FEATURE

Gateways and routers are basic and fairly common components for modern building automation systems (BAS) based on the increasingly popular American National Standard known as "BACnet" (ANSI/ASHRAE 135-1995 and 135-2001). BACnet is widely used for building automation interoperability; however, many design engineers overlook key details for specifying and applying these devices, resulting in schedule delays and, in some cases, costly change orders. Many of the concepts discussed here are generically applicable to gateways and routers for other kinds of BAS communications schemes such as LonTalk. However, this article will focus on BACnet and some of its unique issues.

Specifying Gateways and Routers for BACnet Networks

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WHAT ARE ROUTERS?

BACnet allows six different kinds of local area network (LAN) technology to be used within a single integrated network. This enables designers to balance cost, performance, and flexibility according to need. The reason is that each of these LAN technologies offers unique benefits and constraints. Generally, it comes down to cost vs. performance. Some LAN technologies are very fast or reliable, but they cost more. Others are less costly, but offer lower performance or flexibility. Some technologies trade off maximum distance for speed.

Whenever two or more LAN technologies are to be used for a given BACnet system, there is a need to couple them together so their devices can interoperate. A router's job is to listen to the network traffic on all of its connected LANs and to *repeat* messages that it "hears" on one LAN that are destined for another of the connected LANs.

Figure 1 shows a router that couples together two LAN technologies, Ethernet and master-slave/token-passing (MS/TP). Both of these LANs use the BACnet protocol. When LAN "A" sends a message to "B" the router "hears" it on the Ethernet side and repeats the message on the MS/TP side. Sometimes routers are stand-alone devices, and sometimes the *functionality* of a router is included with a field panel or controller-type of device. Both combinations are common in products available today.

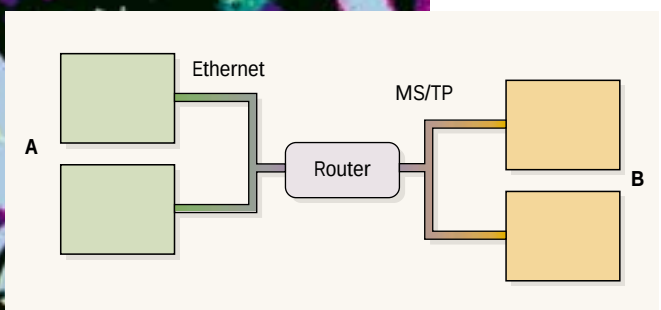

Figure 1.
Router repeats messages from LAN "A" to LAN "B" and vice-versa, even though the two LANs are different networking technologies.

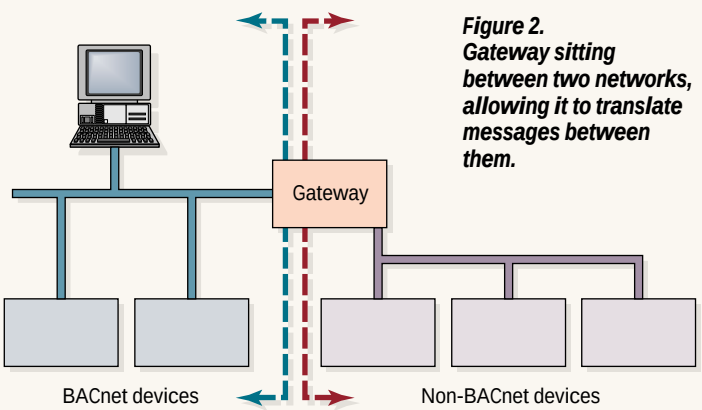

Figure 2.
Gateway sitting between two networks, allowing it to translate messages between them.

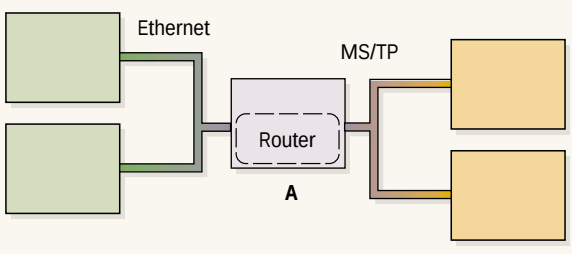

Figure 3.
Device "A" might be a BACnet controller that also has router functionality

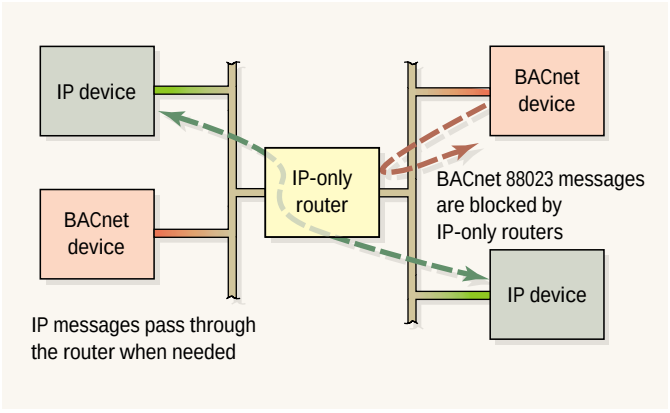

Figure 4.
IP-only routers will allow IP message traffic but block BACnet messages

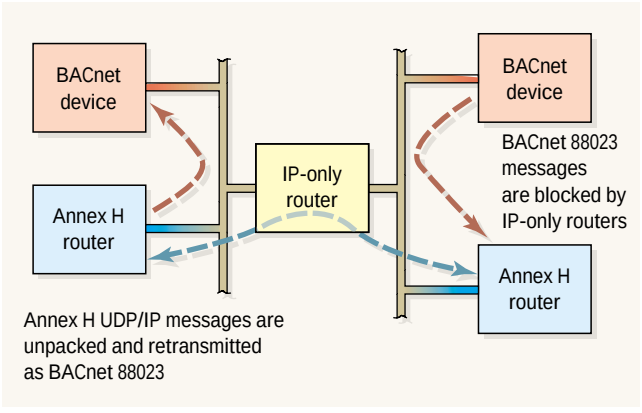

Figure 5.
BACnet Annex H routers are one solution to the IP-only problem, but their cost can add up if there are a lot of isolated BACnet segments in the network.

WHAT ARE GATEWAYS?

A gateway is used to interface a BACnet system with a non-BACnet system (Figure 2). A gateway has a more complex job than a router. In addition to listening to each message, the gateway typically must also *translate* between BACnet concepts and the equivalent ideas in the non-BACnet system. This translation may be a multistep process. A "simple" BACnet request may involve many operations in the non-BACnet side, and some manufacturers may choose to implement less functionality in order to avoid having to support some of BACnet's more complex requirements. Gateways that are available in the marketplace range from fairly simple and low cost to very sophisticated and expensive.

WHEN ARE ROUTERS NEEDED?

When you have two or more devices on different BACnet network segments that need to interoperate you will need a router. Many BACnet routers support multiple connections. For example, Ethernet to MS/TP routers that support two or four MS/TP ports, and sometimes a Point-To-Point (PTP) port. Since the *functionality* of a router may be provided in some controller or field panel devices, it can be a cost advantage to use this kind of controller.

When an existing BACnet system is being expanded, you should specify the LAN technology(s) already in use and be clear that vendors providing new BACnet equipment are responsible for providing the interface to the existing LAN. For example, say you have a BACnet system that is based on Ethernet and you will be expanding that system into a new building. The specification for the new building should require that any new controllers must be provided with Ethernet LAN capability, or a router to whatever BACnet LAN type is being provided. If you fail to specify this detail, you could end up having to procure the appropriate router yourself and absorb its cost.

In many office buildings, college campuses, and other large facilities, it is common to find a LAN infrastructure based on Ethernet. Increasingly, most of the traffic on these Ethernets is IP-based, as in the *Internet Protocol*

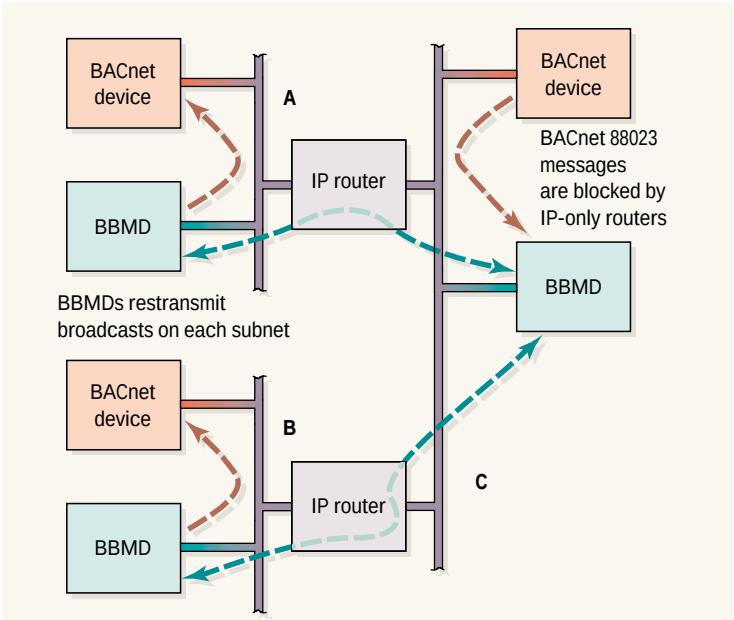

Figure 6.
BACnet Broadcast Management Devices (BBMDs) must be present on every IP subnet having one or more BACnet devices. In this figure, the BACnet/IP device on subnet "C" has sent a message to subnets "A" and "B".

part of TCP/IP. It is very common for IP-based networks to have routers that connect multiple IP Ethernet segments. Some (but not all) IP routers have the policy that non-IP traffic is blocked (not repeated) by the router. In these situations, normal BACnet over Ethernet 8802-3 *messages* will be unable to pass through these types of IP-only routers (Figure 4).

There are several solutions to this problem. One is to install BACnet *Annex H Tunnel Routers* on each BACnet over Ethernet 8802-3 segment that is isolated by an IP-only router (Figure 5). If there are a lot of isolated BACnet segments, this can be costly.

ROUTING ISSUES WITH BACNET/IP

Sharing an IP infrastructure can pose some challenges to BAS devices, especially if IP-only routers are already in place within the network. The good news is that BACnet/IP devices use IP, so messages that are directed to specific devices will easily pass through any in-place IP routers along the route. The bad news is that these same IP routers block broadcast messages by design, and this interferes with some aspects of normal BACnet operation. Most commonly, BACnet devices use broadcast messages to find out about other BACnet devices dynamically. This very useful feature cuts down on configuration and reconfiguration time, so it is highly desirable to have. However, unless all of your BACnet/IP devices are on the same IP subnet (which they generally won't be), these broadcast messages will be unable to pass through IP routers.

BACnet/IP devices are usually used with BACnet Broadcast Management Devices (BBMDs). In a sense, BBMDs are a special kind of "broadcast router." BBMDs are configured to establish connections with each other and listen for broadcast BACnet messages. Upon hearing a broadcast BACnet message, the BBMDs distribute it to their peer BBMDs, which in turn rebroadcast the messages on their respective IP subnets (Figure 6).

BBMD functionality is often included in other BACnet devices, such as BACnet routers and BACnet router/controllers. This can be a cost advantage since separate router or BBMDs are not required when this functionality is available in a controller. However, not all controllers or routers have these features, so it is important to specify the functionality requirements when they are needed.

The important consideration for designers is that each IP subnet, in a BACnet/IP network, needs to have a BBMD to manage broadcasts to and from that subnet. In the diagram above, "A", "B," and "C" are different subnets, so broadcast messages are not automatically forwarded

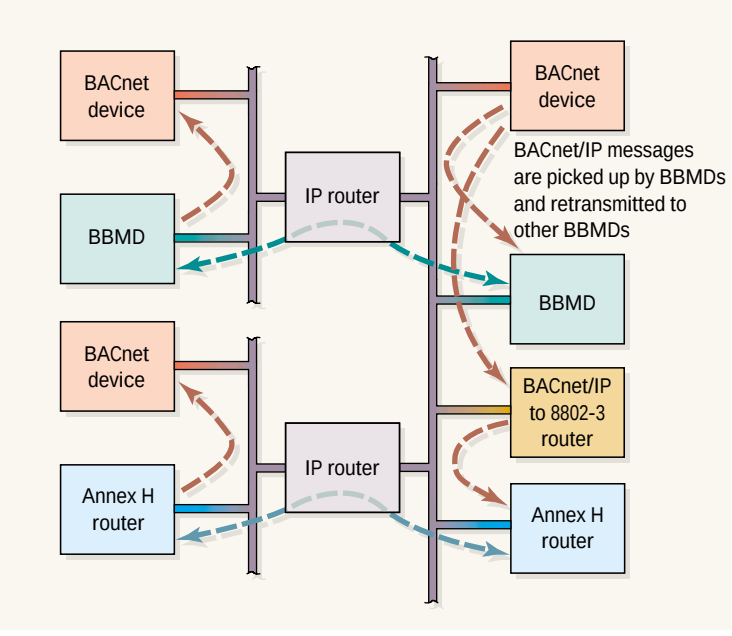

Figure 7. Integrating networks having mixed types of BACnet devices and mixed network technologies can be very complex, requiring different types of routers.

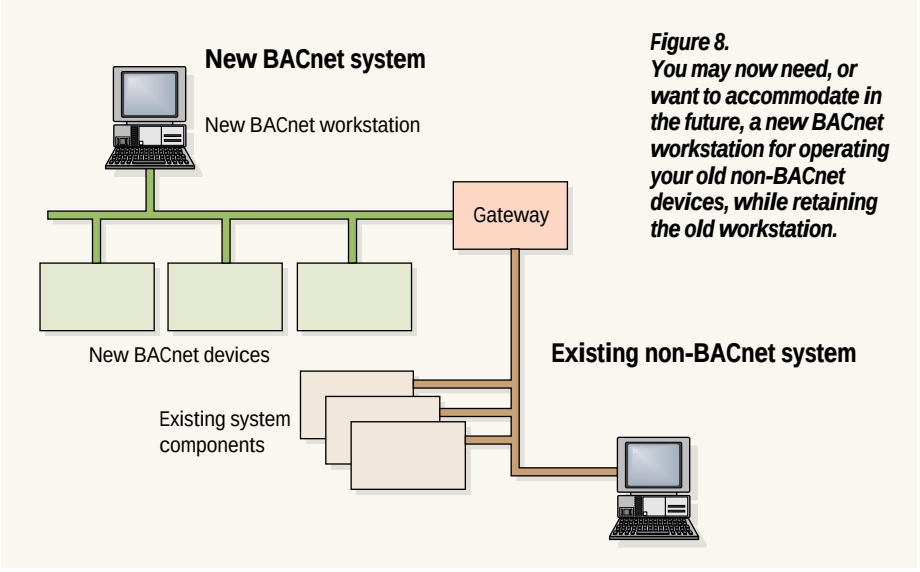

Figure 8. You may now need, or want to accommodate in the future, a new BACnet workstation for operating your old non-BACnet devices, while retaining the old workstation.

Where can readers go for more information?

- **www.gopolar.com/BACnet/learning.html** PolarSoft BACnet Learning Center
- **www.bacnet.org** Unofficial BACnet Committee Website at Cornell University
- **www.bacnetassociation.org** BACnet Manufacturer's Association
- **www.big-na.org** BACnet Interest Group North America

across the IP routers, which is why BBMDs are required in these situations.

In a mixed network that includes both BACnet/IP devices and BACnet over Ethernet 8802-3 devices, you will need a combination of BBMD, Annex H Tunnel Router, and BACnet over Ethernet 8802-3-to-BACnet/IP router functionality to integrate all of the devices (Figure 7). This is true especially when these different types of devices are distributed on different IP subnets.

GATEWAY SPECIFICATION AND PROCUREMENT ISSUES

Whenever you want to interoperate between a BACnet system (or devices) and a non-BACnet system (or devices), you will need at least one gateway to do the translation from BACnet operations into the equivalent operations in the non-BACnet system.

Where do you get the gateway? In most cases, you will have to contact the proprietary system's vendor to find out what kind of

GLOSSARY

8802-3. An international standard ISO 8802-3 that is commonly called "Ethernet," although there are actually several types of Ethernet of which 8802-3 is only one. In this article, we use this term to refer to the use of 8802-3-style Ethernet to carry BACnet messages using the 8802-2 Link Service Access Point (LSAP) 0x82, which is internationally assigned to BACnet.

Annex H Tunnel Router. A special type of router used to connect two or more isolated BACnet network segments that are separated by at least one IP-only router. This router listens for "BACnet over 8802-3" messages on an Ethernet and packages each message in a special kind of UDP/IP message that can pass through IP routers, in effect forming a "tunnel" between the two network segments. The companion Annex H router unpacks and retransmits the message on the remote network.

BACnet(r). The Building Automation and Control Network is the common name for the communication protocol standard ANSI/ASHRAE 135-2001 and its precursor standard ANSI/ASHRAE 135-1995. This is a book that defines methods and procedures for cooperating building automation devices to interoperate using a variety of common LAN technologies.

BACnet Broadcast Management Device (BBMD). A special type of routing device that is used in BACnet/IP networks to distribute broadcast messages across multiple subnets.

BACnet/IP. An extension of BACnet called Addendum A defines this mechanism which uses an internationally reserved UDP socket as a means of conveying BACnet messages over IP networks.

Broadcast. A message that is intended to be received by all devices on a logical network segment.

Cache. A concept for maintaining a table of information that may be examined quickly at any time, but whose content is updated asynchronously.

Ethernet. A family of local area network technologies that provides very high-speed networking features over various types of wiring media. An Ethernet carries packets of information that can be identified according to type. While there are many Ethernet packet types, the most common are Ethernet II (IP) and 8802-3. In many instances, 8802-3 packets also carry 8802-2 datalink information that can further identify subtypes. There are internationally reserved subtypes for both IP and BACnet as well as others.

Gateway. A communications device that connects two or more different types of communications protocols together, translating the concepts of one protocol into the equivalent concepts in another protocol. The idea is similar to human language translators. In the context of BACnet, a gateway uses BACnet as a common language on one side and some non-BACnet (usually proprietary) communication scheme on the other side.

Internet Protocol (IP, TCP/IP, UDP/IP). A communication scheme originally developed by the Defense Advanced Research Projects Agency (DARPA) as a means of facilitating electronic message exchange between research facilities. This technology has become internationally standardized and widely adopted. The most common use of this technology is the World Wide Web. At the lowest level, it is based on Internet Protocol (IP), which is a scheme for conveying and routing packets of information over various kinds of LAN media. There are many additional protocols that use IP to perform tasks. Two common ones are User Datagram Protocol (UDP) and Transmission Control Protocol (TCP). UDP conveys information to well-known "sockets" without confirmation of receipt. TCP establishes "sessions" which have end-to-end confirmation and guaranteed sequence of delivery.

BACnet gateway(s) they offer that would be appropriate for your situation. In open bidding, you may be able to specify that a subsystem or individual piece of equipment being procured must provide either native BACnet device(s) or BACnet gateway(s) with the specific BACnet capabilities that you need. Sometimes you may have to locate a source for a BACnet gateway yourself. You may have an existing facility that is not using BACnet, but you plan to expand the facility using all BACnet, perhaps replacing front-end workstation(s) with BACnet-based ones.

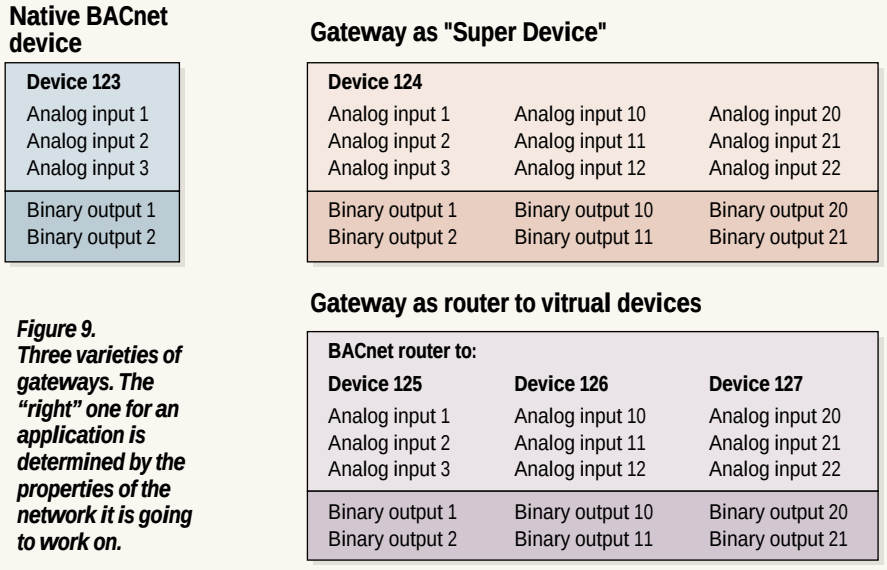

Figure 9. Three varieties of gateways. The "right" one for an application is determined by the properties of the network it is going to work on.

Interoperability. The concept that two cooperating devices can reliably and predictably perform a given function or exchange. When we speak about building automation interoperability, we usually mean a collection of functions that work properly across a given set of vendors or applications.

IP Subnet. The Internet protocol (IP) identifies individual devices using an addressing scheme based on a 32-bit number which is usually divided into four groups of numbers ranging from 0 to 255, e.g., 209.185.47.68. Typically, devices are grouped together and share some portion of this 32-bit number in common. For example, the IP addresses 209.185.47.68 and 209.185.47.82 share the first three components: 209.185.47.xxx. They are said to be sharing the same subnet. Subnets are not limited to the last group and can be larger, such as 209.185.xxx.xxx or 209.xxx.xxx.xxx, etc.

Latency. A time delay. If we send a request to a device and eventually get a response, the time that elapses from the sending of the request to the receiving of the response is the latency.

Local Area Network (LAN). A communication network that spans a limited geographic area and uses the same basic communication technology throughout.

LonTalk(r). A communication protocol originally developed by Echelon Corporation. LonTalk is used in various venues for interoperable communications, notably as LonWorks and LonMark LANs and as a transport LAN for BACnet.

Master-Slave/Token-Passing (MS/TP). One of the transport LAN options for BACnet. This interface is based on EIA-485 and shielded twisted pair wiring for relatively low speed and low-cost (up to 4000' at 76.8K baud). Typically used for low cost devices like unitary controllers.

Native BACnet Device. A device that uses BACnet as its primary, if not exclusive, method of communication. A system that uses native BACnet devices at all major levels (workstation, large controller, and small controller) is a native BACnet system. The concept of native BACnet systems excludes the use of gateways to non-BACnet devices where a suitable native BACnet Device is available.

Network Segment. An electrically separate section of a network. In Ethernet, bridges, hubs, switches, and repeaters can couple together multiple physical network segments into one logical network segment. Broadcast messages can be received by all devices within a logical segment.

Object. The concept of organizing information into abstract components that have externally observable characteristics (properties). We can represent a physical idea, like a temperature sensor, as an object that has properties, like temperature (Present_Value), alarm limits (High_Limit, Low_Limit), and its name (Object_Name).

Point-To-Point (PTP). One of the transport options for BACnet. Based on EIA-232 direct point-to-point connection or via dial-up telephone modems.

Property. An externally observable characteristic of an object. Properties are used to find out information from objects (by reading the property) and to convey information and commands to an object (by writing to the property).

Router. A device that couples together two or more, usually different, LAN technologies. By constantly listening to message traffic on each connection, the router can pass relevant information between two or more connections when needed.

You may want to interoperate the old system from the new (BACnet) system, so you need one or more gateways to the existing system (Figure 8).

The non-BACnet system may be proprietary, and it may be a closely held secret how it operates. Your only choice may be to get a gateway from the proprietary vendor. Some vendors use an "open" communication method that they make available to those who ask, perhaps for free or for a licensing fee. They may use a technology that is well-known to third-party developers even if it is not standardized, as BACnet is. There may be third-party developers who have the communications methods of a proprietary system, essentially "figuring out" the secrets. It may even be possible to contract third parties to attempt reverse engineering in your behalf. The more custom programming and software required, the more expensive a given gateway is likely to be.

Gateway functionality can be provided as part of another device that you already have or will have as part of the BACnet system. It is common for some types of native BACnet controllers to also provide a gateway to that vendor's proprietary products. However, a proprietary interface doesn't necessarily mean BACnet gateway-style access to the proprietary products. A common situation where this occurs is in workstation software. Manufacturer "X" sells color graphic workstation software that communicates with its proprietary "Brand X" controllers, as well as with BACnet devices, allowing you to view color graphic screens containing mixed status and information from BACnet and Brand X devices. This is known as "BACnet Integration." The issue is whether another BACnet device from vendor "Y" can communicate (using BACnet) to the workstation and have the same access to Brand X device information represented as BACnet objects. For example, when a Brand X device generates an alarm, can the workstation gateway software present this as a BACnet event notification to the Brand Y BACnet device? If the workstation software can perform these kinds of functions, then it is truly acting as a BACnet gateway.

Expansion is a key issue in gateways. Although you may purchase a gateway to connect between BACnet and 10 proprietary controllers, suppose you need to add an 11th controller in the future? How much non-BACnet side expansion does the gateway allow, and can you do it yourself without the gateway vendor? Is there an additional fee for additional capability? These are specific questions to ask of the gateway vendor or to look for in its product information.

GATEWAY PERFORMANCE

Most gateways try to provide access to non-BACnet system information by representing that information in terms of BACnet objects and properties. Often the non-BACnet system's devices are modeled by the gateway as either one "super-device" containing lots of objects (representing the non-BACnet system's information) or as a BACnet router to multiple BACnet "devices." In either case, the gateway treats the information in the non-BACnet system in the gateway as if it was a native BACnet controller (or controllers).

Gateways can operate in a variety of ways. Some gateways "fetch on demand," translating BACnet requests and forwarding them on to the non-BACnet side immediately. There may be some *latency* waiting for the answer from the non-BACnet device, so the gateway may appear to be "slow" in responding to requests. Other gateways "fetch-from-cache" by continuously updating a table of information from the non-BACnet side. This continuous update may take place as fast as possible, or it may be triggered by an update period based on time or on a signal from the remote device that the value has changed. While the "fetch from cache" scheme provides quick access, the data may be somewhat "stale" since it was not necessarily recently fetched. Regardless of the approach, it's important for you to know how the gateway will perform in your applications.

SUMMARY

Gateways and routers are relatively simple devices when considered individually. However, in actual network applications, it is important to understand when they are needed and how to specify them. Here are some tips for working with them on projects.

- Some controllers can provide router or gateway functionality at a cost advantage over stand-alone devices.
- Specify in writing who is responsible for providing router(s) and/or gateway(s).
- When sharing Ethernet infrastructure, special considerations are needed if there are IP-only routers in place.
- When choosing BACnet/IP, keep in mind that BBMDs are required on each subnet.
- Consider third parties when procuring gateways, especially when a proprietary vendor gateway is not available or is limited or expensive.
- Assure that expansion capabilities and costs of gateways are known.
- Know the performance and capabilities of any gateway before purchasing or allowing open bids. NC

David Fisher is a charter voting member of ASHRAE's Standards Project Committee 135P and has been active in the development of the BACnet standard (ANSI/ASHRAE 135-1995 and 135-2001) since its inception. He served on the Standing Standards Project Committee-135 until July 2000. He has taught many courses about BACnet, including ASHRAE's Professional Development Seminar "Understanding and Specifying Basic BACnet Systems." (dfisher@gopolar.com)