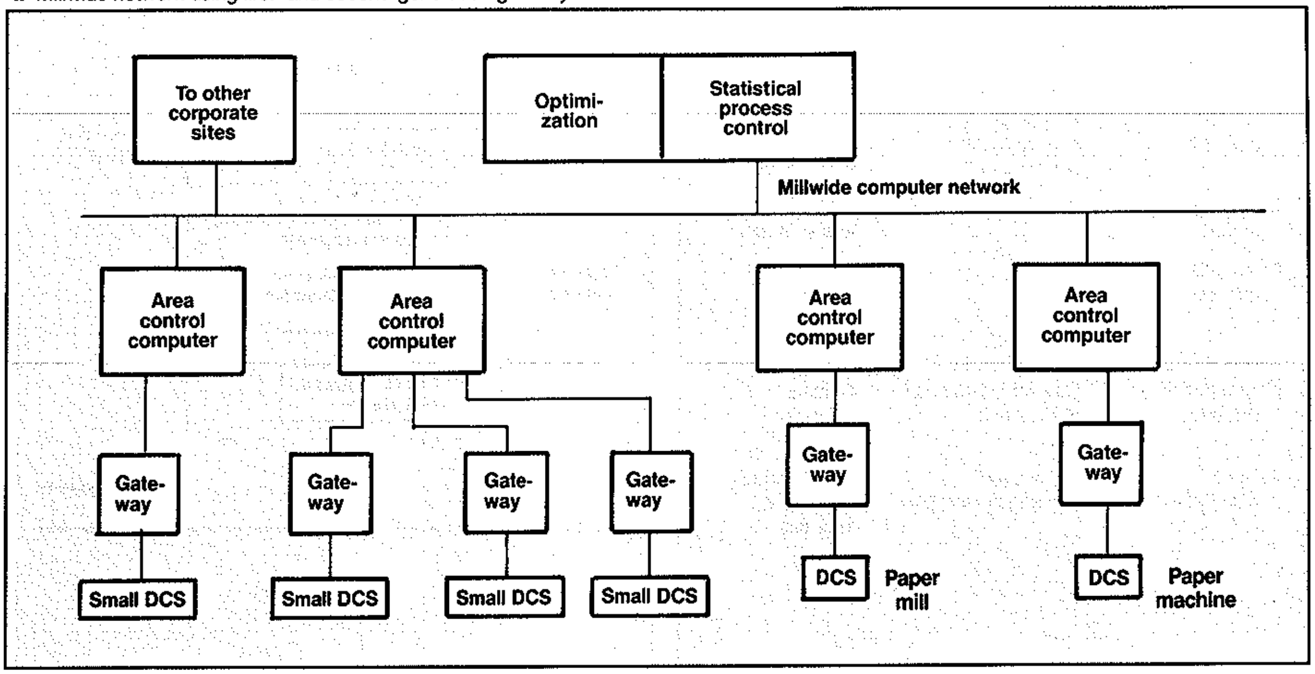
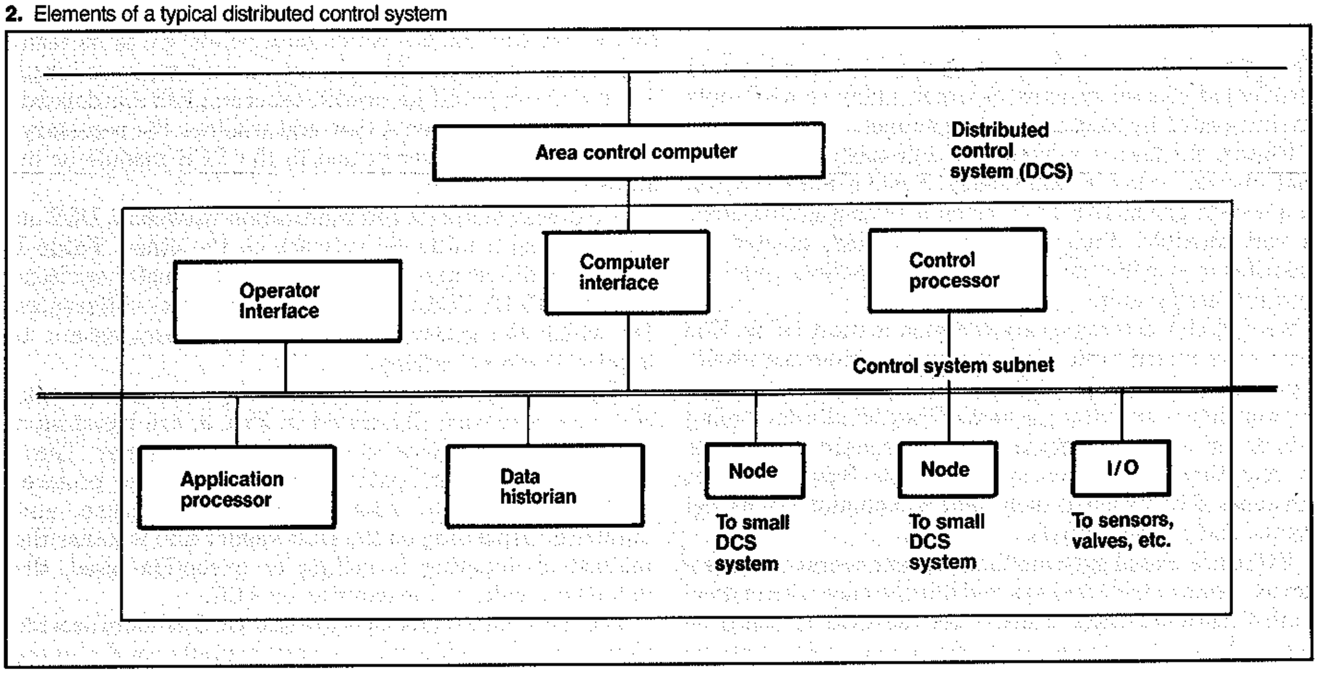
1. Millwide network using first- and second-generation gateways



2. Elements of a typical distributed control system



process and laboratory information. The difficulty of extracting information from multiple unit controllers (DCS and PLC) and from the laboratory makes for inefficient use of process engineering/technical staffs.

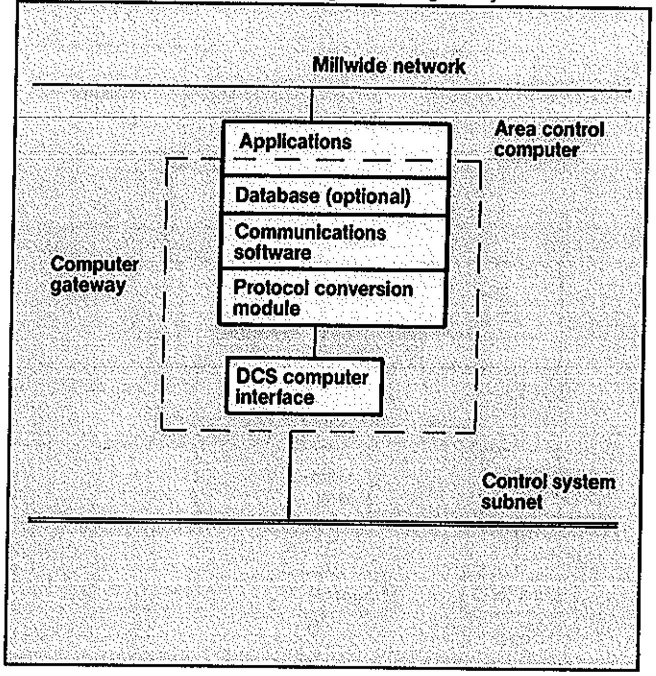
Raw material savings, better quality, and a sound characterization of the process cannot be realized without gateways to connect DCSs to the computer network. Supervisors and plant managers complain, "We just learn how to make a product and they change the specifications of the product or the raw materials." This is a classic example of not having easy access to process and quality information. Many functions in the continuous fine tuning of processes can only be performed automatically; people simply cannot react fast enough.

Examples of this are interactions between different operating units in a vertically integrated plant. With manual fine tuning, a downstream operating unit remains unaware of a process upset until the resulting effect on the product is seen.

1. Differences between a DCS and millwide network

Parameters	*DCS*	*Millwide networks*
Operating systems	Proprietary (closed system w/o external)	Proprietary (widely supported)
Operating mode	Real time	Interactive and/or batch
Communications protocol	Token passing Polled CSMA/CD	CSMA/CD Ethernet
Communications medium	Coaxial/twisted pair (redundant)	Coaxial (single or redundant)
Type of data traffic	Many short messages, updates	Fewer, longer messages and files

3. Basic components of a second-generation gateway



Second-generation gateways

The role of the DCS has changed with the advent of distributed control systems in which many control units are integrated by a control system subnet.

Figure 2 shows a selection of unit-oriented functions that may be linked to the Control System Subnet (CSS) in a second-generation DCS. Such a system architecture is very flexible. Functions can be added, deleted, or modified to provide the special control functions required by a processing unit.

Several characteristics are common to most DCSs. The processors linked to the CSS are usually Motorola 68000-type or Intel 8X86-type 16/32-bit microprocessors that run on proprietary operating systems. They handle data going into or out of process devices such as sensors and valves in real time. DCSs are optimized for frequent, short messages that transfer such data as actuator status, set points, and control signals.

DCSs are closed systems that prevent access to control devices from outside and so avoid interference with critical control activity. Data transfer on the CSS is based on proprietary networking protocols using token passing medium access control or carrier sense multiple access with collision detect (CSMA/CD). Because reliability and data integrity are so important in a DCS, the CSS's coaxial cable or twisted pair may be backed up by a parallel redundant cable. There may even be duplicate microprocessors. In many cases, single points of failure are not acceptable. While they perform similar functions, DCSs from different vendors are unique. They are incompatible and cannot be interchanged for controlling a given process.

Gateway components

The principal task of a computer gateway is to support data flow between the control devices and processes in a DCS and computer systems linked to the network. To do so, the gateway defines which data points are to be read or written into, and it does the actual reading or writing. The specific capabilities needed to accomplish this depend on the nature of the data flow and whether the necessary functions are to be performed in the DCS module or in an ACC.

A gateway supports communication between a DCS on one side and a millwide network on the other. **Table I** shows the differences between the data transfer environment in a DCS's CSS and a millwide network—differences for which the gateway and ACC must compensate to support communications.

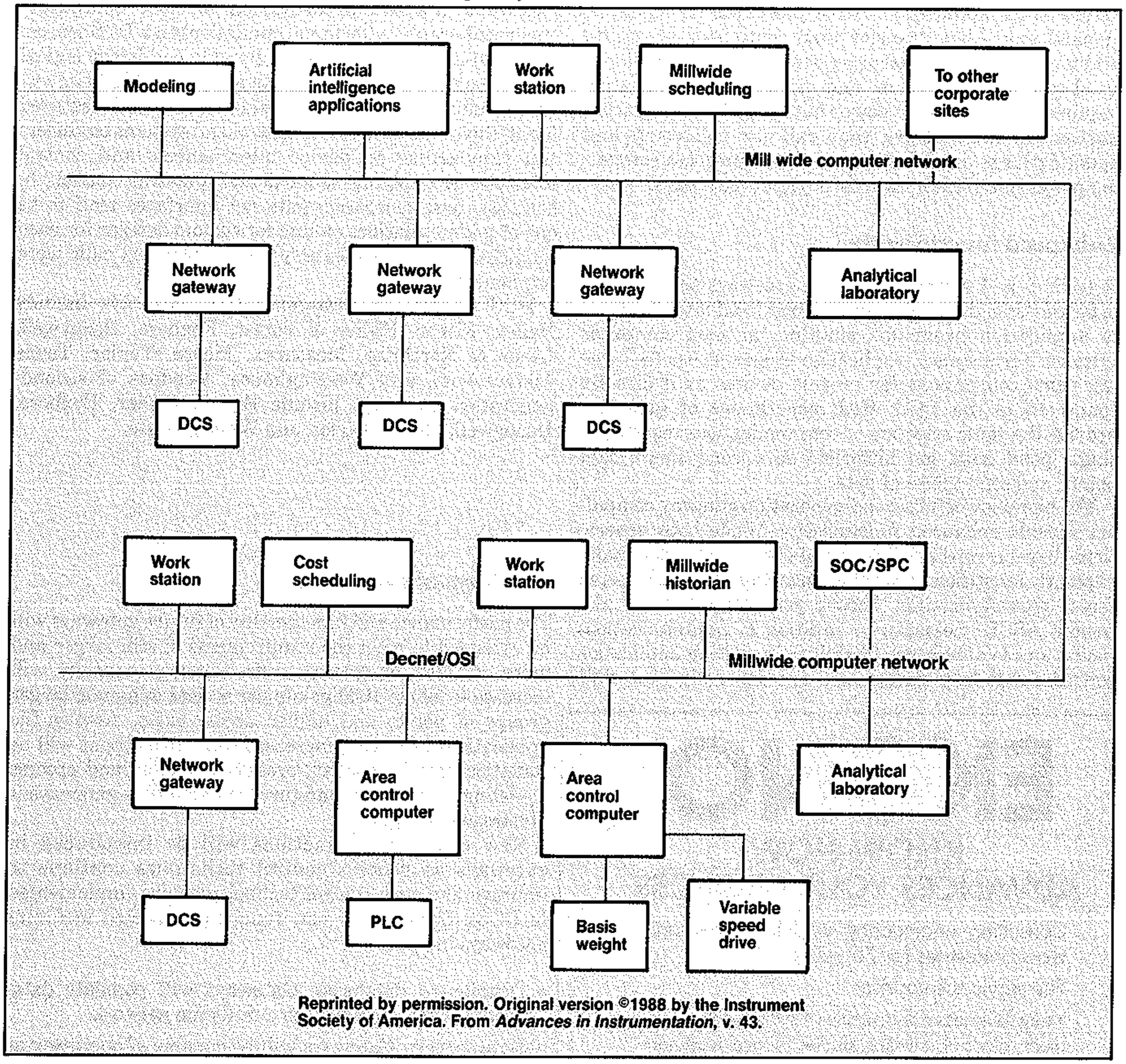
The major functional components of a second-generation computer gateway, illustrated in **Fig. 3**, are based on a built-in microprocessor as the gateway computer. These components are the gateway subnet module, protocol conversion module, communications software, and database. Depending on the DCS vendor and whether the method of updating is polling or exception-based, the database resides in the gateway or ACC.

The communications software that DCS vendors provide as part of a DCS/gateway package actually resides in the ACC. It includes such functions as data format conversion, tag name addressing, and the driver for the protocol conversion module. Other functions such as file transfer and terminal emulation are supported across gateways.

The ACC is usually a general-purpose 32-bit system such as a Digital MicroVAX or VAX computer running the VMS operating system. Networking software executing on VAX computers includes Ethernet modules that handle physical transmission of messages and DECnet modules that convert data between the message format for transmission and the information format understandable to application programs and users.

Second-generation gateways employ two methods of accessing data from process devices. Some poll the devices

4. Possible mill computer network configuration with future gateways



on the CSS in response to a request and transfer the data through the CSS to the gateway and ACC. Others maintain device databases in the gateway that are updated by exception (only changes are sent to the gateway from the devices). The gateway then responds to a request by accessing the appropriate database without having to go to the control system subnet module.

Increased data throughput

Second-generation gateways offer increased throughput and enhanced functionality. First-generation gateways interposed a relatively slow data transfer path between two very fast networks in CSS-based DCSs. Using coaxial cable, they had data bandwidths between 1 and 5 megabits per second (mbps). Networks based on Ethernet and coaxial cable have a bandwidth of 10 mbps. In contrast, first-generation gateways connect to point-to-point DCSs over twisted-pair using RS232 that has a bandwidth of only 9600 bits per second.

To increase data throughput in second-generation gateways, the transmission medium was changed to coaxial cable and the gateway computer changed from an 8-bit to a 16-bit or 32-bit microprocessor. Time to access data on the control system subnet was further reduced by providing data buffers at the subnet nodes. Data are retrieved more quickly from the buffers than from the process devices themselves. As a result, the bandwidth through second-generation gateways (100–400 points per second, protocols X.25/HDLC) is now typically 56 kilobits per second (kbps), nearly six times as fast as first-generation models.

A mill's need for the high data throughputs of second-generation gateways depends on the types of products made, the type and nature of the process, industry, and nature of the application. Batch processes, for example, demand more data transfer than continuous processes. Stable or well-understood processes need not be monitored as closely as unstable or new processes. Optimization requires more computer power but less gateway capacity. Statistical applications that call for collecting and updating large databases generally require less computing power but greater data throughput (gateway).

Enhanced functionality

Both first- and second-generation gateways are designed to be user-friendly in that the gateway itself is transparent to application programs running on area computer systems. For instance, application programs use the same tag name conventions for process devices as if directly connected to the DCS. Both generations of gateways provide the same selection of communications modes: get single point data, get historical data, send single data points, and send tables of data.

The more powerful second-generation gateway computers provide enhanced functionality. While both generations have error-handling capability, errors are more explicitly identified in second-generation models, offering faster troubleshooting. Second-generation models also handle ASCII messages in addition to communications modes and so offer more flexibility in writing application software. All loop parameters are generally accessible across second-generation gateways. Many of today's gateways support presentation of host computer-generated graphics (terminal emulation) on a DCS screen.

Second-generation gateways provide consistent logical interfaces to both the DCS subnet and ACC. DCS/gateway vendor interfaces are well documented and full featured for all their models. Process control and systems engineers can standardize on device interconnects and control software in applying a particular gateway model. In contrast, first-generation gateway interfaces tend to be one-of-a-kind solutions calling for custom designs for each application. Many times only initial, required calls were implemented.

DCS vendors of first-generation gateways include Bailey, Fisher, Fisher & Porter, Foxboro, Honeywell, Leeds & Northrup, Measurex, Moore, Taylor, Texas Instruments, and Westinghouse. Vendors of second-generation gateways include Bailey, Fisher, Foxboro, Honeywell, Moore, Taylor, and Westinghouse.

Gateways of the future

The performance and functionality of future gateways will be extended to meet the requirements of still larger and more complex integrated mills. Gateway capacity will increase to 500 to 1000 points per second to handle larger groups of points and higher access rates. Among the applications requiring increased data throughput will be statistical quality control, product tracking, and process modeling. A possible configuration for future gateways is illustrated in **Fig. 4.**

New computing functions will be introduced in gateways as process control techniques continue to improve and new control technologies are implemented in DCSs. Some of the new functions expected in future gateways include:

- Distributed databases. Gateways will populate databases located anywhere in a millwide network.
- Data servers. Gateways will be capable of operating as nodes on millwide networks. As data servers, they will store historical, process, and laboratory data for access by applications at other nodes. With on-line data storage requirements of 2 to 3 years, data compression will become critical.
- Virtual terminals. Execution of applications by processors anywhere in a DCS or millwide network can be requested at terminals and the results accessed on either side of a gateway. No longer will certain CRTs be limited to single functions or single DCS systems.
- Graphic windowing (X-windows). Workstations will collect and display status and graphical results of multiple applications running in different DCSs or networked computers on both sides of a gateway.
- Access to more data. Configuration data from the DCS will be available to allow applications to be developed to automatically configure plantwide databases and to ensure integrity long-term.☐