A New Age In Building

by
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The emerging BACnet standard brings multi-vendor control systems and intelligent buildings closer to reality.

Intelligent buildings will deliver services that are more reliable, cheaper and more energy efficient because they are based on modern direct digital control (DDC) components integrated into one cohesive system. However, today's DDC systems employ proprietary communication protocols which prevent systems supplied by different manufacturers from communicating with each other. This has resulted in captive customers who buy a control system and are unable to upgrade or expand it without going back to the same manufacturer. This lack of communication capability between control systems made by different manufacturers also prevents the building owner from obtaining the most capable building service by not allowing him to choose, regardless of the system manufacturer, the best energy management and control system (EMCS), the best digital controllers, the best security system, the best fire detection system or the best telecommunications system.

The solution to these problems is an industry standard communication protocol. A standard communication protocol is the cornerstone upon which "intelligent buildings," which integrate these building services into one cohesive system, will be built. It is the lack of industry standards which has kept intelligent buildings a dream for the future rather than a reality today.

BACnet is a communication protocol for *Building Automation and Control Networks* which has been developed under the auspices of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). BACnet has been published as a draft ASHRAE standard and has completed its first public review. Several changes have been made to the draft standard as a result of the public review. A revised version of the standard was approved for publication and a second public review in January, 1994. If this second review proceeds smoothly, it is expected that BACnet will be published as an ASHRAE standard in 1994.

Participants in BACnet Development

The rules for development of American national standards require that all meetings be open to any interested parties and that membership on standards committees reflect a broad range of interests affected by the standard. The ASHRAE committee developing BACnet is known as Standards Project Committee (SPC) 135P. The membership of SPC 135P represents the interests of vendors, users and general interest groups. The current membership of SPC 135P is shown on the opposite page.

The Building Controls Industry is Supporting BACnet

A ground swell of pressure from the user community motivated ASHRAE to form a committee to develop the BACnet standard. Pressure from the user community has increased since expectations have been raised by publication of the draft standard. The largest landlord in the world, the U.S. Government, is also beginning to weigh in. The General Services Administration is planning to make conformance to BACnet a requirement for control systems purchased by civilian federal government agencies. The Department of Defense is also considering a requirement to use BACnet in military facilities. This kind of consumer interest has been a strong influence on manufacturers of building control systems.

The three largest control system manufacturers in the United States, Honeywell, Johnson Controls, and Landis & Gyr Powers have all publicly announced their intention to support BACnet in their products. According to *Energy User News,* at least 17 other manufacturers have also announced similar plans. The Trane Company has announced that it will sell products which implement an early version of BACnet and provide a free upgrade to the final version of the standard.

The National Institute for Standards and Technology (NIST) is forming a consortium to conduct interoperability tests on BACnet implementations. All manufacturers who wish to develop a BACnet implementation have been invited to join the consortium and test their implementations. So far 10 companies have joined the NIST consortium: Andover Controls, American Auto-Matrix, Delta Controls, Johnson Controls, Inc., Landis & Gyr Powers, PolarSoft, Siebe Environmental Controls, Snyder General, Staefa Control System, Inc. and The Trane Company.

There is also international interest in the BACnet protocol. The European Community has formed a standards committee to adopt a standard protocol for Europe. BACnet is one of the leading candidates for adoption as a European standard.

The final answer on the success or failure of BACnet will not be known for some time, but for all of these reasons, there are grounds for optimism. When ASHRAE formed the standards project committee in 1987, there were many in the industry who claimed that ASHRAE was taking on a task that could never succeed. It now looks like these critics will soon be proved wrong.

Membership of SPC 135P

Voting Members	Interest Category
Andover Controls, Inc.	Producer
Cornell University	User
Engineering Economics	User
Gresham, Smith & Partners	User
Honeywell, Inc.	Producer
Johnson Controls, Inc.	Producer
The Kling Lindquist Partnership	General Interest
Landis & Gyr Powers, Inc.	Producer
National Institute of Standards & Technology	General Interest
PolarSoft	General Interest
Public Works of Canada	User
Siebe Environmental Systems	Producer
The Trane Company	Producer

Non-Voting Members	Interest Category
Delta Controls, Inc.	Producer
Energyline Corporation	Producer
IBM	User
RRH Associates	General Interest
Staefa Control System, Inc.	Producer

Control Systems

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BACnet Architecture

Most modern building control systems are based on a hierarchical model. The lowest level in the hierarchy comprises application-specific or unitary controllers. These controllers interface with and are supervised by one or more levels of "field panels." At the top level are one or more operator work stations. BACnet is designed to address all of these levels. In fact, BACnet is designed to accommodate a hierarchical architecture of this type but does not require it.

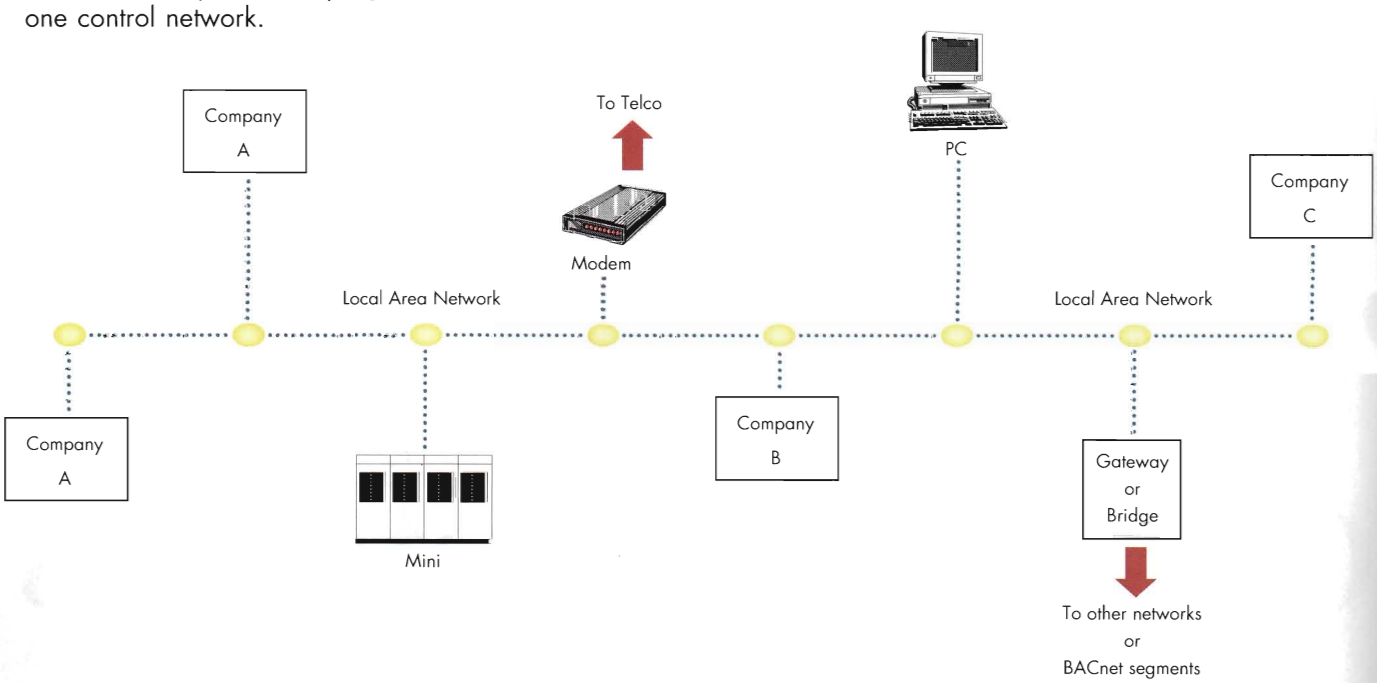
There are many variations on this hierarchical scheme in existing systems and new variations will develop in the future as control technology changes. It is the express intent in BACnet to allow and encourage innovative new approaches to control system architecture.

From the standpoint of the Open Systems Interconnection (OSI) Reference Model for communication processes, BACnet is a collapsed architecture implementing layers 1, 2, 3 and 7, as shown in on the next page. The application and network layers provide a uniform interface to one of several options at the data link and physical layers. These options provide a range in both price and performance, permitting system designers to optimize the architecture to match the needs of the customer.

BACnet Application Layer

The BACnet application layer is based on an object-oriented approach. Standardized objects provide an abstract, network visible view of the proprietary data structures and control algoritms for a controller. BACnet defines a small number of application services which enable the properties of the objects to be manipulated in a very general way. Most of the routine communication between controllers can be carried

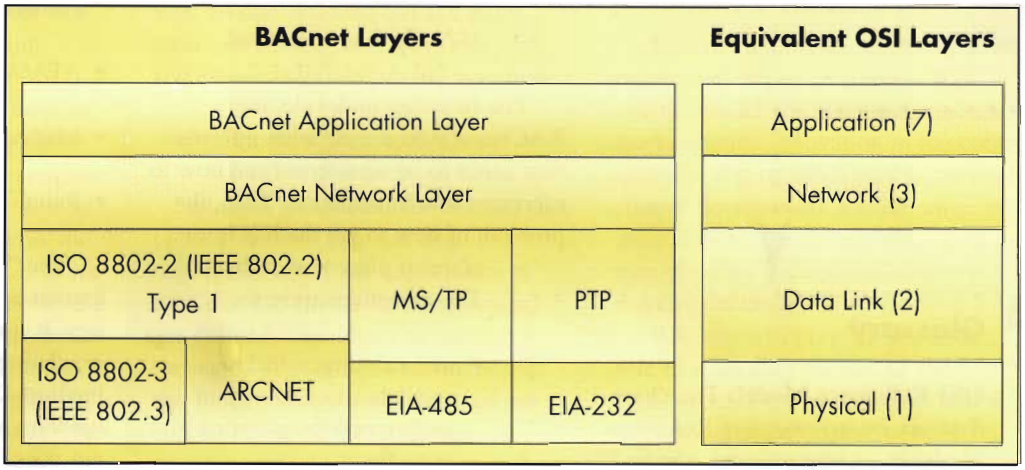
The BACnet protocol provides a means to integrate building control products from different manufacturers (A,B and C) into one control network.



out with only two application services or commands, *ReadProperty* and *WriteProperty*.

This approach has several very important implications. Since much of the complexity of a controller is represented by the objects, the number of application services needed in the protocol can be substantially reduced. For example, downloading a program, changing a temperature setpoint, modifying a schedule, initiating an equipment start-up sequence and much more can be accomplished with one application service, *WriteProperty*. Low cost devices with limited processing resources can possess a great deal of application functionality while only implementing a small subset of BACnet application services. New object-types or new properties of existing object-types can easily be defined to extend the protocol to accommodate new developments in technology. New application services can also be defined but will not, in general, be needed because the existing services are general in nature. This flexibility permits easy extensions that may be needed to integrate non-HVAC building services and also permits vendor proprietary extensions without loss of interoperability. In the case of a proprietary extension, existing functionality is not lost and use of the extension only requires knowledge of the existence and purpose of the new objects.

BACnet Collapsed OSI architecture



BACnet defines 18 standard object types and 35 application services. The application services are divided into five classes: Alarm and Event Services, File Access Services, Object Access Services, Remote Device Management Services and Virtual Terminal Services.

BACnet Network Layer

It is possible in a BACnet system to use four different data link and physical layer options in different parts of a control system. In the language of BACnet each of these different parts would form a "network." The purpose of the network layer is to connect these networks, forming an "internetwork." If there is no need for multiple networks in a control system, the network layer portion of a message collapses to two octets (8-bit bytes), almost eliminating the associated overhead. In control systems where a BACnet internetwork is used, the network layer overhead is not present in all messages. It is only needed for messages which must be routed from one network to another. For local messages the network layer portion again collapses to two octets. The routers which connect different BACnet networks also provide filtering. Only messages which are addressed to devices on a remote network pass through the filter. For example, messages between an operator workstation and a field panel controller which are connected by an Ethernet LAN would not pass through the filter in a router to an MS/TP network which connects unitary controllers. A message from the workstation to one of the controllers on the MS/TP network would pass through the filter. This improves the efficiency on all networks in the system.

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LAN Options in BACnet

The first step in developing BACnet was to decide what information needs to be transferred and how to represent that information. Then, the problem of how to get the bits from place to place was addressed. The objectives were to:

- use existing, widely available technology in preference to inventing something new,
- adopt national or international standards to meet our needs, if possible,
- provide a way to achieve some backward compatibility to existing products,
- provide a range of performance options with respect to speed and throughput,
- provide at least one low cost option to accommodate low cost application specific controllers,
- provide at least one deterministic medium access control option, and
- provide dial-up telephone access.

BACnet provides four options for local area networks (LANs) which could be combined within one control system. From the standpoint of the application and network layers, all of these options look the same because they were all designed to map into the same interface from network layer to data link layer. The options are:

- ISO 8802-2 & ISO 8802-3 (Ethernet)
- ATA/ANSI 878.1 (ARCNET)
- Master-Slave/Token-Passing (MS/TP)
- Point-To-Point (Dial-up telephone)

The "Ethernet" option is a well known and widely used LAN technology. It uses a contention approach to regulating access to the network medium. This is a non-deterministic medium access control because it is not possible to guarantee that a device will gain access to the medium for transmitting a message within a bounded time. This is not generally a problem, but some applications may require a guaranteed maximum delay before being able to send a message.

It was considered essential to have a high performance token-passing option in BACnet for applications which might require deterministic medium access. ARCNET is a widely used standard in the process control industry which is beginning to appear in the building control industry as well. It is a low cost token-passing protocol with a nominal bandwidth of 2.5 Mbit/sec. ARCNET was chosen over international standard token-passing protocols on the basis of cost. The ARCNET trade association claims that there are more installed ARCNET devices in the world than any other protocol.

To achieve the goal of a very low cost option with at least some backward compatibility, it was considered essential to base one choice on EIA Standard 485 (formerly known as RS-485). This is by far the most widely used physical layer protocol in the United States today for building control systems. There was however, no existing data link protocol standard to use with EIA-485. SPC 135P was also unable to obtain access to any propri-

Glossary

OSI Reference Model: The *Open Systems Interconnection* Reference Model is an international standard which provides a template for developing communication protocol standards. The functions of a communication protocol are divided into seven discrete parts or "layers" in the model. Not all of these functions are needed in a building control system. Because of this the BACnet protocol implements only layers 1, 2, 3, and 7 of the OSI model.

LAN: A *Local Area Network* is a communications network that provides interconnection of data communicating devices within a small area. It contrasts with a wide area network (WAN) which provides the same communications capability over a large area. The telephone system is an example of a wide area network.

UART: A *Universal Asynchronous Receiver Transmitter* is a hardware device which is used to asynchronously transmit and receive data over a data communication network.

etary protocols that were suitable, so a new one was created. The result was the Master-Slave/Token-Passing protocol or MS/TP.

MS/TP permits up to 255 devices on a single network. A configurable number of nodes in this address space are designated as "masters" and they form a logical token ring. This is the token-passing part of MS/TP. If Slave nodes exist they have no access to the communication medium except to respond to requests sent to them by one of the master nodes, forming the master-slave part of the protocol. Thus MS/TP can be entirely a peer-to-peer network, entirely a master-slave network, or a combination of the two.

The MS/TP protocol was designed with very specific hardware constraints in mind:

- a UART capable of transmitting and receiving eight data bits with one stop bit and no parity,
- an EIA-485 transceiver whose driver can be disabled, and
- a timer with a resolution of 10 "bit times" (a bit time is the time needed to transmit one bit).

These are very simple hardware requirements intended to be as inexpensive as possible. The idea is to extend BACnet functionality as far as possible into the realm of low-cost devices, perhaps even to smart sensors and actuators. MS/TP was not designed to be used at higher levels in a control system hierarchy. MS/TP is most useful for connecting low-cost devices together. The MS/TP local area network (LAN) would then be connected to one of the higher performance LANs and the rest of the BACnet internetwork through a more sophisticated controller which serves as a router for the MS/TP messages.

These LAN options in BACnet provide several choices for transmission media: shielded twisted pair, coax and fiber optics. Both bus and star physical topologies are possible.

Conformance to BACnet

In order to account for the fact that control devices may not need to implement all of the capabilities of BACnet, six classes of conformance are defined. The intent of the conformance classes is to accommodate the functionality of devices that are commonly used today without creating arbitrary barriers that will restrict future innovation. The classes define communication capabilities, not control functionality.

Some features of BACnet are not included in any conformance classes. These capabilities are divided into "functional groups." An example of a functional group is the Event Initiation Functional Group. Some devices may not have the capability to detect the occurrence of events and initiate reports of their occurrence. Others simply never have a need to, like perhaps an operator work station. The idea of a functional group is to combine communication capability which is needed to perform a clearly defined building control function, without placing artificial restrictions on which devices in the system need to have that capability. Building owners can specify the functionality they want in a device without being experts in computer communications. At the same time manufacturers are not forced to provide unnecessary functionality in a device just to meet the requirements of a conformance class.

Summary

BACnet addresses communication needs at all levels in a hierarchical control model and can easily accommodate future innovation in the control industry. It provides a way to connect control devices with a wide range in price, function and capability. BACnet uses popular, widely available networking technology.

BACnet will play an important role in spreading the use of today's DDC technology in buildings and also the development of new control system technology. By solving the captive customer problem, BACnet will open the market to owners who have delayed adopting or expanding DDC systems. It will become possible to integrate easily EMCS, fire, security, lighting and other building systems to create intelligent buildings. The door will be opened to the development of new third party products such as operator interface software which can be used with any building control system, special fault detection and diagnostic tools which rely on information from building controllers to perform their task, and other innovative products.

The goal of the ASHRAE standards project committee is summarized in the forward to the draft BACnet standard, *"... it is the hope of those who have contributed their time, energies, and talents to this work that BACnet will help to fulfill, in the area of building automation and control, the promise of the information age for the public good!"* With strong support from many control system manufacturers and the building controls market, there is good reason to believe that BACnet will achieve this goal. CBR

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