

DDC and the Web

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Direct digital control (DDC) ordinarily refers to executing control of devices using electronic digital technology to the point of the controlled device. Today, DDC for HVAC systems is usually provided by a networked set of sensors and controllers that are connected to actuators moving controlled mechanical devices such as valves, dampers, fans, and pumps by sending them voltage signals. Access to data on this network often is available for viewing on field panels with integrated displays or by one or more building automation system (BAS) computers (*Figure 1*).

The Web and the Internet

Widespread access to the World Wide Web opens up new opportunities for owner-operators and service providers to use the Web to manage and control facilities more effectively. From a physical perspective, the Internet is the global network of interconnected computers plus the media (wire, fiber optics, wireless) and devices connecting them. From a functional standpoint, the Internet is the set of data highways that allow data to be transported, in principle at the speed of light, from one point to any other point (or node). It is the wiring that connects everything. As such, it provides a mechanism for integrating equipment, systems and processes that historically have not been integrated and for operating them as integrated systems.

This can be done within a building system, on an enterprise-wide basis or even between enterprises (e.g., business-to-business commerce). For building control, networking enables integrated control of systems on a scale that previously could not be accomplished. From an enterprise perspective, data such as energy consumption and cost can be shared be-

yond the operation staff with other departments such as finance and accounting. These departments no longer need to wait for the monthly energy bill to understand how consumption might be changing.

The Internet, however, only provides the connections. It is a technology-enabler. By itself, the Internet provides no solutions, yet it is the critical connection system through which new kinds of solutions become possible.

One of the Internet's most useful services is the World Wide Web. The Web is a globally distributed information retrieval system that enables the nearly instantaneous access to information on any "web page" on any web server connected to the Internet, from any computer that is running a "browser" (*Figure 2*). This is a powerful feature when looking at potential future technology. Other services available on the Internet include e-mail, USENET, and file transfer.

Direct digital control is used in building environmental systems to operate equipment so that it meets the needs of building occupants for heating, cooling, adequate ventilation and lighting. Be-

cause the Internet and Web provide integration opportunities, the discussion in this article extends beyond DDC alone to other aspects of building operation and maintenance that establish the context in which DDC is used. Ways the Internet can be used for detecting and diagnosing equipment operation problems and maintaining systems and equipment are included.

Why Link DDC with the Web

Intranets and Networking

Information technology, including computers, networks and peripherals, are currently applied across nearly all economic sectors and have extended into our homes. A large industry focused only on providing computing devices and networking already exists. Major companies are based on "small" niches within this industry. Building management and control systems can take advantage of hardware, software, and knowledge from this rapidly evolving industry by implementing building controls using the Internet and other information technology. The

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networks used for building control have already been implemented on networking infrastructure from the computer industry. However, we still install separate networks for each system in a building (fire, access control, HVAC). Usually these systems are not connected to local Intranets or the Internet. Rather than installing and managing separate networks, the network provided for business applications also could be used for building control.

Security can be a concern when using business networks for building control. However, access to information and devices on an Intranet can be controlled through password protection, authorization of user access privileges and other schemes for providing data security. The business' operations data transported via Intranets are at least as valuable, sensitive, and reliant on a continuously operational network as the operation of the building. Building systems cannot go down because they provide comfortable and healthy conditions for occupants. Similarly, if a business network goes down, thousands or millions of dollars can be lost. Reliability is important for all network applications.

By sharing the same physical network, the capital cost of a separate network for building control could be avoided and maintenance of the network can be placed in the hands of the professionals in that field — the information technology staff. Of course, the network must have sufficient bandwidth to prevent bogging down building control when a large business application, such as a payroll system, is working. This could be handled by designing the Intranet to serve these loads at lower marginal costs than implementing a separate network just for building control.

In addition to potentially lower costs for the physical systems themselves and improvements to their maintenance and management, using Intranets that are connected to the Internet could provide many other advantages and benefits. Widely accepted networking standards could be used, such as TCP/IP, Ethernet and cabling standards (see IEEE Standard 802 and TCI/EIA-568). Costs of networking are decreasing and performance is rapidly increasing. Also, new standards are being developed to make any appliance with a computer chip network compatible. This will include network appliances (small, easy to use, low-power computers for browsing the web), personal digital assistants and cellular phones. Devices such as microwave ovens, refrigerators, coffee pots, lighting, and other appliances also are being enhanced by appliance manufacturers to be compatible with the Internet (see sidebar on Jini and Universal Plug and Play). Why not connect HVAC and other building systems in the same way?

HVAC equipment and controls could leverage these network and standards development activities produced for other information-technology applications to reduce cost and improve operations.

Information Availability

Today, a single workstation or two are generally dedicated for use as building automation system workstations. Information is only available to those who have access to these workstations at the computer's location. By connecting the building

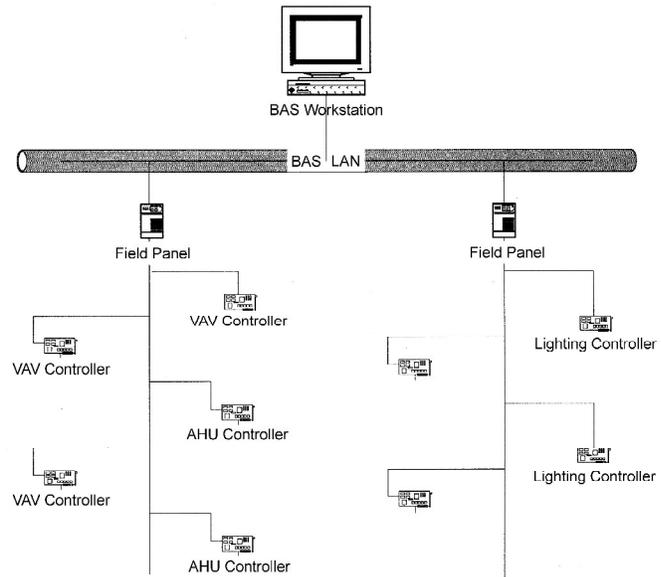


Figure 1: Schematic diagram of a common building automation system structure in use today.

control network to an Intranet, access can be provided at other locations. For example, the finance department would no longer need to wait until the end of the month to monitor energy usage and cost. By connecting to the Internet, building operation and control information could be made available anywhere a web-enabled device with a network connection is available (*Figure 3*). The device could be a desktop computer, a laptop computer, a personal digital assistant or a web-enabled cell phone.

The building engineer could monitor conditions from home or a hotel room. Data could be made readily available to an off-site consultant to solve an especially complex performance problem. With the use of the Internet, a higher level of building operation support could be provided continuously at a reduced cost.

Even building occupants might be given an automated mechanism for providing input used in the control process. Occupant polling schemes might be used to select set-points for operation. Rather than calling in a complaint, an occupant might vote or report a complaint directly by computer to the control system or building operations staff, all through an Intranet. Direct occupant input might even lead to changes in control paradigms.

Improvements in Remote Access

Remote operation today without an Internet connection is accomplished through dial-up access. Access to the information is limited to the person accessing the system modem at the moment. Others must wait for the modem to become available. Building automation systems also currently provide dial-out for reporting alarms to fixed locations, such as a pager, to dispatch service personnel. Information from a BAS is generally available as text only. However, many BAS companies now have or are developing new systems with browser-compatible interfaces so that graphical information becomes available

through the Internet or a direct dial-up connection. A severe limitation of the dial-up mode of direct access is that a connection can be made to only one building at a time.

With an Internet-connected BAS, the same central workstation alarming and service dispatching capabilities would be available, but messages could be sent in more than one form (e.g., pager, e-mail and cell phone) and to more than one location. System access would be enhanced considerably. Information from the system would become available from any Internet connection at any time simultaneously by more than one user. The same interface could be viewed through the Internet as the interface available on the central BAS workstation. More importantly, simultaneous access to many buildings would be possible. This last characteristic would make simultaneous connection to multiple buildings possible continuously, if desired. With a continuous connection to the Internet, the need to dial each building individually to collect data from the BAS would be eliminated. The connection could be maintained for automated reporting of alarms and trend data initiated by the control system, as well as providing for user-initiated actions.

Support Service Enhancements

Despite many articles in the trade literature in recent years on the value of preventive and predictive maintenance, most maintenance in commercial buildings is still governed primarily by a "fix when broken" or "change in response to complaints" approach. In the best cases, maintenance is based on calendar-time or run-time as a preventive measure. Generally, however, alarms, service requests and calls for technical support initiate dispatch of service. The service system is primarily manual and documentation of maintenance is generally limited.

Connection to the Internet could improve management of maintenance in addition to operation. Data sharing via the standard protocols would create the opportunity to integrate third-party software for maintenance management, diagnostics, and other technical and financial analyses. Diagnostic services could be delivered via the Internet to subscribers. Maintenance and repair could be initiated locally or remotely. Expert service personnel and online technical support could be available from central locations to serve many buildings. The best skills could be made available to a broader set of facilities through the Internet.

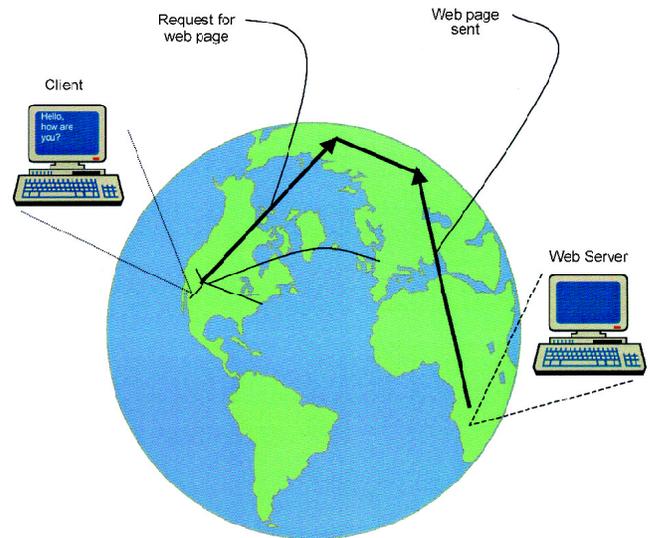


Figure 2: A simplified diagram of access to a web page from a computer connected to the Internet.

In addition to maintenance service, staff training could be offered to operations staff online. Rather than attending a training course at a set location and time, staff could use computerized training, possibly tied to their own equipment, at their convenience. Initial and refresher training could be accomplished at lower cost and without interfering with critical activities within the building. The latest control algorithms could be downloaded via the Internet and implemented without a controls integrator visiting the site. The latest documentation for equipment, systems, and controls could be made available to operations and engineering staff via the Internet.

What's Possible Today?

Can Internet and Web connections for building control systems be implemented today? Yes, but with some difficulty and at a higher cost than likely in the future. Three requirements must be met for building controls to be connected to the Internet: 1) a physical connection to the Internet, 2) a communication protocol transporting data and messages between nodes, and 3) a standard protocol (or standard format) used by all devices

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for data and messages, or translators, between protocols.

The first requirement is relatively straightforward. It can be obtained from an Internet Service Provider (ISP) as one of a number of broadband connections or as a smaller bandwidth telephone-line connection. For most office buildings today, Internet and Intranet connections are placed in many locations but probably not to the building controls system. If not in place, connections would need to be run to the building control system. For new buildings, the networking infrastructure in the building could be designed to provide service for building control and monitoring.

The second requirement can be met by the TCP/IP standard, which governs transfer of data over the Internet (and many LANS), together with gateways, which convert information from one communication protocol to another and connect two networks using those different protocols. In addition to providing transmission of the data, the devices connected must be able to “speak” to one another. This requires that the control devices use a standard protocol or that a protocol converter (sometimes part of a gateway) provide translation from one protocol to another. This converter may serve an entire building automation system, a set of sensor/control points, or even an individual sensor or controller. BACnet® is an example of an open standard for building automation systems data and services. Figure 4 shows various types of connections that are possible and necessary to use the Internet in building control.

Whenever different protocols are used in a distributed network scenario or different protocols are used by different applications, gateways are required to connect every network or sub-network to every other network, as well as to the Internet. These gateways add to cost and serve as an impediment to connecting building control systems to the Internet. Whether the protocols used are standard or proprietary, there will still be differences. The cost of a gateway continues to decline as they become less visible.

If all devices on a building control network were TCP/IP com-

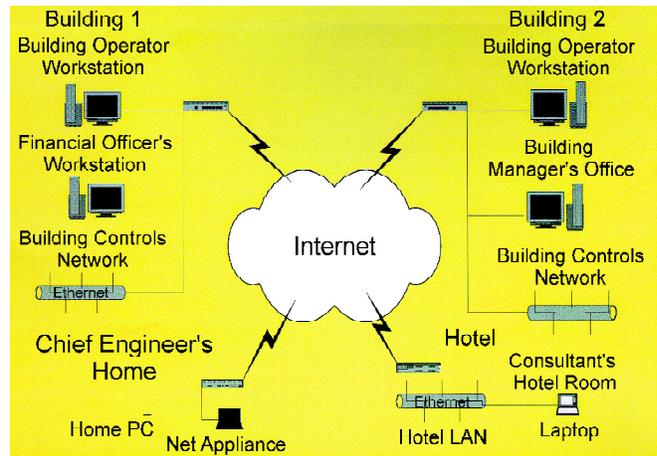


Figure 3: The future of building controls via the internet, where access to building operation information is available to authorized personnel any where at anytime.

patible with each having an IP address, each device would become a node on the net. If they also used the same higher level protocol to communicate or provided protocol conversion at the individual monitoring and control devices, DDC could be implemented directly over the Internet and TCP/IP networks. To protect intrusion by unauthorized users, firewalls can be used for connection of organization or site Intranets to the Internet. Password protection can be used to restrict the access of various levels of users. For example, financial staff would probably have no access to set points or temperature data at various points in the HVAC system. A fully Internet-connected building control system is schematically shown in Figure 3.

One thing should be clear. There is a difference between transmitting information over the Internet and viewing this information. A standard protocol, like BACnet®, might be used with the Internet to deliver information to another BACnet® device. A standard protocol used in conjunction with the Internet does

Jini and Universal Plug and Play

Two standards under development for readily connecting devices of all sorts to computer networks and the Internet are Jini and Universal Plug and Play (UPnP). They are being developed by different collaboratives in the computer industry. Such standards show promise for greatly expanding the role of the Internet in our lives, including HVAC systems. This sidebar provides a brief description of these standards.

Jini

Jini (Sun 1994 – 2000) provides a set of protocols and transaction mechanisms that enables devices to plug to-

gether and communicate over a network without any planning, installation or human intervention. Jini connection technology extends the Java programming model for a single virtual machine to a network of machines. Devices can be plugged into existing networks, announce their presence to other Jini-enabled devices and services, share resources and interact with them. In a Jini network, there are no designated clients and servers; all devices on the network can serve both as clients and servers depending on the service they offer.

The infrastructure of a Jini system consists of a discovery/join protocol and a

look-up service. The discovery/join protocol allows devices to discover and advertise themselves to other devices and services present in the network. The look-up service is a repository of services available to the network members. Entries in the look-up service are objects in the Java programming language, which can be downloaded by the devices requiring that service. All Jini-enabled devices will have some memory and processing power. Devices without processing power or memory may be connected to the network using another device as a proxy providing the memory and processing power required.

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not mean a web browser will be able to display the transmitted building information.

Even connecting monitoring and control devices directly to the Internet or an Intranet does not make them accessible via the Web. To provide control information via Web browsers, the information must be posted on Web pages. This can be done on a supervisory computer for an entire building controls system, at the field panel level, or on individual devices if they were connected directly to a TCP/IP network. These devices would require processing and memory capabilities to enable them to act as Web servers and provide the building information in a format that can be displayed by a Web browser. Today, many BAS manufacturers are beginning to offer Web access to their BAS. The future could bring individual devices that possess limited Web-server capability for their own Web pages.

Third-party programs are somewhat difficult to integrate into building controls networks currently, especially where older, legacy, BASs are present. Many newer BASs provide access to control system data via standard dynamic data exchange (DDE) or object linking and embedding (OLE) technologies. Dynamic data exchange enables two applications running simultaneously to share data and commands. The OLE technology enables an object developed in one software application to be displayed in

In an HVAC control system, a new device, such as a thermostat or piece of equipment, added to a Jini-enabled network can become part of a central control system without having to reconfigure or recommission the control system.

Universal Plug and Play (UPnP)

UPnP (Microsoft 2000) is a distributed, open networking architecture for data transfer and control of networked devices. UPnP supports zero-configuration networking and automatic discovery, whereby a device can dynamically join a network, obtain an IP address, announce its name, convey its capabilities upon request, and learn about the presence

and capabilities of other devices. UPnP provides a balanced protocol / API (Application Program Interface) architecture so that devices can seamlessly interoperate in a multi-vendor environment and with the Internet. UPnP devices can be implemented independent of any programming language, operating system or physical medium. Device vendors can agree on developing protocols on a per-device basis as to the types of services made available over the network.

UPnP leverages the most popular communication protocols and standards such as TCP/IP, HTTP, HTML and XML. TCP/IP and HTTP are communication protocols widely used by the Internet industry to connect and send data between comput-

ers. HTTP and XML are expressive high level languages for describing data. For example, a device interface protocol can express data in XML and communicate it via HTTP to display information in a web-based browser on a desk top computer or a web phone.

The major difference between JINI and UPnP is in how the Application Program Interface is implemented by the individual devices. JINI uses the JAVA programming model and shares services, whereas UPnP shares only the data. Each JINI device may need to download code and process from another device for an action, whereas a UPnP device expects only the data, and its processing is local to the device. ◆

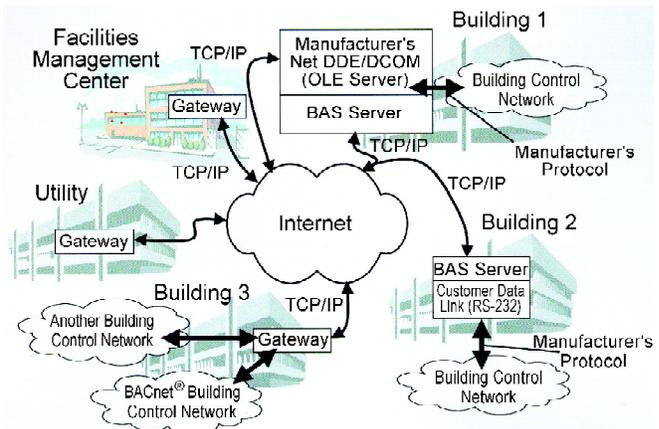


Figure 4: Digital control system connections to the Web possible today.

another. An object created in one program can be linked to, or embedded in, another software application. The OLE technology has proved so useful that it serves as the basis for a process industry standard known as OPC or OLE for process control (OPC Foundation 2000). The OPC standard defines a set of

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interfaces for communicating among a set of diverse process control devices. The intent is to have interoperability between control programs, automation systems, field devices, and business applications without requiring development of specific and custom interfaces, removing customer concerns about compatibility and reducing the cost of interoperable systems. Using these or other technologies to overcome obstacles to integration, many more providers of building operation support software could enter the market, expanding the types and range of applications available and increasing the value of these systems to the owners.

The applications that could become integrated with DDC systems in buildings include:

- Automated, remote, fault detection and diagnostics.
- Total enterprise and end-use energy consumption tracking.
- Verification of energy savings and utility rate structures.
- Benchmarking across building sets.
- Financial impact assessment.
- Forecasting energy needs and preparation of purchasing plans.
- Optimization across multiple building systems and buildings.
- Improved load management.
- Real-time energy contracting.
- Direct online ordering of parts and supplies for repair and maintenance.
- Live reporting and archiving of satisfaction of operation codes and standards (e.g., indoor air quality).
- Asset tracking.
- Building document management.

Looking Ahead

Looking beyond the near-term impacts of connecting building control systems to the Internet, a broad spectrum of opportunities exist for using information technology to improve building operation and management. In this section, a representative set of what is likely is presented.

Supercontrollers

We define supercontrollers as controllers with computational power comparable to today's desktop work station. Some chip manufacturers are producing one-chip personal computers (PCs) that are 133MHz Pentiums with all the input/output, BIOS, etc., needed to execute very sophisticated programs. These capabilities were added to top-of-line desktop computers less than five years ago and are designed into controllers currently. It is reasonable to expect that in five years the first 500MHz supercontroller packaged in a box no larger than cigarette pack will be introduced.

Moreover, supercontrollers capabilities are likely to include self-programming plug-and-play controls; design and performance histories available online; and all data, diagnostics, and analysis performed and published to the Web.

These ultra-small, super-smart controllers will benefit building control products and services by making more valuable information available to service providers. The ease of delivery of huge volumes of pre-processed information and knowledge

would not be possible if not for Web technologies.

Wireless Technologies

The future should also bring greatly increased use of wireless communication for Internet connections, for portions of the Internet and in wireless sensors. Wireless sensor-use in buildings will lead to reduced installation costs for sensors, use of more sensors, increased availability of information, and a greater variety of sensors used in building controls. Much of the underlying technology exists or is being developed for business and military applications and includes wireless LANS, wireless Internet, and passive radio frequency (rf) sensors that can be polled from a remote location.

Web-Enabled Cell Phones

Cell phones with web capabilities are already commercially available (they use today's wireless application protocol [WAP], which does not enable display of full web pages). They have been on the market in Europe for some time. With fully web-enabled building control systems, such devices could serve as service hand tools for building operators and equipment service technicians. In principle, simply by navigating the building's web site with a cell phone, an operator could operate a building or several buildings. This would provide operators with the ability to do anything, anytime, anywhere that they could do at the on-site central BAS computer.

New Sensors and Web-Enabled Telepresence

The future will undoubtedly provide new types of sensors. Low-cost, miniature sensors for sight (video), sound, smell, and touch should become practical. A miniature wireless video camera that today costs about \$200 should, in 10 or 15 years, cost less than \$2. With such costs and no wiring, it will be difficult to justify the cost of driving to the building, climbing to the roof and opening an access panel to look at a damper. Much more fault-detection, diagnosis and troubleshooting will be done before visiting the site. One visit should suffice for repairs and maintenance because the service technician will know in advance all parts and equipment that need to be brought to the site.

Ultimately, Web-enabled technology should be able to provide telepresence. With telepresence, the technician won't need a screwdriver and wrench or to be on site to open up an air handler to see inside. With sufficient sensor variety, supercontrollers could synthesize views of the internals of the equipment and systems they control on demand. This would be accomplished by using the sensed data in models to provide the illusion (using virtual reality) of actually inspecting systems and equipment without being at the site. Such systems could highlight problem areas and deliver images over the Web to an eyes-up display.

Conclusions

Networking technology is becoming available rapidly so that building control systems may benefit by using the same general infrastructure and connecting to the Internet. Use of commercial off-the-shelf components from the information technol-

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ogy industry should lead to increased network performance and lower costs. A transition will be required from today's building control system implementations to tomorrow's fully integrated system with the Internet. This will take time, but moving in this direction should bring cost and performance benefits well beyond today's level of performance and lead to significant enhancements in building operation.

Use of the Internet for building control will create new opportunities for facility managers, service providers and manufacturers. More information will be available to more people, enabling facility operation to become an integral part of enterprise operation and resource planning. Better information will be provided to all parts of a company making decisions related to facility management. This will contribute to the overall improvement of the business of owning and occupying a building.

Presented here is a rosy picture of building control and operation using the Internet and the Web. Will the Web fulfill its promise to provide these benefits? The answer will largely be up to us in the HVAC and buildings industries. The Web is an enabling technology; it is not the solution by itself. We must grasp the opportunity to utilize the incredible information technologies becoming available to improve building operation by adapting them and developing the software applications to use them effectively for building management and control. Failure

to do so will defer the benefits.

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