A Simple Way To Specify BACnet®

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

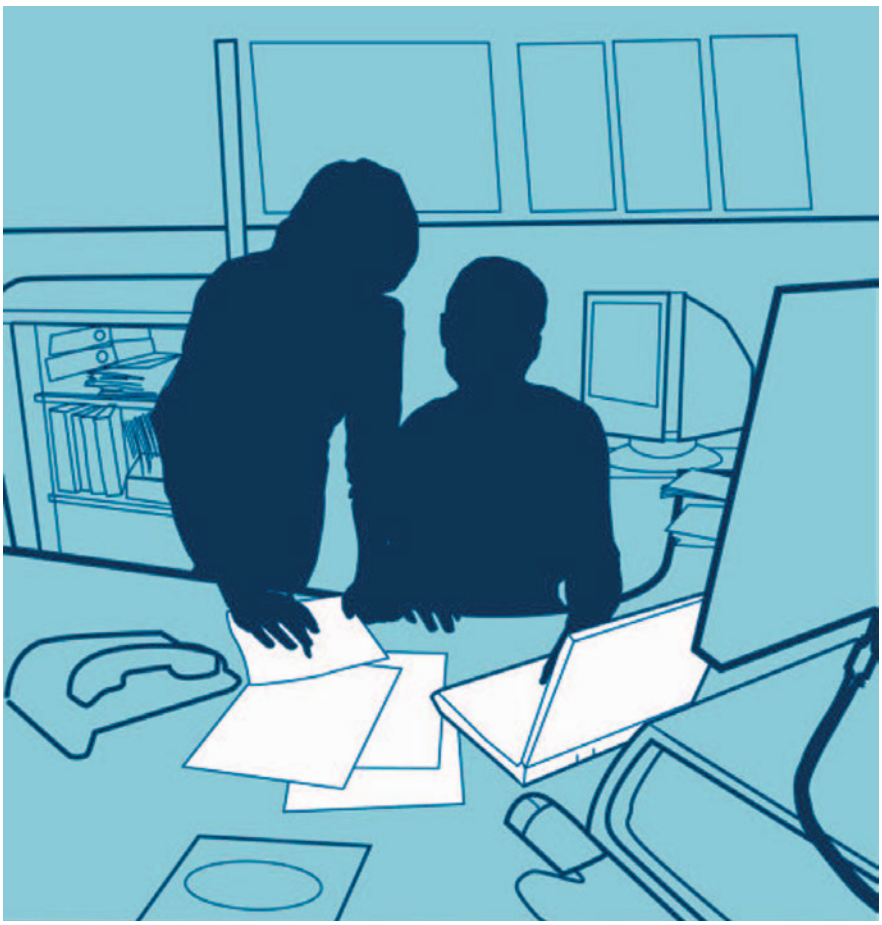
A young schoolboy who had to write a report on porcupines went to his local library for help. The librarian enthusiastically showed him how to use the many encyclopedias and other references available to him. After spending a few hours with these resources he began his report by saying, "I learned a lot more about porcupines than I ever wanted to know."

Many specifying engineers have a similar view of BACnet. ASHRAE developed BACnet in response to requests from end users who wanted a way to integrate digital controls from multiple vendors into a single, integrated, building automation system.

When BACnet was first released, engineers who wanted to specify BACnet turned to the only reference available to them, ANSI/ASHRAE Standard 135-1995, *BACnet — A Data Communication Protocol for Building Automation and Control Networks*. Unfortunately, this document was written to formally establish all the "nuts and bolts" of the BACnet protocol. It is an invaluable reference to a research and development engineer designing a new piece of BACnet hardware, but it was never intended for specifying BACnet systems. In short, it has a lot more information about BACnet than most specifying engineers ever wanted to know.

Nevertheless, there's an old saying that "when the only tool you have is a hammer, every problem looks like a nail" and it wasn't long before project specifications began delving into data link layers and object access services. With time, some specifying engineers became BACnet gurus, able to keep track of new products that were entering the market and use their detailed knowledge of BACnet to specify exactly the products they wanted for a particular project.

Many engineers, however, didn't have the time, inclination, or economic justification to become BACnet experts. They wanted to specify an open protocol that wouldn't leave them locked into a single vendor for all subsequent controls



work, but their project simply didn't warrant an in-depth protocol analysis.

This article is written for these users. It presents a simplified approach to specifying BACnet control systems.

Underlying this approach are three basic concepts:

- No single "right" way to specify BACnet exists. Some projects may require detailed protocol specifications, while a more general approach may suffice for others. The needs of the customer should determine the level of detail.
- The primary goal of a BACnet control system is to control the building. A good control system specification needs to define what the control system will do and how it will present information to the user. The protocol is an important adjunct to these functions, but the project will succeed or fail based upon its performance, not its protocol.
- The BACnet Testing Lab (BTL) can be trusted to verify BACnet compliance. The BTL was established to test and certify products that conform to BACnet Standard Device Profiles. If you design your project around these profiles, you don't need to duplicate the BTL specifications or testing.

With these principles in mind, the following procedure can be used to prepare BACnet specifications for most building automation systems.

Define Your Interoperability Goals

When you talk to facility managers, everyone seems to be in favor of open systems and interoperability. When pressed for details, however, they all have a different interpretation of what interoperability means. Since interoperability is the fundamental reason to specify BACnet, it's important to spend some time deciding what your interoperability needs are.

One of the most common goals of interoperability is to integrate equipment and systems from different vendors into a single building automation system (BAS). Certainly it makes sense to integrate chillers, boilers, variable frequency drives, and similar equipment with the HVAC zone and air-handling unit controls.

The lighting system is another logical candidate for integration into the BAS. You also may want to integrate the fire and security systems into the same BAS. Give some thought as to what type of information from these other systems needs to

be shared with the BAS. It's often very useful to bring alarm and status information together in a single operator workstation, so one individual can monitor all the critical systems in a building. It may be less important to bring maintenance and configuration information into this workstation, particularly if the systems are maintained by separate contractors or separate in-house teams that will use their own dedicated software tools for this task.

If one particular system has only a few monitoring or control points of interest, it may even be more cost-effective to use hardwired points than to build a protocol interface. Determine what information needs to be shared, and detail that requirement in your specification.

The ability to obtain competitive bids on future projects is another compelling reason to specify an open system. It is frustrating to award a contract to a contractor you really don't like because you're locked in to the system provided in a previous contract. Even if you're happy with your current BAS vendor, the ability to get competitive bids on future projects helps to keep costs down.

BACnet has a particular advantage when it comes to keeping your options open, as its support for high-level functions like trending, alarming, and scheduling makes the entire system open to competition. Not only can you have open bidding on the field hardware for any follow-on projects, you can even replace the existing front end if you're not happy with it.

This is not a decision to be taken lightly, as a fair amount of engineering is involved. But, it's not nearly as daunting a task as it would be if the alarms, trends, schedules, time sync broadcasts, file transfers, and other high-level functions all relied upon proprietary protocols. From a specification standpoint, if you want the option of changing vendors at a future date, you need to ensure you specify BACnet for these functions.

Another goal of interoperability is to have the ability to replace one vendor's controller with a similar controller made by a different vendor. This is perhaps not as critical as the first two goals for the simple reason that most DDC controllers are remarkably long lived. When they do go bad, the cost of buying a replacement from the original vendor is not nearly as high as the cost of being locked into that vendor for all future projects.

Nevertheless, you may want to replace a controller with a competitor's product. You may have had a bad experience with one type of controller, and decide to replace this particular model with another vendor's product whenever they fail. You may be plagued with a predatory vendor, who demands unreasonable prices for a replacement controller. Or, your system may be old enough that the existing controller is no longer supplied.

In any of these situations, your specification must provide the flexibility to replace Vendor A's device with one from Vendor B. The easiest way to do this is to require all controllers to conform to one of the standard BACnet device profiles. This will ensure that the basic BACnet functions supported by the original controller are supported by the replacement. Be forewarned that some configuration and programming is required.

Marketing claims notwithstanding, replacing HVAC controllers is not a plug and play operation no matter what protocol you are using. Simple devices like smart sensors and smart actuators may be nearly plug and play, but they still need to be addressed.

Application-specific (canned program) controllers probably will require you to choose among various configuration options to find a configuration that replaces the previous controller, and may require minor edits to the network links of any control programs or graphic that communicates with this controller.

Fully programmable controllers will require you to create and download a replacement control program using programming tools specific to the new control vendor. This is not nearly as onerous as it sounds because it's not required very often, and the new control program can be used in any future controller replacements. For logistical and maintenance reasons, you will want to limit the number of different vendors and controllers in any one system. If you decide to replace Vendor A's VAV controller with Vendor B's, it makes sense to use Vendor B's controller for all future replacements as well.

An alternative strategy to ensure you can replace one vendor's controller with a competitor's product is to specify precise details concerning the controller capabilities, network architecture, object names, and other BACnet properties in your initial BACnet project. If you get all the details right, you could substitute a different vendor's controller with no additional programming or configuration. You could even build a control system yourself, using multiple vendors' components, and not rely on a "lead" controls contractor.

A drawback to this approach is that it requires the specifying engineer to have a thorough understanding of the BACnet protocol and the specification must include detailed information about the BACnet Interoperability Building Blocks, BACnet Broadcast Management Devices, baud rates, etc. This approach is fine if your interoperability needs require it, but it is not the approach described in this article.

Specify What You Need

It's human nature to go into great detail in areas of a specification where details are readily available, and to skimp on areas where details are hard to find. Too much detail can eliminate potential bidders and drive up the cost of your system, while too little leaves you vulnerable to a system that doesn't meet your needs. "You get what you pay for" is certainly true in the world of bid contracting, but so is its corollary, "You pay for what you get."

In general, it's best to tell the bidder what you need, not how to achieve it. If there's a specific reason why you need four-wire platinum zone sensors and 16-bit A/D converters, specify them. Be aware that the sensors cost much more than a standard zone sensor would, and most zone controllers don't have 16-bit A/D

converters. With this specification you'll either exclude bidders or force them to use much more expensive hardware than their standard zone controllers. If what you need is simply an end-to-end accuracy of 0.5°C (1°F), include that in your specification. Multiple bidders can meet that specification at a much lower cost by using standard zone sensors and controllers.

A good way to promote interoperability is to require installation of a BACnet/IP "backbone" for your system. Most, if not all, major BACnet vendors can use BACnet/IP, so requiring a BACnet/IP backbone provides a good connection point for multiple vendors. BACnet/IP also is compatible with the Ethernet protocol, used by most IT departments. In many applications, the existing IT network will work fine as the BACnet backbone.

If you're going to use an existing IT network, it's essential to coordinate with your IT department as early in the specification process as possible. They may have some specific network security requirements to include. If they're going to support the system they may have special computer and operating system requirements as well. When working with IT, coordinate early and often. Hell hath no fury like an IT administrator who catches someone hanging an unapproved router on his or her network.

A fair amount of diversity exists in the field bus architecture used by various manufacturers, so it's best to leave some flexibility. It's seldom cost-effective to run high-speed Ethernet to every VAV controller and smart sensor in a building, so most vendors use a lower-cost twisted-pair field bus for these controllers. MS/TP is probably the most widely used field bus, but some vendors use BACnet/ARCNET, and at least one vendor uses BACnet/LonTalk. Unless you have a compelling need to standardize on one particular field bus type, you will get more competitive bids if your specification allows the use of any of these standard buses.

The primary integration network for future projects is the BACnet/IP backbone, so the existing field bus architecture has no impact on new additions or major renovations. The existing field bus comes into play if you need to make minor additions to your system or replace an existing controller. Even at this level, you are not "locked in" to the original vendor. Several manufacturers support multiple field bus networks, and some controllers can even be switched from one bus type to another. Bridges and routers exist to make seamless connections between different field bus types.

One item you don't want to be flexible about is requiring that the installed system, control program, graphics, database, and all tools needed to program, maintain, and configure the system belong to the customer. One of the primary interoperability goals is for the customer to not be "locked in" to a specific vendor for follow-on work. If the customer doesn't have the engineering tools, the source code for the control programs, and all other software needed to engineer changes to the system, he will depend on the vendor who does have these tools. These tools need to be provided as a part of the contract, and the customer must be free to use them royalty-free to maintain his own system.

It's also essential that your specification makes it clear who is responsible for different parts of the integration task. The primary responsibility for integration lies with the BAS contractor, but contractors supplying other systems need to provide a BACnet interface to their system and expose required information as BACnet objects. This is one area where gateways (protocol translators) may be perfectly acceptable. It isn't necessary, for example, for the boiler manufacturer to expose his entire control sequence to BACnet. For safety reasons, I would prefer the BAS operator *not* be able to edit the boiler ignition sequence. However, it is important to have basic start/stop controls, setpoint adjustments, and similar information exposed to the BAS.

The responsibility to provide a BACnet connection to this data must lie with the vendor who supplies the boiler, and it must be clearly spelled out in the boiler specifications. It is unreasonable to expect a BAS vendor to provide interface panels to every other vendor's system. Since the identity of the other vendors often is unknown when the BAS goes out for bid. There is no way a BAS vendor could prepare a realistic bid that covers every possible supplier of affiliated equipment.

When writing BACnet specifications, use extreme caution if you "borrow" any text from a vendor's sample specification. Most vendor specifications are written to specify that vendor's system. As such, they are filled with "hooks" that require their product and exclude others. Sometimes, these hooks are obvious, as when a brand and model number is included in the specifications. Sometimes the hooks are much more subtle, such as "Building Controllers shall support the following objects and services..." followed by a reasonable-sounding list that happens to only be available from a single vendor. Certainly it can be useful to review these specifications and incorporate whatever ideas are applicable into your project. Be sure you understand the text and aren't specifying details you don't really need.

Specifying Controls

It is very common to see a specification for a DDC system that goes into great detail describing the control hardware, the network architecture, and the operator workstation, with almost no information about how the system is supposed to control the building. This is understandable, as it mirrors the content of the typical "canned" vendor specification. The vendor is selling control hardware and software, so the vendor's specification will describe these in great detail. The vendor is not selling control algorithms, and his specification will not include what mechanical equipment is in your project, so the vendor specification won't detail how various pieces of equipment are to be controlled. This approach may be understandable, but it also is unacceptable.

The primary purpose of a DDC system is to control the building, particularly the mechanical systems. At a minimum, the specification should include the following information for every piece of equipment to be controlled.

1. Operation Sequence. The operation sequence provides a plain text explanation of how the equipment needs to operate in every conceivable mode of operation. (Normal occupied hours, unoccupied hours, smoke purge, etc.) Key control parameters such as setpoints and alarms should be included in the sequence. Take special care to document how local or system-wide energy optimization strategies such as electrical demand limiting or optimal start will affect this equipment.

2. BACnet Object List. BACnet specifies *how* two different systems will exchange information, but the protocol is useless unless you also specify what information will be shared. A BACnet Object List identifies key equipment control data that will be available to other BACnet systems. Most equipment control specifications contain a points list, but for a BACnet system, this should be expanded to include all required BACnet objects. This means the list should include software points, such as setpoints, trends, and alarms, as well as the more traditional hardware (input/output) points. Including software points on this list leaves no doubt as to what information must be available via a BACnet interface to another vendor's system. It also helps to remove any ambiguity about what has to be provided as part of this contract. A world of difference exists, for example, between a specification that says, "any point shall be trendable" and one that includes a table that says, "in this piece of equipment the following points shall be configured to collect trend data with a five-minute sample rate: zone temperature, heating setpoint, cooling setpoint, fan status,…."

Additional information that may be included with each piece of equipment includes:

3. Schematic. Often a simple line diagram that indicates the basic layout of the control system components can be helpful in understanding the sequence and object list. This is not a substitute for the project mechanical drawings, but simply an illustration that lets people see at a glance that "this system has a return air and an outside air duct, a supply air-temperature sensor, a humidity sensor in the return air duct," etc. Keep it simple. Worrying about details like two-way versus three-way valves or parallel blade versus opposed blade dampers is a waste of time if these details are irrelevant to an understanding of the basic control logic.

4. Startup and commissioning instructions. Whether or not you plan to have an independent commissioning agent verify the installation, the controls contractor must do an initial startup and commissioning of his control system. The thoroughness of this commissioning can vary greatly from one contractor to another, so an equipment-specific set of instructions showing what you expect helps "level the playing field" at bid time. These instructions can be even more effective if they're provided as a checklist that requires the contractor to initial each step as he completes it, to write down calibration adjustments and final PID gains, and to provide a printed trend graph of every control loop that shows stability over a 24-hour period.

Use Existing Standards And Resources

Writing a good DDC specification is hard work no matter how you approach it. Don't make it even harder by reinventing the wheel. Several existing standards and guidelines can help make this task easier:

- **ASHRAE Guideline 13-2000,** *Specifying Direct Digital Control Systems*. This guideline provides instructions and sample text for nonproprietary DDC system specifications. The guideline offers detailed recommendations for specifying sensors, actuators, system tools, and other system-wide attributes. The need for operation sequences and other equipment-specific information is discussed, but no actual sequences are provided.
- **ANSI/ASHRAE Standard 134-2005**, *Graphic Symbols for Heating, Ventilating, Air-Conditioning, and Refrigerating Systems*. If you are including control schematics in your specification, this standard can help ensure the schematics are unambiguous and easily understood.
- **ASHRAE Technical Committee 1.4,** Control Theory and Application. Among other activities, this committee is preparing sample operation sequences with schematics and object lists, for commonly encountered HVAC equipment. These sequences are not yet available to the public. When released, they will be very helpful to specification writers.
- **BACnet Testing Laboratory (BTL).** The BTL tests BACnet devices to ensure they conform to the requirements of the applicable standard device profile and lists products that successfully pass the test. The standard device profiles defined by ASHRAE are the BACnet Operator Workstation (B-OWS), the BACnet Building Controller (B-BC), the BACnet Advanced Application Controller (B-AAC), the BACnet Application Specific Controller (B-ASC), the BACnet Smart Actuator (B-SA), and the BACnet Smart Sensor (B-SS). Two major benefits to specifying the use of BTL listed control devices are:
  - Interoperability has been tested and proven through more rigorous conditions than can be achieved in the field.
  - You're assured of multiple bidders. If you "custom design" a BACnet device by specifying a set of BACnet Interoperability Building Blocks that seems appropriate for your project, you may find that only a few vendors build a device that meets your specifications. Unless you've surveyed the market to see who makes what, you could even specify a device that nobody makes. By specifying BTL-listed products that use standard device profiles, you know multiple vendors can compete for your project.

Write Specifications Online?

Even this simplified approach to specifying BACnet requires a fair amount of work. Fortunately, an online tool exists that can help engineers prepare specifications for BACnet systems. It's called CtrlSpecBuilder™ and can be used free of charge at www.ctrlspecbuilder.com. CtrlSpecBuilder is based on

ASHRAE Guideline 13-2000 and uses the approach described in this article to prepare DDC system specifications. Although it is based on the ASHRAE guideline, CtrlSpecBuilder is neither affiliated with nor endorsed by ASHRAE. CtrlSpecBuilder is sponsored by the Automated Logic Corporation (ALC).

ASHRAE Guideline 13-2000 laid the foundation for a non-proprietary specifiification, so ALC created an online tool to help engineers to prepare specifications that followed the guideline. Its goal was to create a level playing field on bid day.

CtrlSpecBuilder uses "wizards" to create specifications. The user is presented with a menu that allows him or her to describe the controls project and select desired options. Sample text from the ASHRAE guideline is inserted, deleted, or edited according to these selections.

The tool also provides menus that let the user define the mechanical equipment and control options to be included in this project, and it uses these selections to prepare sequences of operation, point lists, and schematics for the equipment controls. These are compatible with the draft sequences prepared by Technical Committee 1.4, but CtrlSpecBuilder covers a much wider range of equipment and options than the technical committee addressed.

Finally, CtrlSpecBuilder checks the specification for possible conflicts or omissions, such as specifying reset based upon the OA temperature without also specifying an OA sensor, or specifying VAV zones with no VAV air-handling unit.

CtrlSpecBuilder uses secure sockets layer communications, file encryption, and a strict privacy policy to ensure security of user projects. The Web site has had more than 28,000 visitors who have used the software to prepare more than 16,000 specifications.

Conclusion

Writing a good control system specification is challenging, regardless of the protocol used. Decide what your goals and objectives are, carefully specify the features without over-specifying, provide the sequences and point lists that are the heart of the control system, and make intelligent use of the available references and tools.

Specifying a BACnet system is no different. Your specification just needs to identify the information and functions that must be provided via BACnet objects and services. By requiring the use of BTL-listed products that meet the standard BACnet device profiles, you can avoid needing detailed BACnet protocol specification and verification while still making it possible to get competitive bids for follow-up work.

Steve Tom, Ph.D., P.E., is director of technical information with Automated Logic in Kennesaw, Ga.