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BACnet goes to Washington. Capitol Hill buildings will have BACnet installed during the next few years.

BACnet Today

Significant New Features And Future Enhancements

By Steven T. Bushby, Member ASHRAE, and H. Michael Newman, Fellow ASHRAE

With nearly non-stop increases in computing power and decreasing hardware costs, the last seven years have been exciting for the computing and data communication industries. It also has been an exciting time for BACnet, with thousands of new installations worldwide, new sources of supply, and greater acceptance on the part of engineers, contractors, and building owners.

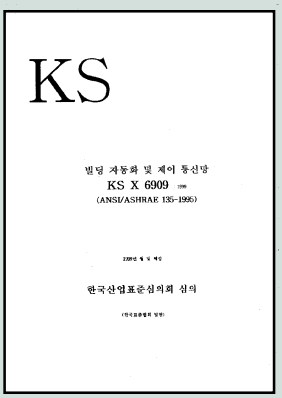
One of BACnet's greatest strengths is its ability to adapt to new networking technologies and the evolving needs of its users. The challenge for ASHRAE Standing Standards Project Committee (SSPC) 135, responsible for BACnet's ongoing development and enhancement, has been to embrace the changes brought by these two forces without unduly affecting existing implementations of the protocol. Backward compatibility has been one of the committee's greatest concerns since it began work in 1995, the year BACnet was originally published as ANSI/ASHRAE Standard 135-1995, *BACnet—A Data Communication Protocol for Building Automation and Control Networks.*

Since that time the SSPC has processed

United States

China

Japan



Korea

'One of BACnet's greatest strengths is its ability to adapt to new networking technologies and the evolving needs of its users.'

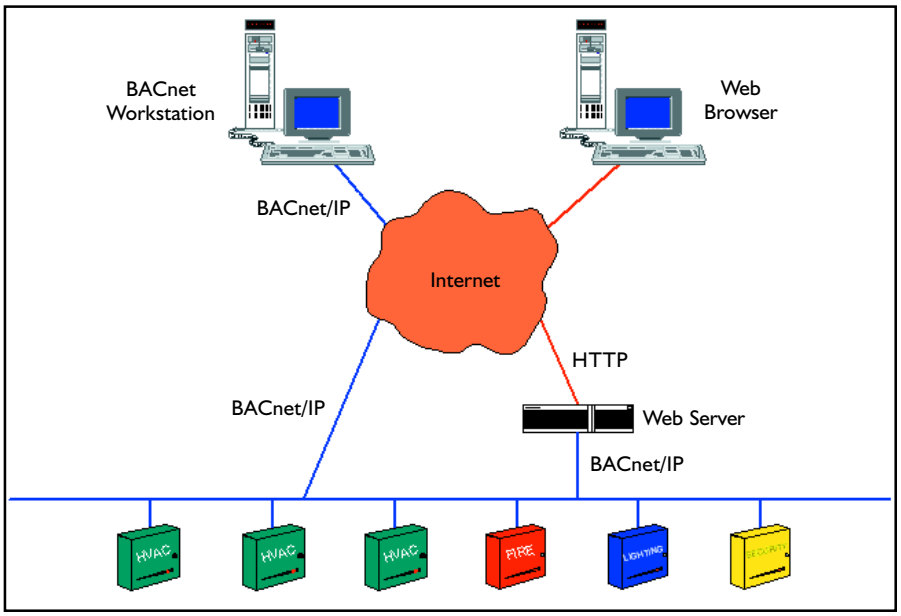


Figure 1: A web server can allow access to a BACnet network via the Hypertext Transfer Protocol (HTTP), the standard communication protocol for transferring web pages.

nearly 200 suggestions from the building automation and control industry. These suggestions ranged from the adoption of new ways to use the Internet to improvements in the tools available to specifiers of BACnet systems.

Five addenda to the original standard were issued between 1995 and June 2001. At that time a new version of the standard, incorporating all of the previous addenda, was approved. We will refer to the original standard as BACnet-1995 and to the latest version of the standard, ANSI/ASHRAE Standard 135-2001, as BACnet-2001.

This article provides an update on the most significant new features of BACnet-2001 and the standard's future direction.

New Networking Technologies

Using BACnet over the Internet was a hot topic even before BACnet-1995 was published. At the time, however, many felt that building controllers did not have the computing power to support an Internet Protocol (IP) stack with its high overhead (the protocol control information for IP adds a minimum of 20 8-bit bytes or octets to every message and many BACnet messages are much shorter than this) or that BACnet local area networks (LANs) could tolerate longer messages without bogging down and affecting system performance.

Nevertheless, BACnet-1995 did offer a way of conveying messages between various BACnet LANs via IP using a technique called "tunneling." This method, described in Annex H, uses special IP-capable devices called "tunneling routers" that intercept non-IP BACnet messages and relay them to peer tunneling routers on the distant LAN for delivery to the intended destination device. *This requires no changes to the BACnet devices themselves*.

The new standard for BACnet over the Internet is called "BACnet/IP." This specification was the first addendum to BACnet-1995 and was published in 1999 as Annex J. It allows BACnet devices to communicate directly with each other over the Internet (or any other IP-based network, for example, a corporate intranet) wherever they may be. It also provides a method for BACnet workstations to "sign up" to receive broadcast transmissions, even if the workstation is not on a BACnet LAN. BACnet/IP is quickly becoming the most popular form of BACnet networking for workstations and building controllers.

Recently, web servers have been used to present information from BACnet networks in a form that can be viewed and/or altered from standard web browsers. The BACnet side requires no changes but the BAS functions (such as alarm history storage, trend logging, metering) must be performed on a machine other than the workstation/browser (*Figure 1*). The principle advantage is accessibility. With proper authorization, a build-

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BACnet™ Interest Group – AustralAsia (BIG-AA)
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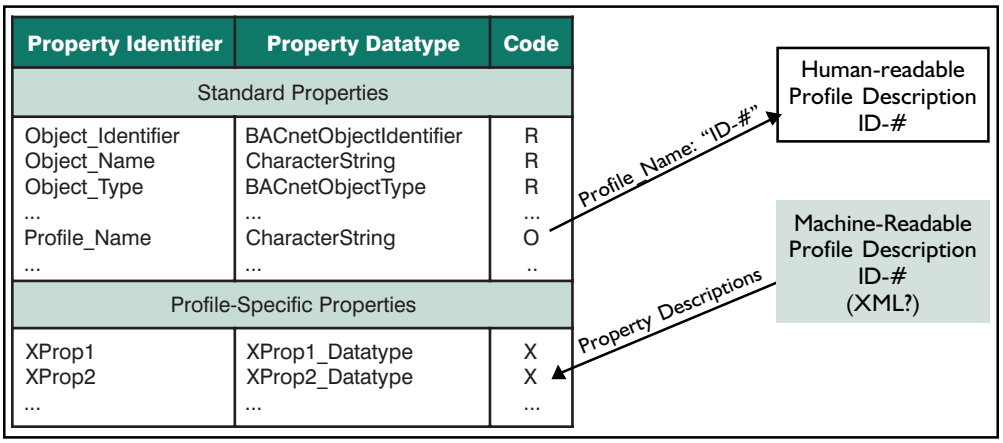

Figure 2: BACnet profiles allow for extending standard object types or creating new ones.

ing automation system can be accessed from any place the web is available. However, using web technology brings up security issues. How do you allow access through firewalls, for example, without exposing your system to hackers? The SSPC has a working group looking into this and other security-related issues.

Interoperability

BACnet often is deployed in systems from a single manufacturer, dedicated to a single task such as HVAC control. But the standard enables much more. As a common communication language, BACnet makes it possible for systems from different manufacturers and/or systems designed for different building automation and control functions to work together.

To facilitate specification of interoperable systems, the SSPC developed a group of related functions that provides what it believes represents the core of interoperability: data sharing, alarm and event management, scheduling, trending, and device and network management. For each of these "interoperability areas," BACnet-2001 lists (Clause 22 and Annex L) the capabilities a user should reasonably be able to expect from a set of "standard" devices such as a "BACnet Workstation," a "BACnet Building Controller," a "BACnet Application Specific Controller," and so on, along with the BACnet capabilities that need to be implemented to achieve them.

The listing of BACnet capabilities for each of these "standard BACnet devices" is called a "device profile." If the capabilities of the standard devices are adequate, a specifier need only require that all provided devices meet the corresponding device profiles of Annex L.

Manufacturers are free to provide more or fewer capabilities than listed in the standard device profiles. The capabilities of any particular device should be listed in the Protocol Imple-

Extensibility: Encouraging Innovation

A major goal of BACnet's developers has been extensibility. No one should be able to say that using BACnet somehow stifles innovation. A major step in this direction has been the addition to the standard of the concept of a profile for describing extensions to standard object types (properties added to the standard properties already defined) or new object types with a completely new set of properties. To achieve this, a pointer to the profile has been provided in the form of a new, optional property called "Profile_Name" that can be used with all object types. This property is a text string that starts with the vendor identifier of the profile's author. This allows different organizations to define their own unique extensions to, for example, an Analog Input object, without conflicting with someone else's extensions.

At the moment, the precise format of the profile is still undefined. The ultimate goal is to make the profile machine-readable, probably by encoding the information using the Extensible Markup Language (XML) (*Figure 2*). This would permit a workstation, for example, to load the profile definitions "automatically" and thus, be able to understand the new characteristics without further human intervention.

The profile scheme lends itself to the development of gateways to non-BACnet protocols, particularly if they are object-based. A good example is a gateway specification to the European Installation Bus (EIB). Since BACnet and EIB have a number of object-type definitions that share many common properties, the interface from the BACnet side can be constructed as a set of standard BACnet object types with EIB-specific profiles that describe the additional properties that are needed to communicate with EIB equipment.

'BACnet is rapidly becoming an international standard that is supported by technical experts from around the world.'

(Top) SSPC 135 vice chairman Bill Swan, right, holds the Chinese version of the BACnet standard in 2000.

(Left) BACnet Manufacturers Association conducts interoperability testing in a NIST laboratory in Gaithersburg, Md.

mentation Conformance Statement (PICS) that is to accompany the device. The format of the PICS is defined in Annex A. PICSs should be available from the manufacturers or, eventually, via the Web site of the BACnet Manufacturers Association's (BMA) BACnet Testing Laboratories (BTL).

The use of interoperability areas, BIBBs (see BIBBs: BACnet's Shorthand) and device profiles has entirely replaced the Conformance Classes and Functional Groups that were defined in the old Clause 22 in BACnet-1995. Conformance Classes and Functional Groups simply didn't work and now they are gone!

Here are some of the new features of BACnet-2001, arranged by interoperability area.

Data Sharing

Two new object types have been added, Averaging and Multi-state Value. Averaging objects provide a way to obtain the minimum, maximum and average value of a particular BACnet property over a specified time interval. The min and max are accompanied optionally by a corresponding time stamp. The Averaging object type represents an excursion into a new area for the SSPC: the definition of objects that blur the line between data communication objects (i.e., objects that make specific device functionality "network visible") and application program-oriented objects that represent certain mathematical or logical operations that could then be used within a device's control software (and, at the same time, are network visible). Why, for example, stop with averaging? There could be a "Square Root" object or a "Logarithm" object or "AND" or "OR" objects that would operate on Boolean properties. It has been suggested that someone work on a standard for programming building automation and control devices. Volunteers?

The second new object type is the Multi-state Value. This offers little new functionality beyond what could be achieved with the Multi-state Input and Output objects but was added

BIBBs: BACnet's Shorthand

The BACnet interoperability areas are defined in terms of a new shorthand defined in Annex K called "BACnet Interoperability Building Blocks" (BIBBs). Each BIBB states what BACnet feature must be implemented, from either the perspective of a client or a server, to achieve some communication result.

For example, the "Data Sharing - ReadProperty - A" BIBB (abbreviated DS-RP-A) says that a device must be able to initiate a ReadProperty request, i.e., must be able to ask some other device for the value of some property of some object. DS-RP-B says that a device must be able to respond to such a request and send back an answer. Ideally, only implementers of BACnet products need to know about BIBBs. However, the shorthand could be useful to others in verifying claims of manufacturers.

in response to concerns about the lack of symmetry between the set of Analog and Binary objects (which have a corresponding Value object type) and the set of Multi-state object types which, previously, did not.

Alarm and Event Management

One of BACnet's key strengths is that it provides a robust but flexible mechanism for defining special events and alarms, and notifying workstations or other devices when they occur. It was also one of the most difficult parts of the standard to develop because little commonality existed in proprietary approaches. No other protocol provides an interoperable way to manage alarms that is adequate to meet the variety of application requirements found in buildings. The alarm and event features of BACnet were crafted from a deep knowledge of HVAC application needs, borrowing ideas from proprietary approaches, and a lot of debate and discussion.

While issues regarding life-safety concerns were being addressed (see sidebar, Developing BACnet: An Open Process), field experience with BACnet alarming helped to identify other potential improvements. Originally, Event Enrollment objects, which are used to monitor a property value for alarm conditions, were restricted to monitoring objects and properties within the local BACnet device. That constraint has been relaxed and a standard way exists for one BACnet device to detect and announce alarm conditions in a remote device.

BACnet-1995 provided a way to subscribe for change of value (COV) notifications for specific properties of specific objects. It became clear that it would be a good idea to generalize this by allowing COV subscription to arbitrary properties and even to provide for sending and receiving COV notifications without the overhead of managing subscriptions. This led to the creation of a SubscribeCOVProperty service and an UnconfirmedCOVNotification service.

It also became apparent that it was difficult to connect a workstation to a BACnet network and obtain sufficient information about alarms that had previously occurred to enable them to be acknowledged from the new workstation. This led to the creation of a GetEventInformation service that can obtain this information. Enhancements that provided these features were combined with the life-safety proposals as part of the same addendum to the standard.

Scheduling

Scheduling occupancy periods in the zones of a building can be a complex process. The 1995 standard provided a way to define weekly schedules that are active for a specific period of time and also an exception schedule that overrides a particular day. The schedule object was restricted to scheduling other objects within the same device. This restriction has been relaxed and vendors may choose to schedule objects in remote devices.

Developing BACnet: An Open Process

BACnet's alarm and event management features have been very successful but, because of the expertise of the people directly involved, they were also HVAC-centric. From the beginning it was envisioned that BACnet would be used for a variety of building automation and control applications, not just HVAC. Around the time BACnet was published in late 1995, European companies in the fire alarm industry were discussing the adoption of a standard that could be used to integrate fire alarm systems with HVAC control systems. They focused on protocols that were being debated within European standards committees and heavily marketed "open protocol" options being controlled and promoted by private U.S. companies. The experts involved concluded that BACnet was the only protocol available that could be scaled from very simple to large complex systems. It also offered the kind of flexible networking topology that would be needed. European life-safety experts initiated a series of communications with the newly formed ASHRAE SSPC 135.

In the United States, the National Electrical Manufacturers Association (NEMA) Signaling, Protection, and Communications Section (3-SB) is the home for standards activity related to communication in life-safety systems. They work closely with the National Fire Protection Association (NFPA). At a NEMA 3-SB meeting in April 1997, European life-safety experts met with one of the authors, who was making a presentation about BACnet. The Europeans indicated that they were working to adapt BACnet to life-safety systems and had identified some needed functionality that was not included in the standard. These discussions led to a formal proposal that was submitted to the NEMA 3-SB committee in April 1998, for new BACnet objects and services that could remedy the identified shortcomings.

One of the issues was that devices used for life-safety applications have defined modes of operation that can be changed and also specific operational states relevant to that mode. Examples of modes include enabled, disabled, test, manned, unmanned, armed, prearmed, etc. These modes need to be visible over the network and the operational details for the device typically vary from mode to mode.

Another issue was that life-safety systems support the con-

The exception schedule mechanism can be used to represent even very complex scheduling components. However, a potential problem can occur under circumstances where several events are combined to make a single exception schedule. A workstation can read the exception schedule, even from a device made (and programmed) by a different manufacturer and see the overall result. However, there is no way to figure out and display to the operator the component events that were combined to make the exception schedule. A proposal is in the public review process to solve this problem by making network-visible the partial day schedules that are combined to make up an overall exception schedule.

Trending

During the development of BACnet, considerable discussion about trending occurred. A consensus was never reached. Many other issues were pressing, so it was decided that a standard method for trending could wait. BACnet had a file object and services to read and write files. If a file format could be agreed upon, these tools could be used to provide trending capabilities. The thinking at the time was that we needed a consensus on a file format. Pressure from the marketplace would help to focus attention on this issue and perhaps make it easier to achieve a consensus.

Early developers of BACnet products quickly decided that creating a robust trending mechanism should be a high priority.

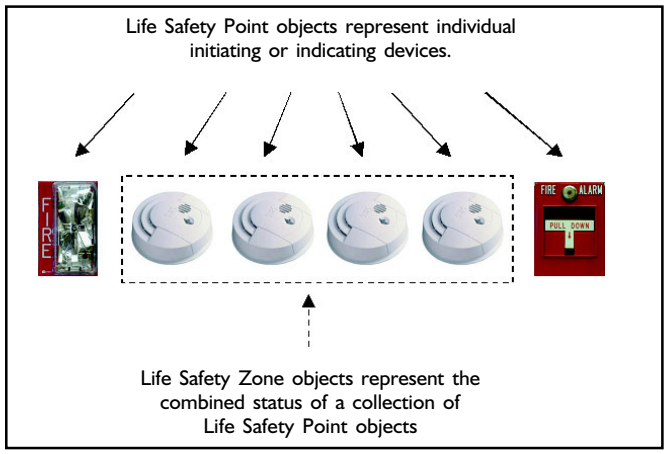

Figure 3: Life Safety Point and Life Safety Zone objects expanded BACnet capabilities for life-safety applications.

Experience from vendor extensions to the standard provided the basis for a proposal that was later adopted as part of BACnet. The end result was the creation of a new Trend Log object type and a new ReadRange service designed to permit the retrieval of trend records based on user-selected filter criteria.

The Trend Log object makes several parameters network-visible that describe how trend data is to be collected. If these parameters are writable, they can be used to configure the trend collection details. The Trend Log monitors a property of a referenced object and, when predefined conditions are met,

cept of latching in certain operational states until an authorized human takes some action. There is also a distinction between a "trouble" condition and an "alarm." Operators need to be able to both "silence" and "reset" devices and these actions have specific meaning in the life-safety industry. Sometimes devices need to be viewed and manipulated individually. At other times a group of devices need to be viewed or managed as a collection. BACnet-1995 could not easily accommodate any of these needs in an interoperable way.

The National Institute of Standards and Technology (NIST), involved in both the NEMA 3-SB and SSPC 135 committees, facilitated the formation of an *ad hoc* group of experts from both groups to deliberate the European proposal. The result was a combined working group of life-safety and BACnet experts who cooperated with, and reported back to, the NEMA and ASHRAE committees. Two building industry communities had combined forces to address a common interest and a mechanism was created to ensure that experts in both communities had ample opportunities to review and comment on the technical work.

The result of this effort was publication of some life-safety additions to BACnet for a public review in April 2000. Comments received during the public review resulted in some revisions and a second public review in March 2001. Final publication of the addendum was approved in June 2001. The resulting additions to the standard were a Life Safety Point object type that represents the characteristics of an individual initiating or indicating device (e.g., a smoke detector or alarm bell), a Life Safety Zone object that represents the combined characteristics of a collection of life safety points, and a LifeSafetyOperation service that enables the special human interactions required (*Figure 3*).

The process that was used to develop the life-safety additions is not unique. Similar collaborations are now underway with the lighting and utility industries. Other proposals are being considered that originated from outside the United States. These activities illustrate several key points about BACnet. First, new capabilities can be added that enable whole industries to enter the BACnet world. Second, the process is open and flexible so that professional bodies other than ASHRAE can contribute. And finally, ideas and input come from all over the world. BACnet is rapidly becoming an international standard that is supported by technical experts from around the world.

'BACnet has steadily gained acceptance throughout the world. It has been translated into Chinese, Japanese and Korean, and has been designated as a national standard in Korea.'

The Dirksen Senate Office Building will be the first Capitol Hill building to use BACnet throughout.

it saves or "logs" the value to an internal buffer along with a time stamp. The data can be logged periodically or when a change of value for the monitored property occurs. The monitored property may be in the same device as the Trend Log object or in an external device. It is possible to define specific start and stop times for collecting trend data and to enable or disable trend collection using BACnet messages.

Each Trend Log object maintains an internal buffer to hold the trend data. The vendor is free to choose the size of this buffer and whether it is fixed in size or dynamically changeable. If a buffer becomes full, the least recent record is overwritten when a new record is added, or the Trend Log may be configured to stop collecting new data. The trend data is retrieved using the ReadRange service. Intrinsic reporting mechanisms are defined for Trend Log objects that can be used to send a notification that a buffer is becoming full.

The acquisition of trend records by remote devices has no effect upon the state of the Trend Log object itself. This allows independent sequential access to the log records by multiple remote devices.

The Trend Log object is designed for logging values for a single property of a single object. The SSPC is deliberating a proposal that, if approved, would result in a more complicated object that allows collecting a set of property values in each record of a trend log.

Device and Network Management

The only new feature added in this interoperability area is the UTCTimeSynchronization service. The service supplements the existing TimeSynchronization service by conveying Coordinated Universal Time (UTC) instead of the time at the location of the timeserver. Historically, UTC was synonymous with Greenwich Mean Time, the local time at the zero meridian that passes through Greenwich, England, and is used as a global time reference. It can be determined from various sources such as NIST's short-wave broadcast stations WWV and WWVH and from Global Positioning System satellite transmissions.

The significance of this new service is that it was added as a result of the growing recognition that BACnet systems can cross time-zone boundaries and can be, in some cases, global. Using UTC as the basis of the time synchronization allows a single server to coordinate the time in a BACnet internetwork, regardless of its geographic extent.

BACnet Procedures

In BACnet-1995, Clause 19 dealt solely with command prioritization. Later on, it became apparent that a variety of procedures, in addition to those dealing with command prioritization, are commonly required in building automation and control systems, and could be carried out entirely with BACnet objects and services. These should be standardized.

The first such set of procedures added to Clause 19, now entitled "BACnet Procedures," describes "Backup and Restore." These procedures allow configuration data to be backed up and subsequently downloaded in an interoperable way even if, as is usually the case, a device has been initially configured using proprietary tools and techniques. The new procedures required the addition of several properties to the Device ob-

ject type, the most prominent of which is the Configuration_Files property, an array of identifiers of File objects that, together, contain all relevant configuration data needed to restore a device to its current state.

Future Directions

Having established a firm foothold in the world marketplace and demonstrated the extensibility of the original design, BACnet is beginning to grow into many new application areas. SSPC 135 has established working groups to deliberate and propose new capabilities in several areas. In many cases ASHRAE experts are working cooperatively with other professional societies in a manner similar to the successful effort with the fire alarm industry.

• A Lighting Applications Working Group (LA-WG) has been formed. This working group is cooperating with both NEMA and the Illumination Engineering Society of North America. The focus of the LA-WG is to develop network visible ways to represent the kind of control logic that is found in lighting control panels. These are things like flexible groupings of lights, pre-defined lighting scenes that can be recalled with the push of a button, fade control, and warnings and overrides for unoccupied periods. These represent the kind of high-level functionality that may be important in an integrated system.

• Many parts of the world are moving away from regulated, monopolistic electric and gas utility providers toward open, competitive markets for energy supplies. In the near future it will be important for building automation systems to communicate with utility providers to negotiate prices, reduce or shift peak loads, exchange billing and quality of service information, and perhaps other functions. The SSPC has created a Utilities Integration Working Group (UI-WG) to investigate these issues and develop suitable extensions to BACnet. The UI-WG is reaching out to utility companies and the Electric Power Research Institute for dialog on these issues.

• Access control systems are another building control application for which there is beginning to be some significant interest in BACnet. There is a great deal of appeal to linking access control systems with fire detection, lighting, and HVAC control for better energy and comfort management, and also to provide critical responses during emergency situations. In addition to actions that the systems may be programmed to take automatically, they can provide a wealth of information about the conditions in the building and the location of occupants that is helpful to emergency response personnel. The Life Safety and Security Working Group (LSS-WG) is shifting its focus to these areas.

• BACnet has enabled the interconnection of multiple buildings using IP protocols and the combination of what were historically stand-alone systems in a building. These capabilities have brought with them new security concerns. Thus, a whole web of network security issues are becoming important in integrated building systems. The SSPC has created a Network Security Working Group (NS-WG) to investigate and deliberate these issues. Their charter is to identify relevant security issues, assess risks, and propose appropriate solutions. In many cases it is expected that solutions already being applied in the fields of information technology and electronic commerce will be directly applicable for building automation systems. Other threats may arise that will need BACnet-specific solutions.

• For several years the SSPC has been working on a companion standard to BACnet called 135.1P, *Method of Test for Conformance to BACnet*. This standard, now in the public review process, will provide a comprehensive set of tests that can be used to determine the communication capabilities of a BACnet device. The draft version of this standard is already being used by the BACnet Manufacturers Association (BMA) as the basis for an independent testing and listing program for BACnet devices. The BACnet Interest Group -Europe is cooperating with the BMA in this endeavor and will open and run an independent testing laboratory in Europe. A very close and cooperative relationship has been developed between the SSPC and these industry associations.

Conclusion

While this article has focused on the technical developments leading up to BACnet-2001, much of the real excitement has been in the political and commercial arenas. BACnet has steadily gained acceptance throughout the world. It has been translated into Chinese, Japanese and Korean and has been designated as a national standard in Korea. It is already a European Community Pre-Standard and is in a parallel approval process that will lead to its becoming a full-fledged European and ISO standard. Moreover, recent surveys have revealed that BACnet installations are in nearly 100 countries and on every continent, including Antarctica. This has been the result of one central fact: BACnet is a true consensus standard of the building automation and control industry whose development, enhancement and use is open to all.

Note

BACnet is a registered trademark of ASHRAE. Use of trademark names does not imply recommendation of any commercial products by the National Institute of Standards and Technology.

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