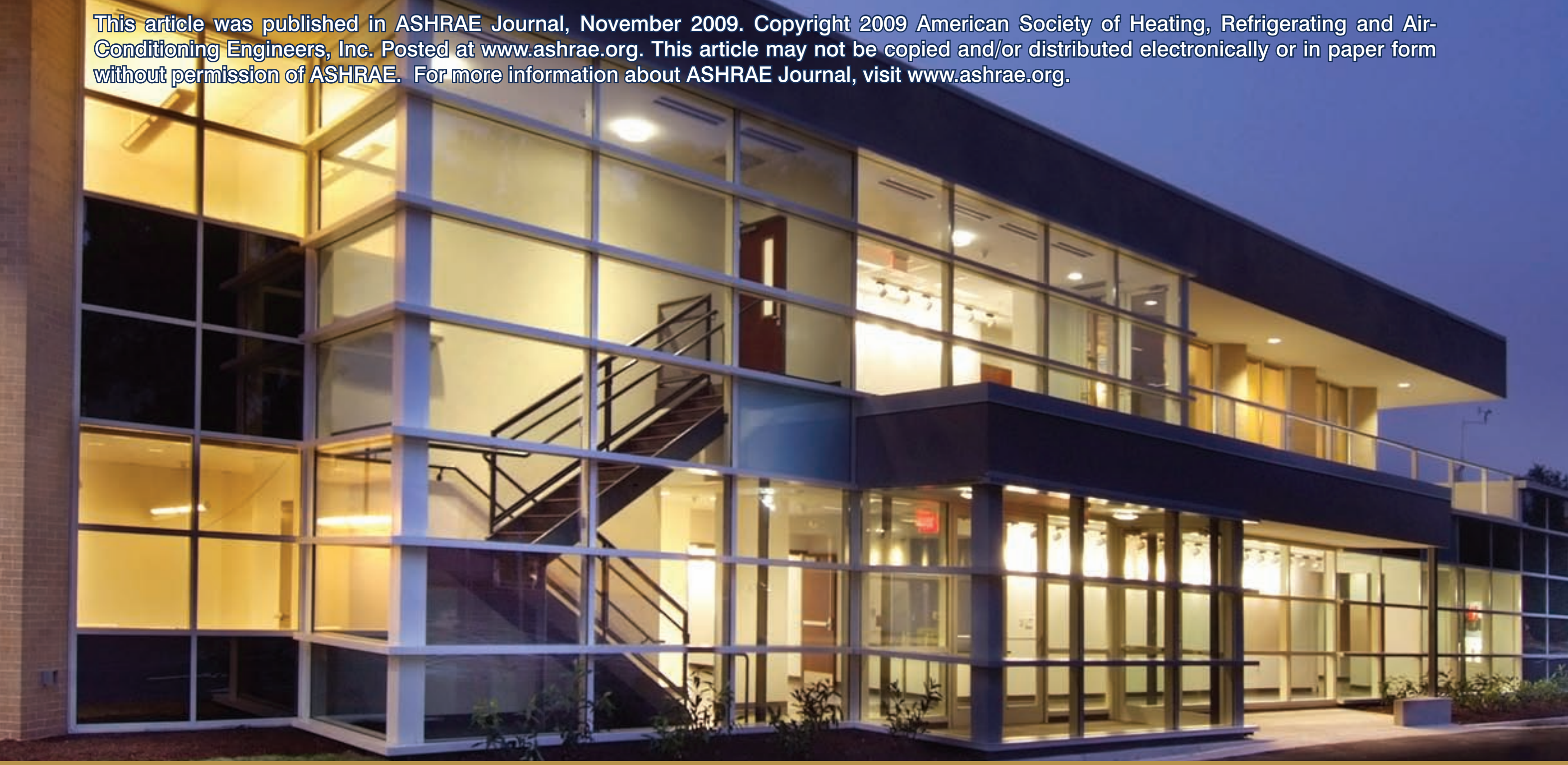

An UnTangled Web

How BACnet® Is Connecting At ASHRAE's Headquarters

By Steve Tom, Ph.D., P.E., Member ASHRAE

Oh what a tangled web we weave,

When first we practice to deceive!

Sir Walter Scott may not have been thinking of building automation systems when he penned those lines, but until BACnet came along anyone who tried to build a control system using products from multiple vendors might have felt the vendors were trying to deceive. At the very least, they certainly weren't trying to make things easy. Proprietary protocols, multiple network topographies, custom user software, and incompatible wiring turned many control rooms into a tangled mess. BACnet became the great untangler. Add another level of openness by putting the control system on the Web, and you have the ASHRAE Headquarters Renovation project.

The ASHRAE Headquarters building was originally constructed in 1965 to provide offices for an insurance company. ASHRAE purchased the building in 1981, performed extensive renovations, and made other modifications to the building throughout the 1990s.[1] As with many buildings that have lived through multiple changes in use and configuration, energy efficiency and indoor environmental conditions fell somewhat short of ideal. The ASHRAE Board of Directors decided in 2005 to initiate a major building renovation with sustainability as a central theme. They set a goal of achieving LEED-EB and LEED-NC Gold ratings from the U.S. Green Buildings Council. They also decided to create a "Living Lab" and make building performance data available to researchers around the world via the Internet.[2]

Since no one company has a monopoly on good ideas, the decision to

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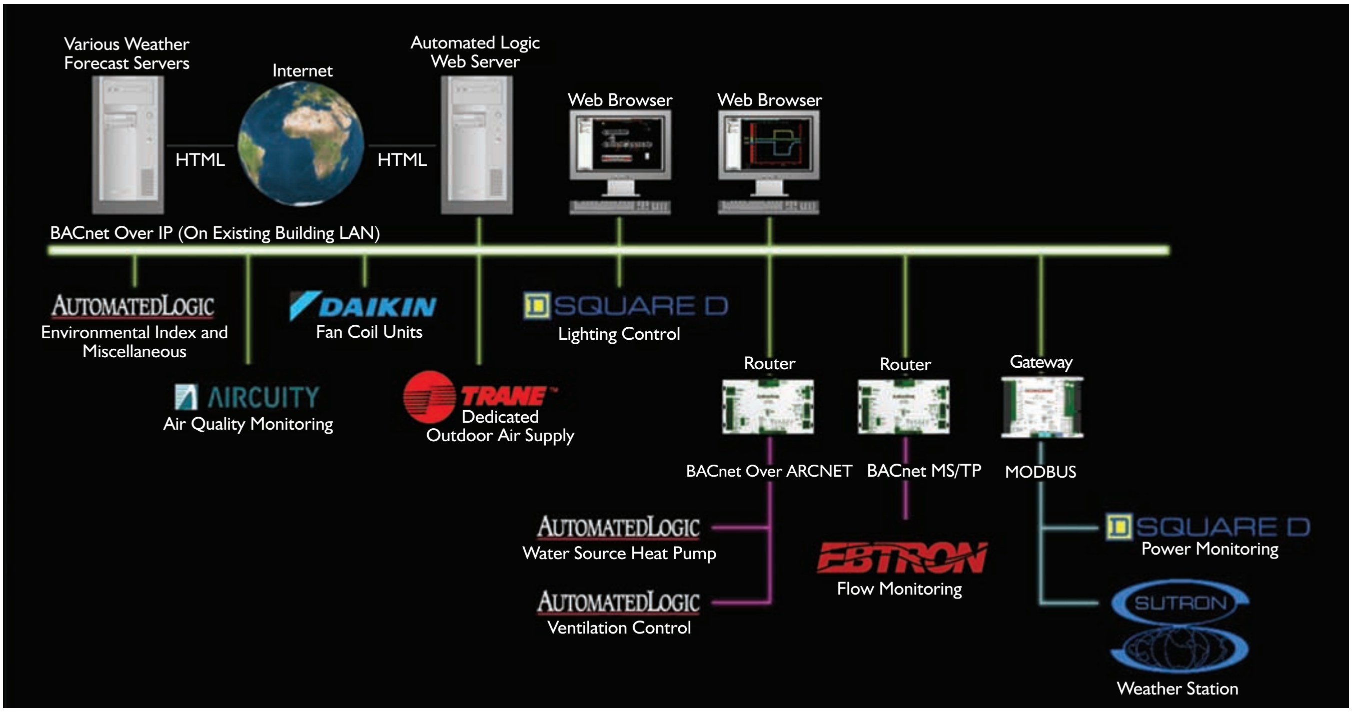

Figure 1: Controllers monitor overall building conditions and miscellaneous monitoring systems.

make this a showcase for innovative building technologies meant there would be multiple vendors' equipment used in this project. The operation of this equipment had to be closely integrated to maximize the overall building performance, which made BACnet the logical choice for the building automation system. BACnet was designed from the ground up to provide a common protocol for building automation, allowing manufacturers of HVAC, lighting, and other building systems to communicate freely. It also provides a widely accepted interface for equipment using other protocols, such as MODBUS, to interface with the main building automation system.

In this project, BACnet integrates information from 23 types of major equipment made by seven manufacturers into a single user interface. Much of this equipment is native BACnet, but MODBUS and HTML protocols are also integrated into the system. The user interface presents roughly 1800 I/O points and key software values on the graphics, with countless additional data values available through trends, schedules, configuration properties, and other detail screens.

The BACnet network consists of a BACnet over IP backbone that runs over the existing building LAN. Five BACnet routers link this backbone to two BACnet over ARCNET controller networks and three BACnet MS/TP controller networks. One hundred and twenty control devices are connected to these networks. Device IDs are generally assigned by the vendor that supplied the device, using the convention of having the vendor's BACnet number serve as the first two numbers of the device ID. Overall coordination of the device IDs and integration of the BACnet system was performed by the vendor who supplied the main building automation system. A conceptual network diagram of this system is shown in *Figure 1*.

Figure 1 shows that controllers that monitor the overall building conditions and miscellaneous monitoring systems (environmental Index,[3] refrigerant leak monitoring, photovoltaic power monitoring, etc.) are connected directly to the BACnet/IP backbone. This network also has an indoor air quality monitoring system. The air monitoring system automatically retrieves air samples from throughout the building, and tests the samples for CO_2, particulates, and humidity using laboratory quality sensors.

Variable refrigerant flow (VRF) fan coil units provide primary heating and cooling on the first floor of the building. These units can be accessed via a manufacturer's control panel connected to the BACnet/IP backbone. Ventilation is provided by a dedicated outdoor air supply (DOAS) unit from a different vendor that supplies zone VAV boxes controlled by a third vendor. BACnet integration of schedules, overrides, sensor readings, and other key data is essential to the operation of these units.

Some custom integration logic was required for the fan coil units because the operating modes for these units did not directly correlate to the heating and cooling setpoints used by other equipment and because these units operated on Celsius while the rest of the building systems operated on Fahrenheit. A typical fan coil graphic is shown in *Figure 2*. The data on this graphic comes from three vendors, but BACnet allows it to be seamlessly integrated into a single user interface.

A field-installed set of dampers and airflow stations controlled by the primary BAS manufacturer controls the flow through the unit to maintain the required ventilation and building static pressure, while the unit is controlled by an OEM BACnet controller that sits on the IP backbone. All the zones within the building communicate their needs for heating, cooling, ventilation, and dehumidification to the controls for this unit, which then adjusts its operation to meet the aggregate needs of the building. More than 200 BACnet communication links are used to optimize the control of this unit. The primary graphic for this unit is shown in *Figure 3.* A separate graphic was used to illustrate the control of the dampers and airflow stations.

Lighting control is provided by BACnet-controlled circuit breakers connected to the IP network. Zones near outside walls contain photocells that automatically scale back on the amount of energy used for artificial lighting when natural lighting is available. Interestingly, these sensors are connected to a controller made by a different vendor than the lighting panel but are integrated into the lighting control scheme using BACnet.

Ventilation for the VRF zones on the first floor and heating, cooling, and ventilation for the water source heat pumps (WSHP) on the second floor are controlled by controllers on a BACnet over ARCNET field bus. This is connected to the main IP backbone by a BACnet router. Since the networks on both sides of this router are BACnet, complex data such as alarms, schedules and trends pass freely through the router. The router simply transfers the BACnet messages from one medium to another, similar to the way telecommunica-

Figure 2: BACnet allows data from three vendors to be integrated in one place.

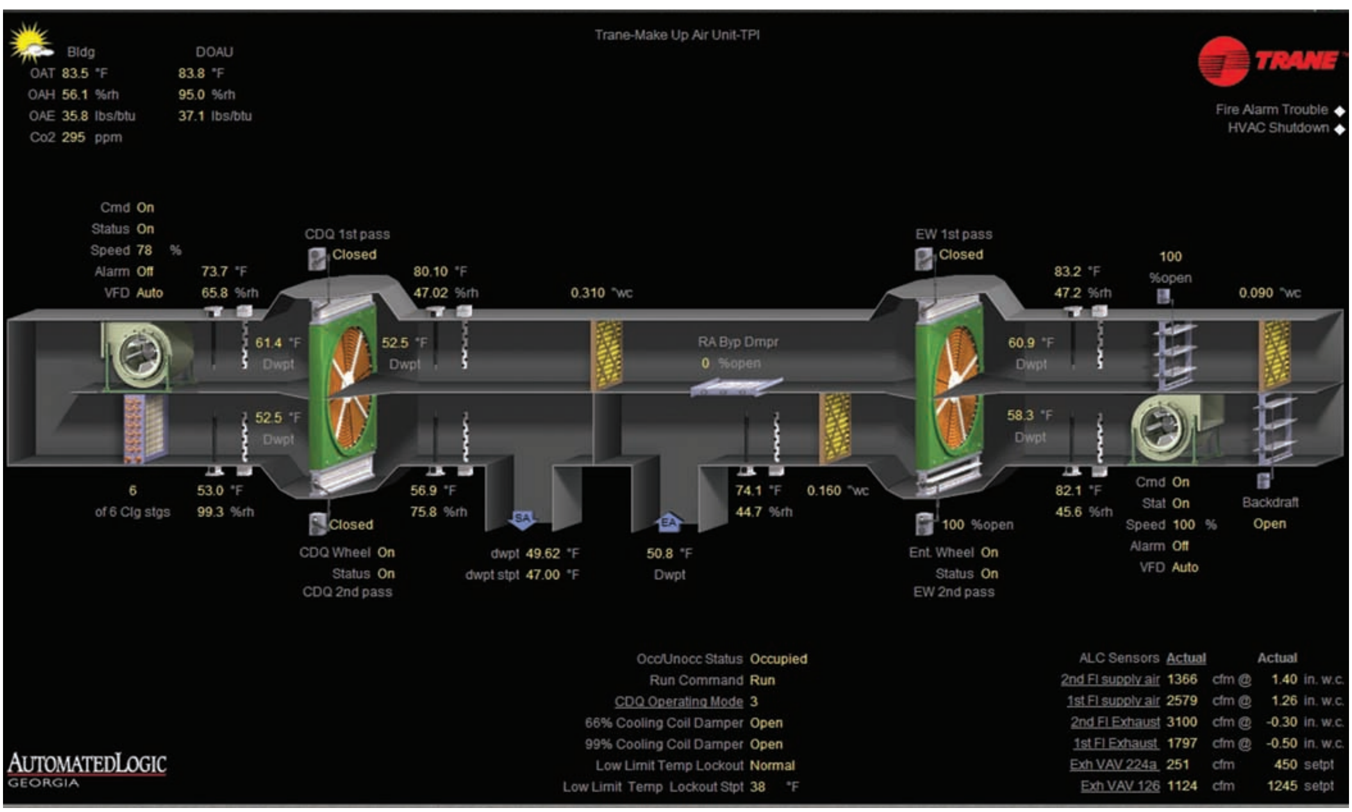

Figure 3: More than 200 BACnet communication links optimize control of this dedicated outdoor air system.

tions routers transfer audio and data signals between fiber optics and copper wire. A similar router connects the main IP backbone to a BACnet MS/TP network used to provide independent monitoring of selected VAV boxes. A typical graphic for one of the WSHP units is shown in *Figure 4*. As with the other graphics, information on this graphic comes from multiple manufacturers' systems.

Power monitoring and data from an outdoor weather station are provided through a MODBUS interface. This requires a protocol translator or gateway between the two networks. As is typical of gateways, this transfers individual data values but not complex data structures like schedules or trends. Neither of the MODBUS systems requires schedules, and trending of the data from the MODBUS devices is provided by a BACnet controller on the BACnet side of the gateway. The power monitoring includes total building consumption and submetering of the major systems, lighting loads, and plug loads on each floor. (As a side note, the MODBUS meters and BACnet lighting controls are from the same manufacturer. It is not unusual for manufacturers to offer this type of equipment with two or three protocol options, to make integration easier.)

At the top level, a Web server collects information from all the vendors' equipment and generates Web pages that provide the user interface to the system. Depending on the privileges assigned to them, users can view the system, run reports, make minor adjustments to setpoints and other operating parameters, or make major changes to the control logic through a standard Web browser. These browsers can be connected to the local building network or anywhere with Internet access. As shown in *Figure 1*, this Internet link also allows weather forecasts to be incorporated into the BAS Web pages. If the weather data had been needed by control applications, a BACnet Web services link could have been established, but since the information is only being presented as information on a graphic a simple html link between Web pages is used. A Web services link will be used in the future to extract data from the system and make it available to researchers accessing the Living Lab data.

Figure 1 shows how everything should connect in theory. How does it work in the real world? Very well, according to Charles Miltiades, an engineer with Automated Logic of Georgia and the primary controls designer on the project. "We provided the equipment suppliers with the device instance numbers and IP addresses we wanted them to use, and then we used BACnet discovery to map their points."

He noted that this was easier and less error prone than trying to type point addresses into all the integration mappings, like they had to do with the MODBUS interfaces. The most difficult part of the integration was getting the fan coil units and the ventilation units to work together to achieve the desired zone temperature, as the operating sequence for the fan coil units did not use heating and cooling setpoints in the same way the ventilating units did. This was a controls challenge, but not a protocol issue. Once Miltiades figured out how to get the dif-

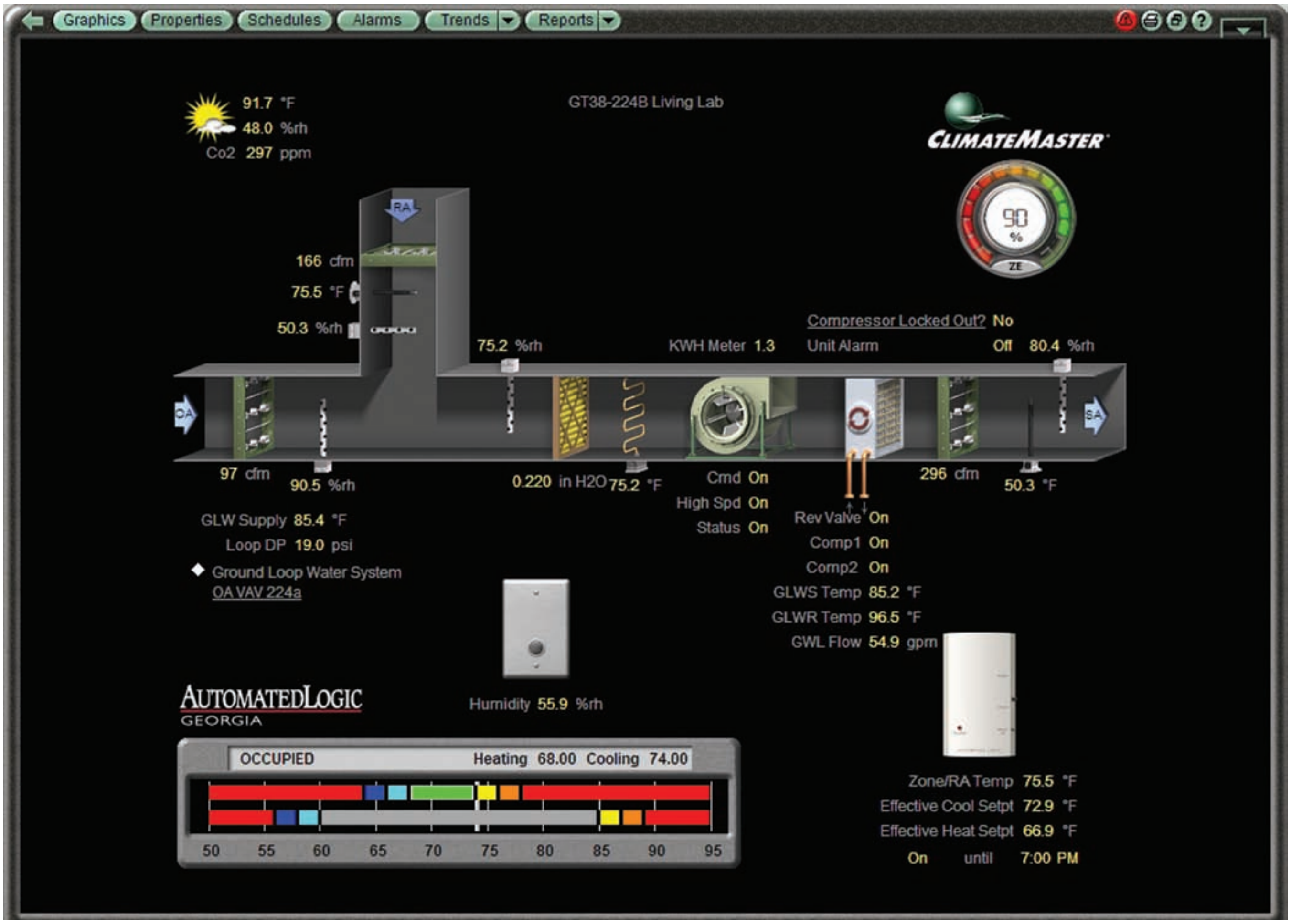

Figure 4: Typical water source heat pump graphic, displaying data from multiple manufacturers' equipment.

ferent equipment sequences to work together, BACnet made it easy to link them.

Miltiades also noted that this project, by its nature, enjoyed a high level of support and cooperation by all the vendors. He has worked on other projects where the local representatives were not easily found or did not know what points were available through their equipment interfaces.

"BACnet discovery is even more valuable on those projects" he observed.

From the end-user perspective, BACnet provides a seamless integration. "It appears to the user to be one large system," said Michael Vaughn, ASHRAE's manager of research and technical services. He also noted that "it allows me to easily recognize subsystems and navigate, for example, between the building's weather station, sub-metered power panels, and zone set-points with just a click or two of the mouse. The ability to trend and view points on a variety of systems with just a few clicks is another big improvement for us." Vaughn estimates the building's energy use is about 30% below the baseline consumption in 2007, but there is still room for improvement.

"We are still commissioning some systems for the cooling season and optimizing others," he said. "The BAS has been very useful in this effort by helping to identify areas that require additional attention or could be improved."

This is helping them to exceed their initial goals for the building. They believe they have more than enough points to qualify for a Platinum rating under LEED-NC, but USGBC is still reviewing the construction phase credits.

Vaughn described some additional goals, "We also hope to obtain a new construction rating under the Green Building Initiative's Green Globe rating system. Once the building is fully commissioned and after we have a full year's worth of operating data, we plan to obtain ratings under LEED EB, ENERGY STAR, and Green Globes to name a few."

Perhaps most importantly, he noted that the system provides a consistent space environment year-round, which gives people a comfortable and healthy place to work.

References

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3. Tom, S. 2008. "Managing Energy and Comfort." *ASHRAE Journal* 50(10):18–26.