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Stone Mountain Elementary near Denver is part of a school district that uses Web-based BACnet systems for most of its buildings.

BACnet[®] Passes Test

By **Jeff Lucas**, Associate Member ASHRAE, and **Aaron Nahale**, Member ASHRAE

The Douglas County School District (DCSD), located in the Southern Denver Metropolitan area, continues to be one of the fastest growing school districts in Colorado and one of the top 10 fastest growing in the country. The district, which covers nearly 900 square miles (2330 km²), has grown from 40 schools in 2000 to more than 55 schools in 2007.

Fifty-six of the school district's 70 buildings now have BACnet building automation systems that are Web-based. Six additional schools are under construction with more slated in the near future. All will use the BACnet protocol. The district's BACnet network includes more than 25,000 hardwired inputs and outputs and more than 102,000 BACnet objects. The network has devices from 10 manufactur-

ers, including building automation control systems, variable frequency drives, power consumption meters, chillers, condensing boilers and lighting controls.

Information from the network is accessed via the district's building automation Web server. The Web server allows multiple users to access the control systems without the need for multiple software licenses. The system is accessible from any computer

on the district's wide area network. It is used by controls specialists, HVAC technicians, preventive maintenance staff, electricians, custodial staff, administrators, contractors, and energy management personnel.

Users interact with the system via animated Web pages. The Web pages are tailored to the needs of the end users. The head custodians may have view-only access to the school to which they are assigned. When logging on, users see animated depictions of the school's HVAC system, equipment status, floor plans with color-coded room temperatures and all alarms. The Web graphics also include links to trend

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logs complete with two weeks of data. The district's controls staff has begun incorporating links to other pertinent documents such as electronic copies of as-built mechanical drawings, testing and balancing reports, and equipment O&M manuals. The documentation was converted from their original formats to PDFs and linked to the Web graphics. It was decided to include this expanded documentation when the district began an in-house retro-commissioning program led by the district's controls team.

Many benefits exist to having remote access by multiple user groups. With more user access to information and data such as trend logs, the district is seeing improvement in managing and responding to equipment problems, alarms, and comfort complaints. Critical equipment failure can be detected and immediately generate a BACnet event. The event can be routed to a cell phone or to an e-mail address. Occasionally, the district's O&M staff is informed of, and addresses, a problem before the building's occupants know it exists. Service work is managed more efficiently and effectively, and considering the geographic size of the district, labor hours and fuel are saved.

The network is growing and improving constantly. The district's controls department maintains the system from the ground up and often installs and programs many of the devices on the network. For example, the controls department has automated the HVAC systems in 120 of their mobile classrooms and has integrated them onto the BACnet network. The mobile classrooms are air conditioned and heated with electric heat, so this system has saved a large amount of energy. The controls department also has programmed the system so every piece of equipment can be set to "unoccupied" with the one button. In the event of a snow day, it takes a matter of seconds to set 57 buildings and 120 mobile classrooms to their unoccupied parameters even though the system includes several manufacturers' devices. It is nearly impossible to accomplish the snow day programming without an open protocol like BACnet.

How BACnet Was Chosen

The biggest advantage to a BACnet system is interoperability. In fact, this advantage is the primary reason the district decided to move to a native BACnet building automation system. In 2001, DCSD's limited O&M staff was faced with the challenge of maintaining five different building automation control systems. Each of these systems had its own proprietary protocol and could only be operated by its own centrally located operator workstation. An added challenge was training staff on each of these systems. Making matters more interesting, during 2001

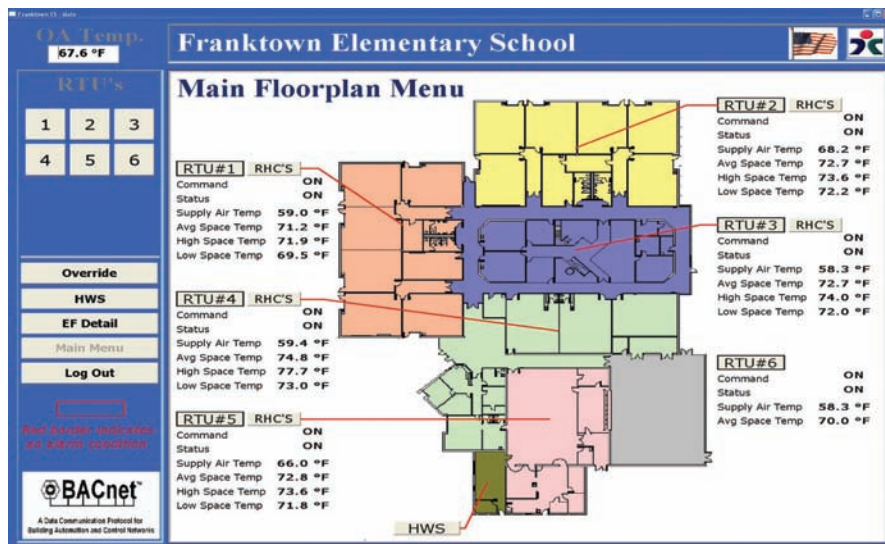


Figure 1: Example of a typical school's main graphic page.

two high schools were undergoing remodels that included new building automation systems, one with BACnet and the other with LonWorks®.

The O&M staff wanted to standardize to avoid the added cost of product/system training, inventory, lost time due to travel and repair, and maintenance services. The choices were to use a sole source for the building automation systems or specify dissimilar manufactured systems interconnected over a common network. Because the district was interested in the advantages of competitive bidding, the decision was made to standardize on an open protocol building automation system.

After investigating LonWorks and BACnet, the decision was made to specify BACnet systems for all future projects. The main reasons BACnet was chosen were:

- ASHRAE was behind the development of BACnet while LonWorks is a private enterprise;
- BACnet working groups are continually updating the BACnet standard;
- BACnet/IP enabled the district to use the existing IP network for building automation communication;
- Case studies of existing large-scale BACnet systems proved that BACnet was a viable option;
- BACnet installations already existed within the DCSD; and
- BACnet was designed specifically for building automation systems.

Ultimately, BACnet allows the district to have many of the advantages of a single control system and still reap the benefits of competitive bidding.

Identifying BACnet Vendors

The next step was to identify who could provide a BACnet system with the desired level of interoperability. The controls



staff began investigating. The BACnet Web site provided useful information such as the vendor gallery and links to vendor Web sites. The staff reviewed Protocol Implementation Conformance Statements (PICS) and BACnet Interoperability Building Blocks (BIBBs). Useful information was also found on the BACnet Testing Laboratory (BTL) Web site and the BACnet International Web site.

The research identified three manufacturers as possibilities. In addition, the district wanted to give its current vendors the opportunity to be considered. A total of five manufacturers/vendors were chosen as potential bidders.

Evaluating BACnet Systems

The district wanted to be sure they would receive the functionality they needed. An added concern was that the district's consulting engineers and architects were not adequately knowledgeable to specify the new vision of an open protocol system. A live demonstration of interoperability was suggested to allow vendors to demonstrate how well their systems could operate on the district's network under actual conditions. The district's controls staff proceeded to create an objective test that was dynamic. The prescribed demonstrations would test the interoperability of each system.

The controls staff created a list of functions they wanted a system to provide and an associated test procedure for each function. Each vendor is required to demonstrate the ability of their system to:

- Reside on the district's wide-area network, and make information available anywhere on the network;
- Self-discover BACnet objects from any workstation connected to the network—no manual or deliberate mapping of databases;
- Create standard BACnet objects;
- Allow for the tuning of a PID control loops;
- Create custom programming;
- Backup all configuration and program information;
- View, override and modify all aspects of any control system;
- Objects and programming (on site and remotely); and
- Create, delete and modify standard BACnet objects.

The district formally invited the five vendors to participate in a product demonstration/interview. The results of the dem-

onstration are used to pre-qualify bidders for two elementary school construction projects. The invitation included a nine-page detailed description of the step-by-step live demonstration they may be asked to execute. It also listed all documentation the district wanted.

The required documentation determined compliance for the upcoming projects and future projects. Each vendor was required to provide the following at the demonstration/interview:

- BACnet Protocol Implementation Conformance Statement (PICS) and BACnet Interoperability Building Blocks (BIBBs) documentation for any products proposed for the upcoming elementary construction projects;
- A network diagram outlining the proposed building automation system for these projects. This diagram would include system architecture, specific model and point

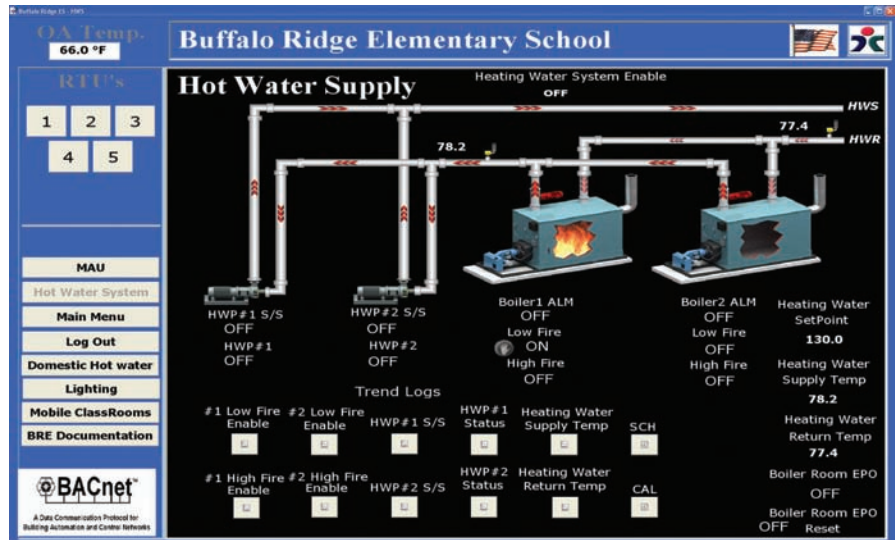


Figure 2: DCSD's standard graphics provide links to trend logs, schedules and calendars.

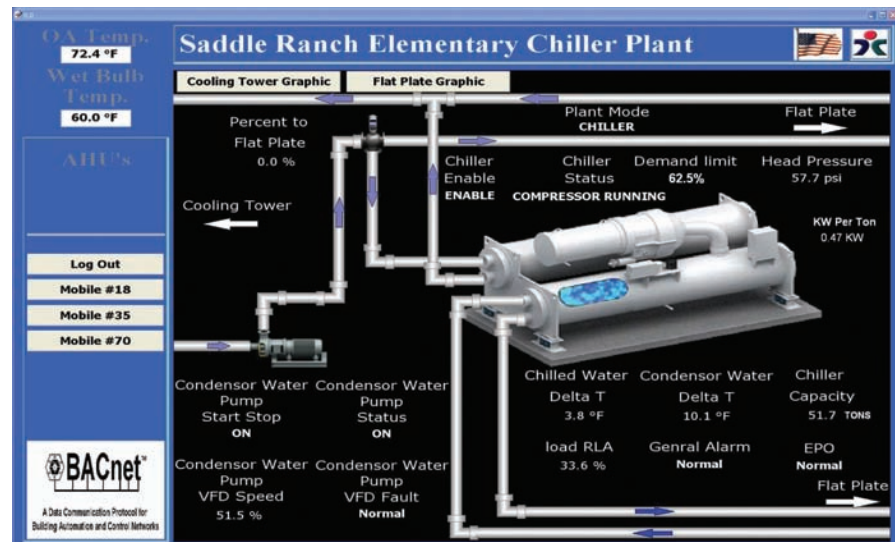


Figure 3: Graphic presents streamlined BACnet data from three manufacturers.

- capacity for each device, the network speed at all levels, and the number of devices on the proposed system;
- Written confirmation indicating which of the district's points and features were included in the proposal for these projects;
- Written confirmation that the building automation controller's proposal provide the trending capacity specified;
- Written confirmation that the building automation controller's proposal meet the spare-point capacity specified;
- A written training plan for providing unlimited training as specified along with curriculum and frequency of each class; and
- A list of references from schools where similar systems have been installed.

In addition, each vendor was given an opportunity to present any additional information that would support their proposal:

- Benefits and features unique to their products

- Installation practices including:
 - The qualifications of the vendor installation personnel or subcontractors
 - Photographs of existing installations
 - Special certifications, e.g., UL 508A fabricated panels
 - Device labels and tags
 - Warranty support staffing and response time including:
 - The number of staff available to respond to warranty requests
 - The location of their service department
 - Post-warranty support
 - Process and lead time to receive replacement parts
 - Availability of a software subscription or other process to keep the district's software tools current
 - Hourly rate for service calls
 - Examples of as-built documentation
 - Examples of typical HTML graphics
- More important than the documentation was the live dem-

Testing the Vendors

Nine pages of detailed directions were given to the vendors. This shows an example of one section.

User Interface Demonstration—Object Creation, Overrides and Alarms

Step 1

Vendor creates a weekly schedule to command the supply fan BO on and off at the following times:

Day	On	Off
Monday–Friday	06:00	18:00
Saturday	09:00	13:00
Sunday		All Day

Step 2

DCSD demo facilitator performs self-discovery at BACnet operator workstation.

- Weekly schedule appears at operator workstation as a BACnet object.

Step 3

Vendor configures the Supply Fan Failure Event to announce an alarm to the BACnet operator workstation if the Supply Fan Status BI fails to detect fan operation when the Supply Fan Command is ON; note that no alarm should announce if the Supply Fan Status BI detects fan operation when the Supply Fan is OFF.

Step 4

DCSD demo facilitator performs self-discovery at BACnet operator workstation.

- Event appears at operator workstation as a BACnet object.

Step 5

Vendor adjusts digital controller time and date to an "occupied" time.

- Supply Fan Command BO indicates ON at BACnet operator workstation.
- Supply Fan Failure Event alarm message annunciates at BACnet operator workstation.

Step 6

DCSD demo facilitator manually overrides Supply Fan Status BI to the ON condition using the BACnet operator workstation.

- Supply Fan Failure Event indicates "return to normal" at BACnet operator workstation.

Step 7

DCSD demo facilitator manually overrides Supply Fan Command BO to OFF condition using BACnet operator workstation.

- Supply Fan Failure Event remains Normal at BACnet operator workstation.

Step 8

DCSD demo facilitator releases the manual override to Supply Fan Command BO using the BACnet operator workstation.

- Supply Fan Command DO indicates ON at BACnet operator workstation.
- DCSD demo facilitator performs self-discovery at BACnet operator workstation.
- Trend object appears at BACnet operator workstation.



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onstration. Each vendor was allowed 30 minutes to set up its equipment. To facilitate a quick setup of the demonstration, DCSD provided hardware and software to simulate the existing DCSD wide-area network. In addition, DCSD suggested that each vendor preconfigure their BACnet/IP device to a specific IP address. They were given two hours to complete all sections. A review committee of district staff from the O&M and construction departments, as well as outside architects and consulting engineers, was present for each vendor's demonstration.

Each vendor was required to follow a number of predefined demonstration sequences. The demonstration included interoperability tests of the following objects:

- Inputs and outputs;
- System variables;
- Schedules and calendars;
- Trend logs;
- PID loops; and
- Database backups.

A brief example of the detailed test can be found in the sidebar "Testing the Vendors."

Results

The test was straightforward and invaluable. Of the five vendors evaluated, one was unable to get its system to communicate over the BACnet/IP network, one performed 20% of the test successfully, one performed 70% successfully, and one performed 90% successfully. Only one vendor performed the tests 100% successfully.

Most vendors brought in factory experts, i.e., technicians or design engineers. Only one used only local support to set up and perform the test, which they completed 100%.

In the end, the evaluation committee selected two vendors for its current and future projects. The selection has ensured that both systems can interoperate over a common district IP network and are accessible via the Web while using BACnet. The goals of maintaining competitive bidding and interoperability were achieved.

Lessons Learned

The demonstration was a learning experience for all involved. At least one manufacturer redesigned its product because of what it learned during its demonstration. The district's consulting engineer admitted that although they had been specifying building automation systems for years, they did not really understand how the systems worked until they participated in this evaluation.

Often, the consulting community is not well versed in controls and may not be well informed about open protocols. Even with BACnet Testing Laboratories Listings (BTL), PICS, BIBBS and vendor promises, not all BACnet systems can perform the critical tasks that an owner wants. Nothing in those certifications or listings says the system has to be easy to use. Tasks that appear routine to a qualified vendor, such as creating an alarm object and trending objects, are not always simple.

Building automation systems are important to the proper operation and energy management of your building. Substantial time and effort are needed to prepare for selecting your next building automation system. Do not take a salesperson's word for what a system can do. Find a manufacturer that will prove that its system works and integrates the way you need it to. Most BACnet building automation systems perform the same tasks, but it is important to recognize some do them better than others. A building automation system that the O&M staff can understand and interact with is less likely to be overridden and ultimately saves energy and improves comfort over the lifetime of the system.

Research manufacturers and vendors before buying your next building automation system. Identify what you want your system to do now and in the future. Test drive the system before you buy.

Acknowledgments

The graphical interface illustrations were created by Richard Pumo, controls specialist for Douglas County School District RE-1. ●