Integrated networks and killer applications... the 21st Century has reached the buildings industry in time for facility managers and owner-engineers to respond to pressures to cut costs, increase profits, and thrive in a data-driven, decision-making market

Facilities Management in the 21st Century

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Managing distributed buildings, such as municipalities, school systems, office campuses, and industrial plants, requires a wide array of skills and tools for building operations, maintenance, engineering, forecasting, budgeting, health, safety, and security. Over half of the commercial buildings over 50,000 sq ft in size in the U.S. have some type of building automation system (BAS).[1] These systems help the facility managers in their day-to-day operation of the building HVAC, life-safety, lighting, and security systems.

Recent developments in open communication standards for building automation systems as well as the pervasive use of Internet and intranet technologies have created a flood of new options for owners and operators of distributed facilities. Deregulation in the utility industry also represents opportunities and challenges. The impact of these new technologies and market developments is the increasing need for available building-generated information. To benefit from these changes, facility managers, owners, operators, and energy service providers are challenged to acquire or develop new capabilities and resources to better manage this information and, in the end, their buildings and facilities. We refer to the resources as distributed facilities management systems.

This article provides an overview of the technology infrastructure and software applications that enable the owners and operators of distributed facilities to meet these new challenges.

DISTRIBUTED FACILITIES MANAGEMENT

Having a BAS in every building is not sufficient to address the growing needs of the facility manager and owner-engineer. The networks that tie the BAS with the rest of the enterprise and the intelligent software applications that manage the BAS are the keys for the next generation of distributed facilities management systems.[2] Controls manufacturers, engineers, and researchers are developing software solutions that take advantage of integrated networks to provide easy access to operating and control data.[3,4,5,6,7] Use of state-of-the-art controls that facilitate distributed processing, coupled with gateways that provide interfaces between the control networks and the data networks (Internet and intranet, respectively), will provide better monitoring and control of the building systems and enable management of distributed facilities from either a central or remote location.

In addition to monitoring and control, seamless integration of the control networks with the Internet will

*Pacific Northwest National Laboratory is operated by Battelle for the U.S. Dept. of Energy.

open new opportunities, such as:

- automated, remote fault detection and diagnostics of building systems and subsystems,
- tracking energy use and end-uses by building or group of buildings can lead to better monitoring and verification of guaranteed savings contracts, better reporting, and benchmarking of building performance,
- ability to forecast energy budgets and prepare energy purchasing plans,
- optimization across multiple buildings and building systems,
- ability to control load and equipment in response to varying utility rates (*e.g.*, real-time pricing, time-of-use rates).

The primary beneficiaries of control-network integration with the Internet include facility managers and owner-engineers of multiple buildings, such as university campuses, school districts, retail stores, restaurant chains, U.S. General Services Administration buildings, and banks. Property management firms, energy service providers, and utilities also stand to benefit tremendously from these opportunities.

Benefits from integrated facilities management include:

- lower energy expenses,
- fewer occupant complaints and faster resolution of problems,
- reduced liability and litigation expenses (relating to IAQ issues),
- reduced churn (*i.e.*, turnover of tenants),
- higher tenant rents (commensurate with higher quality facilities),
- improved performance of occupants, such as students and teachers or manufacturing and office workers, because of a better indoor environment.

Building Automation Systems

In the past, most BASs used proprietary architectures, leaving building owners and controls designers with no choice but to specify BAS field devices and controllers from a single vendor for compatibility. The customers did not have the flexibility to choose the best products, controls, and services at optimum prices for the desired performance from different vendors. With the advent of BACnet, which is an open standard protocol (ASHRAE/ANSI standard), owners and designers now have a choice. Also, customers have a choice of an alternate open protocol from the LonMark Association, which is based on LonWorks from the Echelon Corp. Both protocols support integration of the control networks with the Internet. However, there are buildings with state-of-the-art, modern BASs that are still proprietary. For these BASs, the manufacturers are providing gateways to interface the control networks with the Internet. There are many buildings with older or “legacy” systems that are based mostly on proprietary architectures. The manufacturers of these legacy systems may never develop interfaces to the Internet for these systems because the architectures are outdated and the systems are being replaced gradually.

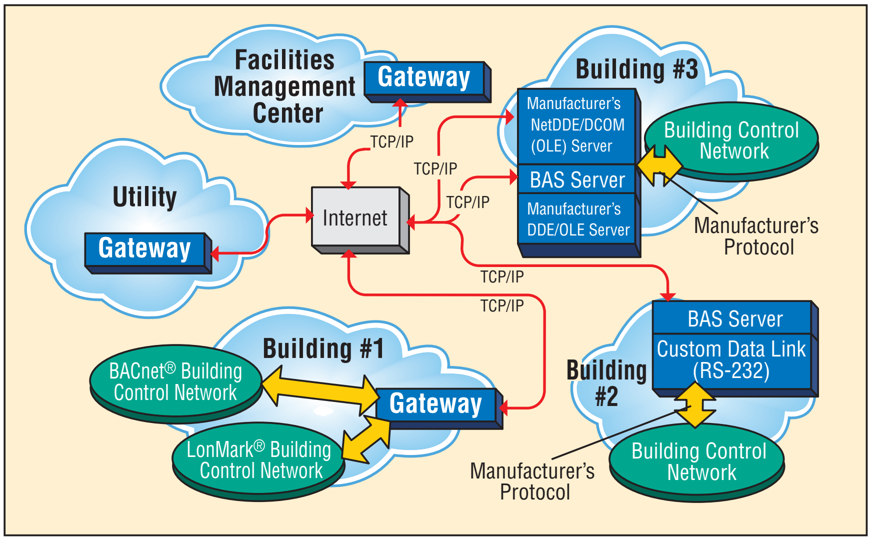


FIGURE 1. Example of integration controls networks from different buildings

INFRASTRUCTURE REQUIREMENTS

Networked software applications that can harness the vast potential of integrating control networks with the Internet require access to data from control panels or sensing devices that are distributed across buildings. Being able to exchange data and information between field devices and software applications is the key to successful implementation of networked software applications.[2] Although software applications are independent (and should always be) from the process of gathering data, the capability to gather data is dependent on the functions provided by the BAS and the communications protocols it uses. The type of interface (gateway) that exists between the control network and the Internet is also important (Figure 1).

An infrastructure supporting the next generation of software tools that owners and operators will use to manage distributed facilities requires:

- a control network with a BAS or intelligent devices (in each building),
- a mechanism or a transport layer that ties the field panels and the devices on the control networks to the Internet,
- and finally, the “killer software applications” that enhance facility management.

NETWORKING DEVELOPMENTS

Building automation systems have evolved over the past two decades from pneumatic and mechanical devices to direct digital controls (DDC). Today's BASs consist of electronic devices with microprocessors and communication capabilities. Widespread use of powerful, low-cost microprocessors; use of standard cabling; and adoption of standard protocols (such as BACnet, Lon-

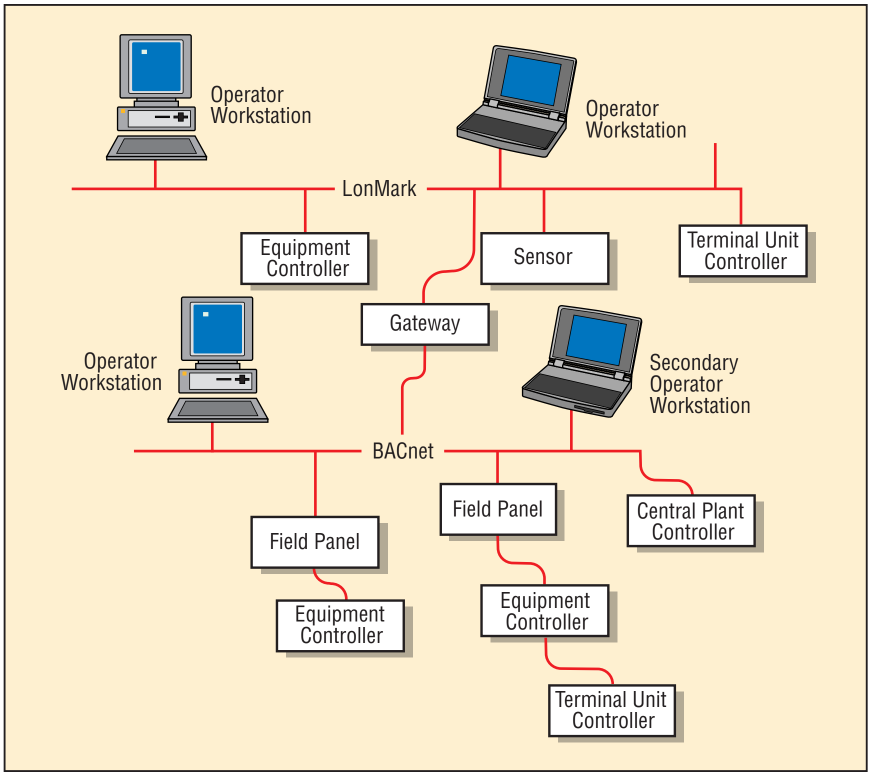


FIGURE 2. Modern BASs. The field panels and controllers have powerful microprocessors that allow for processing of information and control action with the devices rather than at a central supervisory controller.

Works) have led to today's improved BASs. Most modern BASs have powerful microprocessors in the field panels and controllers that will soon be embedded in the sensors as well. Therefore, in addition to providing better functionality at a lower cost, these BASs also allow for distributing the processing and control functions within the field panels and controllers without having to rely on a central supervisory controller (Figure 2).

Many BAS manufacturers support either BACnet or LonWorks protocols; some even support both.[8] Recently, ASHRAE approved a BACnet/IP addendum that makes it easier to monitor and control building systems from remote locations over the Internet.[9] LonWorks is also heading in the same direction.

The manufacturers of BASs are also developing gateways to connect modern proprietary control networks to the Internet, making it easy for distributed software applications to share information. However, there are many legacy BASs in the field for which gateways are needed but do not exist or will never be developed. In such situations, there are three ways to connect these systems to the Internet: 1) dynamic data exchange (DDE), 2) object link and embed, (OLE), and 3) developing a custom interface between the BAS and the Internet for legacy systems that do not support either DDE or OLE. See the sidebar below on networking concepts for more about DDE and OLE.

DATA GATHERING TOOLS

Without easy access to data from meters, controllers, and equipment distributed throughout the facility, it would be difficult to realize all the benefits of distributed facilities management. Although the details of data gathering depend on the type of BAS and the protocols it supports, integrated networks do provide some standard methods to access data from geographically distributed facilities.

As part of a larger U.S. Dept. of Energy project to develop an automated diagnostician, called the Whole Building Diagnostician (WBD), prototype tools were developed to collect data from BASs locally or over the Internet. These tools allow building-generated data to be collected at any time interval and stored in a database.

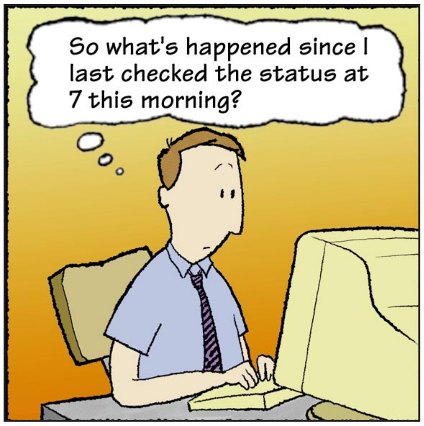
Many BAS manufacturers provide DDE/OLE servers to facilitate data ex-

Networking Concepts

Ideally, the control network in each building would be connected to the Internet using a gateway or a global controller that would provide a set of common functions independent of the BAS. However, in practice this may not be true—especially in a heterogeneous (mixed protocol) BAS environment where each gateway may have a different set of functions. In a homogeneous BAS environment, or where the BASs conform to a single-standard protocol, the gateways will provide common functionality.

Some BAS manufacturers currently provide either a DDE or an OLE server that enables third-party software applications to communicate with field panels and devices. DDE is a standard Microsoft Windows® message-passing protocol that defines a mechanism for Windows applications to share information with one another. In the early 1990s, Microsoft developed OLE as a replacement for DDE. Both DDE and OLE have networked versions that support the TCP/IP (Internet) protocol (netDDE and DCOM-distributed component object model, respectively). The non-networked versions require an application server that supports communications over the Internet. Because DDE and OLE are standard protocols, the DDE/OLE servers from various manufacturers provide similar functionality.

If the BAS does not support a gateway to the Internet or a DDE or OLE server, a custom software application is required to communicate with field panels and devices over an RS-232 port. In addition to the custom software application, an application that allows for communication over the Internet is required.



change between controllers/devices and software application programs. The WBD data collection tools, running in the background, initiate a DDE "conversation" between the DDE server provided by the BAS manufacturer and the WBD database and collect data at time intervals set by the operator. Relationships defined during setup of the software for the building are used to map data from the sensors for each of the air handling units (AHUs) and building end-use meters into the WBD database. The data-gathering tools are independent of the WBD's diagnostic modules; therefore, any application can use the data-gathering infrastructure. By querying the database, raw data can be retrieved for use by other software applications, such as programs used to reconcile metered data with utility bills and to charge tenants for energy use. Software applications that make use of building-generated data are now described.

KILLER APPLICATIONS

Connectivity of control networks with the Internet allows third-party software developers, in-house developers, and BAS manufacturers to develop independent software applications that can be deployed from a central location. These applications put networking capabilities to work by gathering and processing data, sending out control commands, and generating reports. The cost of these software applications can be spread over a large number of buildings when used from a central location. Centralized monitoring also enables facilities and service providers to hire expert HVAC engineers and analysts to analyze several buildings rather than one or a few.

Remote Automated Diagnostics

Effective use of diagnostic tools can help facility managers and operators cut the cost of operations and consumption of resources while improving the comfort and the safety of occupants. Continuous diagnostics for building systems and equipment will help remedy many problems associated with inefficient operation of buildings by automatically and continuously detecting system performance problems and bringing them to the attention of building operators.[5] Some of these problems might otherwise go undetected. Advanced diagnostic tools can even suggest causes of problems, make recommendations for solving problems, and estimate the cost of not solving a problem. Until recently, access to data in real time was one of the major obstacles for widespread deployment of remote automated diagnostic tools.

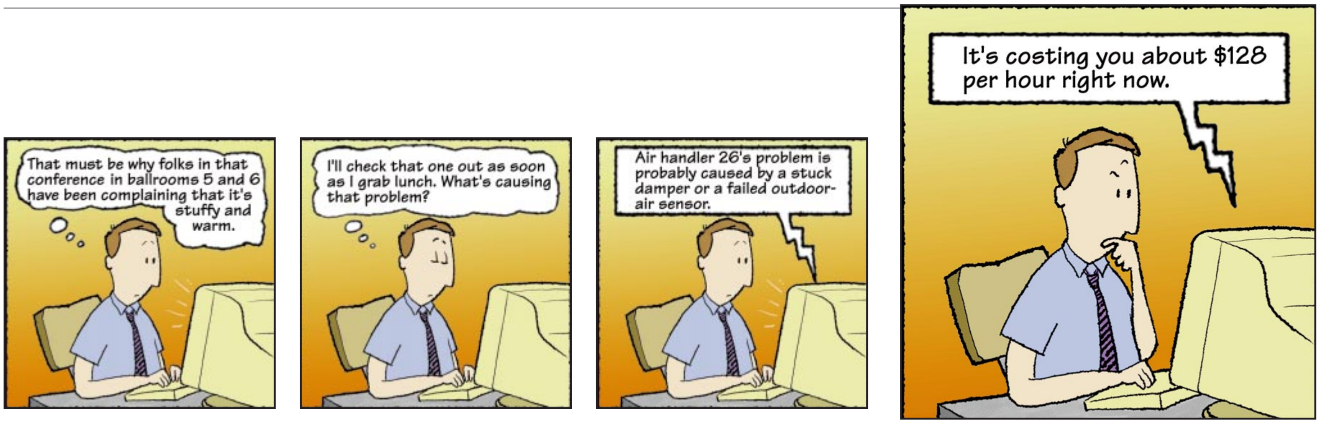
Although fault detection and diagnostics have been an active research topic for several years, only a few software applications are available today. Lack of a well-defined infrastructure and difficulties in accessing sufficient quantity and quality of data are two of the reasons for the slow start.

Tracking Energy End-Uses

Because energy accounts for a significant portion of the operating cost in many facilities, facility managers, energy service providers, and owners alike will benefit from a software tool that tracks energy end-use. For example, the benefits for an owner of a re-

Whole Building Diagnostician

As part of its mission in commercial buildings research and development, the U.S. Department of Energy (DOE) Office of Building Technology, State and Community Programs, in collaboration with industry, has developed a tool that automates detection and diagnosis of problems associated with energy consumption in buildings and their systems.[5,6,7] The tool, known as the Whole Building Diagnostician (WBD), currently has two modules—the whole building energy (WBE) tool and the outdoor air/economizer (OAE) diagnostician. The OAE module monitors the performance of air handling units (AHUs) and detects problems with outside air ventilation control and economizer operation, using sensors that are commonly installed for control purposes. The OAE diagnostician can be configured to monitor the performance of any number of AHUs in one or multiple buildings. The WBE provides diagnostics related to aggregated energy end-uses, namely building total electric energy, building total thermal energy, HVAC electric energy other than chiller energy, and chiller or packaged-unit energy. The WBD can be employed either in a distributed environment or at a central location where a single operator or a group of users can continuously monitor the performance of building systems or AHUs. Initial results from the field tests are described later in this article. For more information on the Whole Building Diagnostician and to obtain details on how to get the software, visit the Website at *http://www.buildings.pnl.gov:2080/wbd/*.



tail chain or a facility manager of a large campus with distributed facilities include:

- ability to generate reports in several different formats (*e.g.*, by region, sales volume, or building type),
- ability to benchmark historical, normalized (*i.e.*, with respect to weather, size, sales) end-use consumption between similar buildings/facilities. Comparison with benchmarks can help identify operational inefficiencies.
- ability to forecast energy budgets and prepare energy purchasing plans.

An energy service provider who has signed a guaranteed savings (*i.e.*, performance) contract with a facility can reduce his risk and increase his reliability by tracking end-use consumption and calculating savings continuously. From a central location, the energy service provider or facilities personnel can also identify problems associated with unscheduled operation of equipment (such as lights and HVAC equipment) as a result of control malfunctions or errant programming.

Methods to estimate savings from energy-efficient retrofits using measured end-use data have evolved over the past 10 years.[10] The early developers of software tools for tracking savings often used special data logging equipment coupled with low bandwidth phone lines for communication—a cumbersome application. With integrated networks, the software applications can collect, analyze, format, and display data more easily for multiple buildings and synthesize the data into a variety of reports, depending on their end use. Real savings from energy conservation measures can be compared easily with estimates from engineers, contractors, and operators.

Load Aggregation

To negotiate favorable utility rates and tariffs in a deregulated utility environment as well as ensure that the contract limits are not exceeded, the aggregated load and demand profiles of individual buildings and the entire distributed facility are required. Aggregation is facilitated by connecting existing meters or control networks to the Internet and passing the meter or sensor readings as data in real time for subsequent analysis by operators or other building staff. Aggregating real-time data across the facility can help identify where to curtail energy use if demand is close to exceeding the negotiated limit.

Whole-Facility Cost Management

In the deregulated utility environment, one of the greatest cost-savings opportunities for facility managers and operators lies in the ability to control and optimize whole-facility energy consumption. Due partly to deregulation, utilities are now offering rates that vary by hour-of-day and day-of-week, similar to the real-time pricing rates and time-of-use rates offered by some utilities. To take advantage of time-varying rates, facilities will need advanced control strategies.[11] Strategies include: HVAC load shedding (for chillers, thermal storage, supply and zone temperatures, fans, and pumps); load shifting (using pre-cooling or thermal storage); and fuel shifting (gas, oil, and steam standby generators).[4] These strategies not only require monitoring access to data from sensors and meters but also the capability to control equipment from a central location.

In addition to the energy charge, most utilities also have a demand charge that can be as high as $25 per KW or more. In some cases, the peak period is tied to the utility's system-wide peak. In such a case, predicting the system-wide peak and implementing the load-control measures during a 2 or 3 hr window surrounding the anticipated time of the peak will save a large facility (such as a naval base) a significant amount in demand charges. Pacific Northwest National Laboratory (PNNL) developed a sophisticated software tool for naval bases in San Diego. The tool calculates the probability that any particular day's system peak will be the monthly system's peak. The tool uses short-term (today), medium-term (1 week), and long-term (30-day) weather forecasts, as well as a baseline model of the utility's loads system-wide. All weather data are collected over the Internet for the analysis. Facility managers and energy service providers can optimize whole facilities using such sophisticated software tools, if the required data are available.

EXPERIENCE FROM THE FIELD

Several BAS manufacturers, third-party software developers, and national laboratories are developing infrastructures and applications that are independent of the BAS and the communication protocols. In this section, we describe one such implementation that has been developed by PNNL.

The outdoor air/economizer (OAE) diagnostic module, which is part of the WBD, is being used to detect and diagnose problems with AHUs in several buildings. Data from the AHUs are collected at a centralized location using an architecture similar to that described earlier.

The WBD uses data collected periodically from the sensors that are used for controlling the AHU operations. These data are automatically read and transferred through the BAS to the WBD database using the manufacturer's DDE server and the data-gathering tools developed by PNNL. The data-gathering tool passes a request for data to the manufacturer's DDE server. The requested data is then returned by the DDE server and stored in the WBD database. A set of predefined relationships established during setup of the software is used to map data from the AHU sensors into the database. The OAE diagnostician then processes new data as they come in, and operators view the results at their convenience. Alarms of varying priorities are generated when thresholds are exceeded.

The OAE diagnostician has been proven effective in identifying outdoor air ventilation and economizer operation problems in air handling units. Furthermore, the small sample of air handlers monitored has confirmed our suspicion that most economizers do not work as intended. The field test results confirm this suspicion; of the seven AHUs monitored, four were found to have problems shortly after initial processing of data. The problems found included sensor problems, return air dampers not closing fully when outdoor air dampers were fully open, and a chilled water controller problem. All problems have been confirmed by inspection of the AHUs. The results also indicate that automated diagnostic technology promises to help identify and eliminate these common problems.

SECURITY ISSUES

Although integrating control networks with the Internet exposes the control networks to the potential for an attack from elsewhere on the Internet, there are technologies available in the market today that provide tight security (*e.g.*, authentication and authorization) to overcome security problems. In addition, the privacy of the data being transmitted over the Internet can also be protected with use of encryption.

CONCLUSIONS

As BAS manufacturers continue to adopt open standards and provide interfaces to connect the control networks to the Internet—coupled with development of networked software tools—building managers, facility operators, and energy service providers will have access to more sophisticated and automated software tools that will enable them to manage distributed facilities more efficiently. These advances will provide better controls capability and help enhance automated remote diagnostics, preventive maintenance, and monitoring of performance contracts. We recommend that building owners and operators stop using proprietary systems and insist on systems that are based on open standards to take full advantage of the recent advances. **HPAC**

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