

***STRATA* Resource Inc**

Investigating Open Systems

Comparing LONWORKS[®] and BACnet[®]

White Paper

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1. Executive Summary

Open Systems have changed the way we address building automation. The Open System vision of a total building control network that encompasses every building system has now become the owner's baseline expectation. In addition, owners are looking for open solutions that break the sole-source lock, enable competitive bidding and allow best-in-breed product selection. For an Open System to deliver this vision it must have a dynamic application, be able to utilize enterprise technologies and present new opportunities and added value for manufacturers, system integrators and owners alike.

The challenge in the market is selecting an open system technology. There are many technologies available that claim to be an "open system technology". Each has its merits, but only the LonWorks Technology and the BACnet Standard have gained wide acceptance and application. They both aspire to the same goals, however, they have very different network, software and hardware requirements. For all practical intents they are mutually exclusive solution approaches. Ultimately, one must be chosen over the other. The two can co-exist at an installation, but are relegated to sharing information through a gateway. This architecture defeats the benefits of an open system and underutilizes each technology.

Before deciding between LonWorks and BACnet three areas need to be considered: the Open System goals; respective market presence; and solution approach. Both aspire to the Open System goals of *implementing an End-to-End solution that is Open, Interoperable and Multi-Vendor*. Comparing market presence illustrates the influence each has on the market and comparing solution approach reveals the strengths and weaknesses of each approach. A comparative evaluation of LonWorks and BACnet with respect to the Open System goals provides the basis for making an informed decision.

Comparing market presence involves evaluating user community activity and the extent of the installed base. When evaluating the user community it is apparent that the LonWorks community is larger, is producing more products and has more certified devices than the BACnet community. Comparing the installed base for each is more of a challenge. The available information shows a significantly larger LonWorks installed base consisting of millions of devices installed worldwide. Comparing market presence shows greater market acceptance for the LonWorks technology over BACnet. This implies a greater demand for LonWorks products and an active community of manufacturers and system integrators.

Comparing solution approach shows the similarities and differences between LonWorks and BACnet. Evaluating their similarities shows that both can deliver complete End-to-End solutions with an array of control devices and operator interface options. Focusing on their differences shows significant divergence in several notable areas including device interoperability (and interchangeability), network management, product distribution and integration of new technology.

The device level interoperability differences affect network architecture and the ability to create multi-vendor solutions. The LonWorks technology enables peer-to-peer data exchange at the field level and with the supervisory/management level, creating a flat network architecture with the potential for multi-vendor interoperable networks. To proliferate these networks, the LonMark[®] Association has established physical and application layer guidelines and functional profiles (each is available on the LonMark website). The functional profiles facilitate device-to-device communications by defining a set of functional characteristics for specific device types. This enables owners to choose, substitute, and integrate products from multiple vendors, thereby providing competition and competitive bidding. By contrast, the BACnet standard, while also defining how devices can exchange information, does not define device profiles analogous to LonMark profiles. Instead, manufactures are free to choose which BACnet functions to implement within devices. This results in devices from competing manufacturers that may not communicate device-to-device or be freely substituted with one another. Device-level BACnet data is typically exchanged through supervisory devices creating a tiered network architecture. Future network expansion is dependent on manufacturer specific applications to interface with supervisory devices.

Network management functions are used in every control solution to design, configure, commission and install devices. In proprietary solutions these functions are tied to a proprietary network database and are either distributed among several software applications or bundled with the operator interface application. Often network management functions appear invisible or operate automatically in the background during system/device configuration. The LonWorks approach collects all of the network management functions into a single independent software application to perform all network functions. Many LonWorks network management applications and network tools use the LNS[®] network operating system (available from Echelon[®]), which provides a common network database and client-server environment for all LonWorks installations. Many vendors have developed LNS-based products that can interact with devices and interface with operator interface applications from multiple vendors. This flexibility strengthens vendor independence by enabling network service from a wide array of network management tool providers. In contrast, BACnet solutions rely on a network management tool that is specific to the vendor supplying the solution. There is no BACnet equivalent to LNS; each vendor supplies a custom network operating system and network database (which may require multiple tools to implement).

Product distribution and the integration of new technology are two vital areas for commercial success and market influence. LonWorks and BACnet solutions are both available from several manufacturers, but only LonWorks component products are available from independent distributors. There is no independent distribution of BACnet component products. Independent product distribution provides system integrators and owners the opportunity to select the best-in-breed products without being tied to a manufacturer specific solution. The LonWorks community has also embraced new technology (new to building automation) like XML, IP and Web Services. Products are readily available, opening new opportunities for property owners and system integrators. The BACnet community has been slower to adopt new technologies, resulting in longer time to market for new products.

Selecting an Open System solution is a matter of choosing either a LonWorks or BACnet solution. Both are capable of delivering an End-to-End solution, however, for product availability, product diversity, vendor choice and the latest technology, LonWorks has a significant market lead.

2. Introduction

The demand for open systems in building automation has resulted in the development and promotion of numerous "open system technology" solutions. The landscape of options is crowded and confusing, with each option appearing to achieve the same goals of implementing an open, interoperable, multi-vendor solution. By evaluating the technologies that meet the open system goals and are being embraced by owners, system integrators and manufacturers as End-to-End solution options, the landscape clears to just two choices - LonWorks or BACnet.

The LonWorks Technology and the BACnet Standard have gained widespread application and are the clear choice as the leading open system technologies. They have distinguished themselves above the rest with a flexible architecture focused on meeting the growing requirements of building automation. Despite their achievements, LonWorks and BACnet have very little in common. They have very different origins, distinctive network architectures, diverse hardware and software requirements, and each has a core group of devout followers.

LonWorks and BACnet may aspire to the same goals, but they use vastly different methods and technology. The solutions are mutually exclusive and owners seeking an open solution must select either LonWorks or BACnet. Owners have turned to the numerous articles, discussions, debates and arguments circulating throughout the industry as the basis for their decision. In most instances these discussions are bias toward one technology by presenting an incomplete picture of the other. There are even examples where devout followers have argued that their solution is the only technologically and ideologically correct solution. The number of biased articles makes it difficult to arrive at an informed decision when selecting a technology. Only an objective, side-by-side comparison presents a complete picture of each technology and provides the basis for an informed decision when choosing a solution.

An objective, side-by-side comparison of LonWorks and BACnet is the best method for understanding their differences, achievements and potential.

The goal of this paper is to present an objective comparison of LonWorks and BACnet as the basis for an informed decision when selecting an open system. Several aspects of respective technology, history and achievements are discussed.

3. Open System Goals

Before comparing LonWorks and BACnet an understanding of their mutual goals is needed. They both aspire to the open system goals of enabling *the implementation of an End-to-End solution that is Open, Interoperable and Multi-Vendor.*

3.1. Defining the Goals

The open systems goals originate from owner frustrations with the rising costs of maintaining a sole-sourced proprietary system. They want to break the sole-source lock and bring operating costs under control without sacrificing quality. They expect open technology manufacturers to provide a full-featured, complete solution and not just parts and pieces. To meet these requirements, open systems must meet the functional needs of the building, be easier to expand than a proprietary solution, be capable of combining disparate building systems, allow best-in-breed product selection and enable competitive bids.

The following table presents a definition for each Open Systems goal.

Goals	Definition
<i>Open</i>	The technology is available for any manufacturer to develop and deliver devices as individual products or as part of a complete solution
<i>Interoperable</i>	Devices use peer-to-peer communication to share information within a single system (e.g. HVAC) and across multiple systems (e.g. HVAC and Security) without the use of a gateway or translation software
<i>Multi-Vendor</i>	A solution can be constructed using devices and software produced from different manufacturers, without the need for gateways or manufacturer specific software or network tools
<i>End-to-End Solution</i>	A holistic approach that applies the technology to every system level from field devices to the operator interface and ancillary products (e.g. diagnostic tools)

Table 3.1 - Open System Goals and Definitions

3.2. Achieving the Goals

A technology must meet all of the open system goals to be considered an open system. Achieving some, but not all of these goals does not result in an open system. There are several technologies that meet one or more, but not all of these goals. Consider the following points when evaluating an Open System:

- There are companies that claim their proprietary technology to be *Open*. These companies make their protocol and hardware architecture available to third party manufacturers, and offer certification for any third party product developed. Their technology is available for any manufacturer to develop products, but it is not an Open System because a single company controls the underlying protocol.
- Select proprietary solutions have a level of *Interoperability* between either HVAC and Security systems or HVAC and Lighting systems. This is limited interoperability, exclusively with products from a single manufacturer. Their devices use peer-to-peer communication across multiple systems, but it is not an Open System because it is exclusive to a single vendor. This precludes an alternate vendor from making network modifications because they do not have access to the single vendor's proprietary tools.
- Several technologies are available that can create a limited *Multi-Vendor* environment, such as Modbus. Manufacturers have applied Modbus to a variety of products, and it is possible to use Modbus products from multiple manufacturers in a single system. Using Modbus products from multiple manufacturers does not make an Open System, because it cannot deliver an End-to-End solution.
- Nearly every proprietary solution is an *End-to-End* solution offering a holistic approach. Each product in a proprietary solution is manufacturer specific and therefore not an Open System.

An Open System must be an End-to-End solution with a multi-vendor product mix that uses peer-to-peer communication across all building systems.

3.3. Delivering the Goals

LonWorks and BACnet technologies both aspire to the same Open System goals, but the task of delivering the goals is left to the manufacturers and integrators. Each technology provides a level of design and implementation flexibility and options not seen in traditional proprietary control systems. The result is a market of solutions and products that carry either the LonWorks or BACnet name where some achieve the Open System goals and others do not. For owners to benefit from the Open System goals they need to first recognize how LonWorks and BACnet deliver upon the goals and second, require products and solutions to meet the goals.

The following points discuss how the LonWorks and BACnet technologies achieve the Open System goals and how to recognize implementations that deliver the goals.

- *Open* - Both technologies are readily available to manufacturers for the development of products and solutions. This is facilitated through standards organizations, which cultivate industry expertise to maintain and update standards. The BACnet Standard is maintained and available through the ASHRAE[®] organization and the LonTalk[®] protocol is maintained and available through the ANSI/EIA¹. The LonTalk protocol document is the core component of the LonWorks technology, and the LonMark guidelines and the Neuron[®] processor are often used to fully implement a LonWorks solution. All LonMark guidelines are maintained by the LonMark Association and are available on their website. Two different semiconductor manufacturers manufacture the Neuron processor, which is the processor of choice for product development. Solution components, guidelines and core standards are maintained and available for both LonWorks and BACnet.
- *Interoperable* - LonWorks and BACnet provide access to interoperability differently. The LonWorks technology provides field level interoperability to all devices, which creates a flat network of peer devices. This is critical for implementing multi-vendor solutions and for eliminating the need for gateways and translation devices. The only way to inhibit LonWorks interoperability is to use proprietary data types. Adhering to LonMark guidelines (functional profiles, SNVT, SCPT) will safeguard interoperability. The BACnet standard specifies several interoperability areas - data sharing, alarm and event management, scheduling, trending, and device and network management. Each area represents a specific set of BACnet elements that manufacturers must choose to implement uniformly to provide interoperable products (there is no required subset of elements for BACnet compliance).
- *Multi-Vendor* - Manufacturers can use either LonWorks or BACnet to develop a multi-vendor solution. Part of the original intent for the creation of each technology was to enable and promote the development of multi-vendor solutions. The only hurdle is getting manufacturers to develop products that use standard data types and not proprietary data types. There are many vendors that offer LonWorks and/or BACnet product and solution options, but not all of them faithfully use standard data types. The LonWorks standard data types (SNVT, SCPT) are available from the LonMark Association and the BACnet standard data types (standard objects) are published in the BACnet Standard document. Using proprietary data types limits the effectiveness of each technology and inhibits the creation of a multi-vendor solution.
- *End-to-End Solution* - There are numerous examples of LonWorks and BACnet installations worldwide. Not all of them delivered what the owner was expecting and not all of them deliver an End-to-End solution. Several vendors offer a gateway solution that appears to be an End-to-End LonWorks or BACnet solution. An End-to-End solution does not require a translation device between the HMI and the field devices or between field devices controlling different building systems.

Recognizing which open system solutions deliver the Open System goals is the key to achieving the benefits of open systems. Both the LonWorks technology and the BACnet standard were designed to meet the open system goals; however, some manufacturers have used the inherent flexibility in these open technologies to close their solution and effectively deliver a proprietary solution. A LonWorks or BACnet solution that delivers the Open System goals adheres to standard data format guidelines, is interoperable between different vendors and does not use a gateway architecture.

¹ The LonWorks protocol, commonly referred to as LonTalk, is ANSI/EIA 709.1-B, Control Network Protocol Specification. It is maintained by the CEA through their standard processes and is available through their affiliate, Global Engineering Documents. LonTalk is an Echelon trademark and for the purposes of this document, references to LonTalk denote ANSI/EIA 709.1-B.

4. Comparing LonWorks and BACnet

Comparing LonWorks and BACnet is not always an "apples to apples" comparison. There are significant differences in technology and solution approach. When exploring these differences there is a tendency to get lost in a technical discussion of bits and bytes, which is more relevant for the computer and software industries than it is for the building automation industry. A comparison relevant to building automation should focus on market presence and solution approach. A market presence comparison is an indication of user and manufacturer acceptance, through the number of user organizations and product availability. A solution approach comparison illustrates the tangible differences and implementation issues to consider when evaluating a solution. The following sections compare the LonWorks and BACnet market presence and solution approaches.

4.1. Market Presence Comparison

Market presence is an important factor when faced with choosing between competing technologies. Numerous technologies have been developed, marketed and praised only to disappear from the market place after a few years of service. The difference between the technologies that thrive and the ones that fade is not always technology based. Very often, success or failure is a function of market acceptance, product availability and product diversity.

In general, the market presence of Open Systems has profoundly affected how business is conducted. From owners to manufacturers to system integrators, it is changing how projects are specified, products are manufactured and solutions implemented. Consider the following points when evaluating the market presence of Open Systems:

- Owners are using open systems to seize the opportunity and advantage of choice. They are choosing manufacturers, choosing products and choosing system integrators, with no sole-sourced strings attached.
- Manufacturers are producing products and solutions to meet open system specifications. Open system technology puts less demand on the manufacturer's resources. For proprietary solutions, a manufacturer has to invest in ongoing R&D for solution maintenance and improvement. For an open solution, a third party is maintaining and updating the core technology enabling the manufacturer to focus on strategic business areas.
- System integrators no longer have to represent multiple manufacturer product lines to meet all project specifications. Representing multiple product lines often requires a dedicated internal resource for each product line. Using an open system technology enables system integrators to use products from multiple vendors without the need for specific training on each product line, which lessens the demand on internal resources. Open systems technology enables a system integrator to focus on a single solution approach for all building automation applications.

Open Systems have changed the way business is conducted. It is not a question of whether Open Systems have the market presence to survive, but a question of selecting which open system technology to use.

Evaluating the LonWorks and BACnet market presence with a focus on accessibility to products and user-base clearly demonstrates the influence each technology has on the market. The number of manufacturers developing products is an indication of the availability and diversity of products. The size of a technology's user-base is directly related to the longevity of the technology. User groups that promote the use of the technology further market penetration of their adopted platform, promote best practices in local regions, and are an indication of overall market acceptance.

The following table lists several LonWorks and BACnet statistics that relate to market presence on a worldwide basis:

Topic	LonWorks	BACnet
Statistics	<ul style="list-style-type: none"> • April 2002 - Over 18 million LonWorks devices installed • Over 30 million Neuron processors shipped • Developers worldwide - Thousands • LNS[®] plug-ins listed - Over 240 • LonWorks product database - 924 products listed from 155 manufacturers¹ • Engenuity Systems - 1196 products for sale on website² • LNO product database - Over 500 products listed³ 	<ul style="list-style-type: none"> • BACnet Vendor ID⁴ - Over 120 • BMA[®] Product Database - 63 products listed from 8 manufacturers⁵ • 2000 BMA Survey Results⁶ <ul style="list-style-type: none"> ○ Installations 19,054 ○ Countries 82 ○ Gateways 2,410 ○ Devices by Network Type <ul style="list-style-type: none"> ▪ Ethernet - 11,970 ▪ ARCnet - 95,567 ▪ MS/TP - 248,500 ▪ PTP - 1,549 ○ Workstations 15,807 ○ Large Controllers 53,391 ○ Unitary Controllers 299,600
Certification	<ul style="list-style-type: none"> • LonMark Interoperability Association Members - Over 300 worldwide • LonMark Certified Devices - Over 490 • Companies with Certified Products - Over 90 • LonMark Task Groups - 17 • LonMark Functional Profiles - Over 68 	<ul style="list-style-type: none"> • BMA Members <ul style="list-style-type: none"> ○ Corporate - 23 ○ Individual - 11 ○ Affiliate - 4 • BTL[®] Listed Devices⁷ - 35 • Companies with Certification - 6 • BACnet Working Groups - 7
Certification Centers	<ul style="list-style-type: none"> • North America - LonMark Association, USA • Europe - Austria • Asia - NTT Data, Japan 	<ul style="list-style-type: none"> • North America - BTL (BACnet Testing Laboratories), USA • Europe - German Certification Center Pending
International & Country Organizations	<ul style="list-style-type: none"> • LonMark Interoperability Association (USA) • European LonUsers[®] Web Portal • LonUsers International User Groups (~ 670 companies represented) <ul style="list-style-type: none"> ○ LonUsers Austria ○ Belgian-Luxembourg Lon User Group ○ LonUsers Group Denmark ○ LonUsers Finland ○ LonUsers France ○ LON Nutzer Organization (Germany) ○ LonUsers Italia ○ LonUsers Netherlands ○ LonUsers Norway ○ LonUsers Sweden ○ LonTech Thun (Switzerland) ○ Polish LonUsers Group ○ United Kingdom Open Systems Assoc • Annual conferences for LonUsers in China, Korea, Japan 	<ul style="list-style-type: none"> • BMA (BACnet Manufacturers Association) • SSPC-135 (The BACnet Committee) • BIG-NA (BACnet Interest Group - North America) • BIG-EU (BACnet Interest Group - Europe) • BIG-AA (BACnet Interest Group - AustralAsia) • Annual conferences in North America and Europe

Table 4.1 - LonWorks and BACnet Market Presence Comparison

4.2. Market Review

The information available indicates that, when compared to BACnet, LonWorks has the greater market presence with a larger installed base and a larger community applying the technology. An accurate count of installed LonWorks and BACnet devices is difficult to obtain, because companies producing and installing building automation products and systems do not publish data of this type. For installed LonWorks devices, the number of Neuron processors delivered is the best guideline. Even though LonTalk can be ported to any processor, the Neuron processor is still the primary choice for many manufacturers. For installed BACnet devices, manufacturer survey responses are the only guideline, because BACnet is not based on a specific technology. BACnet product development and installation can easily escape notice. As a result the total number of BACnet devices installed is anybody's guess. What is easier to determine is

the size and activity of each user community. The LonWorks community of users is larger based on the number of available products and the large number of user groups. The various LonWorks product databases and the activity of the LonMark Association are indicative of an active community of manufacturers and system integrators. The BACnet community is active, but smaller by comparison with lower BMA membership, less product certification activity and fewer user groups.

4.3. Notes and Definitions

1) LonWorks Product Database

This is a global database of LonWorks based products hosted by Echelon Corporation. It includes products from various manufacturers and is devoted to the promotion of the LonWorks platform, Open Systems and interoperability in the controls network industry. The database is intended to be the most comprehensive collection of LonWorks devices and services available worldwide. It does not represent all available products and services, but it is the best available source of information. (www.echelon.com)

2) Engenuity Systems

Engenuity Systems is an independent distributor of LonWorks products and materials. They are the largest US distributor of LonWorks products, representing a global range of products from manufacturers and software developers. Their website includes product information, Internet demos and online commerce. (www.engenuity.com)

3) LNO Database

The LNO (LON Nutzer Organisation e.V.) is an organization of companies, institutions and distributors of LonWorks technology in the German speaking countries. It is one of the largest, oldest and most active LonUsers organizations. The LNO Product Database is a collection of products, providers and information on LonWorks products available from companies in German speaking countries. (www.lno.de)

4) BACnet Vendor ID

BACnet Vendor IDs are issued to requesting companies. A company must have a Vendor ID prior to developing BACnet products. Not all companies issued a Vendor ID produce BACnet products or solutions. As of October 2003, 122 Vendor IDs have been issued and are distributed internationally as shown in the following table. (www.bacnet.org)

Country	#	Country	#	Country	#
USA	67	Switzerland	5	Belgium	1
Japan	21	United Kingdom	3	France	1
Canada	8	Australia	3	Italy	1
Germany	6	Korea	2	Netherlands	1
		South Africa	2	Sweden	1

Table 4.2 - BACnet Vendor IDs

5) BMA Product Database

This database is hosted by the BMA and lists BACnet products available from BMA member companies. It includes products from various manufacturers and is devoted to the promotion of the BACnet platform. It may not represent all available products and services, but it is the best available source of information. (www.bacnetassociation.org)

6) BACnet Manufacturers Association (BMA) Survey

Survey responses are the only way to track BACnet use because the BACnet Standard is not based on a specific technology. In 2000 the BMA conducted a survey of its then 15 corporate members to determine how many BACnet products were in use. Only 6 companies responded to the survey and the results of their responses are presented in the Table 4.1. (www.bacnetassociation.org)

7) BTL (BACnet Testing Laboratories)

The BTL tests BACnet products for conformance to the BACnet standard. Products successfully tested are listed on the BTL website and carry the BTL mark. The BTL operates independent of the BACnet Committee and ASHRAE®, but is closely monitored by the BMA.

4.4. Solution Approach Comparison

A direct comparison of solution options most often reveals the deciding factor(s) for selecting a particular solution. The key to effectively comparing any two solutions is to evaluate similar aspects of each in a side-by-side comparison. This illustrates strengths and weaknesses and ultimately provides the basis for selecting the solution most appropriate for your application. The challenge is identifying shared elements that influence the installation, life cycle, expandability and serviceability of the installed system.

Creating a comparative table of LonWorks and BACnet elements is a challenge. Their approach to building automation is very different, and in several cases elements of one do not exist in the other. Ultimately, the topics selected represent implementation and product issues along with milestones achieved by each technology since their inception.

The following table is a comparative overview of LonWorks and BACnet elements. The table serves as a summary of topics and their significance to each approach. Supporting arguments and additional detail for each topic are supplied in the sections following the table.

Topic	LonWorks	BACnet
History	1988 – Protocol developed by what later became Echelon Corporation (1990) 1994 – LonMark Organization formed 1995 – 1 st LonMark Certified Device 1997 – LNS 1.0 released 1998 – 100 th LonMark Certified Device 1999 – 200 th LonMark Certified Device 1999 – i.LON [®] 1000 release - IP integration 1999 – LonTalk becomes ANSI/EIA standard 709 2001 – i.LON 100 release - XML Web services 2001 – 300 th LonMark Certified Device 2002 – LonTalk Update release by ANSI/EIA 2002 – 400 th LonMark Certified Device 2003 – 500 th Certified Device (estimated)	1987 – ASHRAE [®] committee formed 1995 – BACnet1995 Released 1995 – BACnet1995 becomes ANSI standard 1998 – BIG-NA and BIG-EU established 1999 – BMA Established 2000 – BTL Established 2000 – BIG-AA established 2001 – BACnet2001 Released 2001 – BACnet2001 becomes ANSI standard 2002 – BTL begins product testing 2002 – XML Work Group established 2003 – Becomes ISO Standard 16484-5 2003 – 35 BTL listed devices
Network Architecture	<ul style="list-style-type: none"> • A “bottom up” solution focused on device interoperability • Open standard that employs a common protocol • Flat network topology 	<ul style="list-style-type: none"> • A “top down” solution focused on HMI integration • Open standard that can employ multiple protocols • Tiered network topology
Network Management	<ul style="list-style-type: none"> • Network Management tools available from many sources (approximately 30) • Single tool to access any vendor's devices - not vendor specific • Single tool to access all media types • View and configure network devices • View network variables and establish peer-to-peer communications • Single tools enable graphical presentation of network and common database to store network characteristics 	<ul style="list-style-type: none"> • Limited network management functions • No network management tool to view all supported protocols, typically requires tool from manufacturer that supplied subsystem or system • No common database for network characteristics

Topic	LonWorks	BACnet
Operator Interface Software	<ul style="list-style-type: none"> • LNS developed as a vehicle for HMI communication • OpenLDV™ with core LNS components available with Echelon NICs to allow any non-LNS based HMI to interface with LonWorks networks • Many native LNS HMI applications • Many manufacturer specific communication drivers • LNS DDE available from Echelon • LNS OPC available from several 3rd party developers/suppliers • LNS database back-up and restore features 	<ul style="list-style-type: none"> • Originally BACnet was intended for use at the operator level • Several native BACnet HMI applications • Several manufacturer specific communication drivers • Most HMI communication uses IP or ARCNET protocols
Design Guidelines	<ul style="list-style-type: none"> • LonMark Association sets LonWorks guidelines (physical layer; application layer via functional profiles), which define mandatory and optional data elements, and product certification requirements • 68 - LonMark Functional Profiles (LFP) • 30 - LFPs in development • Define standard data types (SNVT and SCPT) <ul style="list-style-type: none"> ○ Over 170 published SNVT ○ Over 290 published SCPT • LonMark Association certifies products 	<ul style="list-style-type: none"> • BACnet standard defines architecture and sets broad development guidelines • Identifies data types, PICS format, BIBBs and device profiles • 150 - published data types • 23 - published standard objects • 67 - published BIBBs • 6 - published device profiles • BACnet committee maintains the BACnet standard, but does not certify products
Certification	<ul style="list-style-type: none"> • Device certification performed by the LonMark Association and through Certification Centers using manufacturer independent tools • Devices certified against LFP • LFP defines mandatory and optional data elements (direction and type) that manufacturer must implement • Published LFPs available at LonMark website 	<ul style="list-style-type: none"> • BACnet Testing Laboratories (BTL) test and list BACnet products using manufacturer independent tools • BTL does not set BACnet development guidelines; they not establish mandatory/optional data elements for devices • BTL test and verify manufacturer's selected use of BACnet • Certified devices include a complete PICS document, which indicates BIBBs used • Ultimately, BTL to test all BACnet products - devices and software
Device Architecture	<ul style="list-style-type: none"> • Generic controller - Neuron Chip processor, Neuron C programming language, I/O Channels, Transceiver • Hosted controller - Neuron Chip plus 3rd party processor • Non-Neuron - 3rd party processor with ported implementation of LonTalk • Majority of LonWorks controllers use the Neuron Chip processor 	<ul style="list-style-type: none"> • Processor independent • Programming language independent • Final controller specification at manufacturer's discretion • No device protocol usage guideline • Majority of devices use MS/TP protocol
Devices	<ul style="list-style-type: none"> • All devices use LonTalk, most devices use the Neuron; some are non-Neuron devices • Infrastructure - Routers, web servers, gateways, NIC • Non-HVAC - Access, Energy Management, Fire & Smoke Control, Motor Control, Lighting, etc • Data Collectors - schedulers and trend loggers 	<ul style="list-style-type: none"> • All devices are protocol specific • Routers - used to translated between protocols or extend existing LAN • Supervisory Devices - typically use multiple protocols • Gateways - most commonly developed BACnet device • Non-HVAC - Access, Lighting
Diagnostic Tools	<ul style="list-style-type: none"> • Network Diagnostic tools available from several vendors • Single tool can access and evaluate a multi-vendor network • Single tool can access all media types 	<ul style="list-style-type: none"> • Very few diagnostic tools available • Must be maintained to include new BACnet objects and data types

Topic	LonWorks	BACnet
Protocols	<ul style="list-style-type: none"> • Single protocol - ANSI/EIA-709.1 (LonTalk) • EIA/CEA-852 to tunnel LonTalk over IP • Embedded into every Neuron Chip • Can be ported to almost any processor or microcontroller • Every LonWorks devices uses LonTalk • Supports various media including unshielded twisted pair, fiber optics, radio frequency, infrared, and power line carrier. 	<ul style="list-style-type: none"> • Multiple protocols supported • BACnet/IP, Ethernet, ARCNET, MS/TP, PTP, LonTalk • All industry standard protocols • Each with specific implementation and media requirements
XML, IP & Web Services	<ul style="list-style-type: none"> • i.LON device series <ul style="list-style-type: none"> ○ Peer-to-peer ○ Web Services ○ Ethernet NIC • EIA-852 - LON/IP products available from several manufacturers • LNS API accessible over IP directly • Porting existing LFP profiles to XML (coordinating effort with the "XML/Web Services Guideline" development under the auspices of CABA) 	<ul style="list-style-type: none"> • XML Work Group established to investigate the application of XML in the BACnet Standard • Long-term goal to develop an XML method for the automated configuration of BACnet systems • Developing a machine-readable device description language tentatively referred to as "XPICS" for "XML Protocol Implementation Conformance Statement"
Distribution	<ul style="list-style-type: none"> • Direct from manufacturer as part of a complete solution • Many companies produce solution independent LonWorks devices (lighting, sensors, drives, power metering, security, life safety, diagnostic tools, etc.) • Independent distributors representing devices from multiple vendors 	<ul style="list-style-type: none"> • Direct from manufacturer as part of a complete solution • Very few companies produce solution independent BACnet devices (lighting, diagnostic tools, gateways) • No independent distribution
Related Standards Qualifications	<ul style="list-style-type: none"> • IFSF – International Forecourts Standards Federation (EU petrol station controls) • IEEE 1473L– In train controls • AAR – Electro-pneumatic braking controls; USA • SEMI – Semiconductor Equipment Manufacturer's Industry • Finnish Homes – Automation standard • CEN-TC247 – EU government buildings (in process) 	<ul style="list-style-type: none"> • ISO Standard 16484-5 • CEN-TC247 – EU government buildings • Korean National Standard • Endorsed by NEMA

Table 4.3 - LonWorks and BACnet Solution Approach Comparison

4.5. Solution Review

The above comparative table presents a spectrum of information on topics relevant to LonWorks and BACnet users. There are several differences noted in the table to consider when selecting a solution. The most significant differences affect creating an Open System project specification and the maintenance required during the solution life cycle. An Open System project specification must specify acceptable products, certification levels and network architecture to ensure that a vendor solution meets the owner's expectations. After installation the owner is tasked with maintaining the network and will focus on replacement product availability, replacement product certification level and network architecture issues. The key differences noted in areas of product availability, product certification, and network architecture from Table 4.3 are discussed below.

- Product availability is the primary issue when constructing a multi-vendor installation. Creating a multi-vendor installation is only possible if you have access to vendor products apart from their respective solution. An overwhelming majority of BACnet products are solution-specific and available only as part of a total solution from a single vendor. There are a few infrastructure products and lighting controllers available as individual component products. This makes best-in-breed product selection almost impossible. Having

VAV controllers from vendor A and FCU controllers from vendor B in a single project is unlikely because these products are typically not available for purchase apart from their respective solutions. Furthermore, the BACnet standard does not define functional characters of specific controller types (like VAV and FCU controllers), making it difficult to integrate a multi-vendor installation. By contrast, there are over 1000 LonWorks products distributed by Engenuity Systems produced by manufacturers worldwide. There are many vendors that offer their products to customers as individual units through Engenuity and as complete solutions direct from the factory. This is possible because the LonMark Association has defined functional characteristics for specific device types, enabling integrators to routinely craft solutions from devices of pre-defined characteristics. The LonWorks technology has fostered greater product availability, enabling best-in-breed selection for creating multi-vendor installations.

- Product certification methods and results differ significantly between LonMark and the BTL. The most significant difference is that LonMark sets specific guidelines (LonMark Function Profiles - LFP) that products are certified against and the BTL does not. If a manufacturer wants to produce a LonMark Certified device, they must follow the requirements specified in the LFP. The LFP specifies the mandatory and optional network variables and configuration properties for each device type. The BTL does not set product guidelines to test against. BTL tests against a broad classification of requirements called BACnet Device Profiles. There are 6 profiles that describe a range of functionality and effectively establish 6 categories that represent all BACnet control devices. The BACnet standard does not define data requirements or the action to be taken upon data that is received. Ultimately, the BTL tests the selected BACnet functions implemented by the manufacturer for compliance to the BACnet standard.

The difference in certification practices is best illustrated by an example of a vendor seeking certification for a VAV controller. For LonMark certification the vendor must adhere to the VAV LFP. The LFP guarantees repeatability (for the mandatory network variables and configuration properties) from vendor to vendor by defining the data to be exchanged and the actions to be taken upon receipt of the data by the VAV controller. For BTL testing the vendor must adhere to one of the BACnet Device Profiles. BACnet Devices Profiles do not specify functional characteristics specific to the device type. As a result, there is no VAV BACnet profile. The vendor is left with tremendous development latitude with respect to BTL listing. This makes repeatability from vendor to vendor unlikely.

- The BACnet and LonWorks network architectures differ greatly. BACnet is a "top down" approach that typically involves supervisory controllers and multiple protocols, each with its own implementation and media requirements. The supervisory controllers connect the field level protocol to the management level protocol and typically contain scheduling and trending functions. The combination of multiple protocols in a single solution, combined with the vendor specific nature of the supervisory controllers, make it difficult to replace the system integrator or system products. LonWorks is a "bottom up" approach that uses a single protocol that supports multiple media types to create a flat architecture of devices that adhere to specific functions with no supervisory controllers. A single protocol is used throughout a LonWorks network regardless of the media and manufacturer. This creates the flat architecture, and it enables the owner to replace the system integrator and/or system products without losing the initial investment.

When faced with creating a project specification or maintaining an installed solution, the areas of product availability, product certification and network architecture are of paramount concern. For product availability and certification, LonWorks has a clear advantage. There are more LonWorks products available from more sources than BACnet products, and LonMark product certification guidelines and expectations are precisely defined, whereas the BTL expectations are not. In the area of network architecture, the advantage depends on owner expectations. If an owner expects an Open System solution to provide the option to easily replace the system integrator or replace original installed products with products from another vendor, then LonWorks presents a clear advantage. If these issues are not part of the owner's expectations or requirements, then either technology is applicable.

5. The LonWorks Technology and the BACnet Standard

Table 4.3 is a concise presentation of topics and information relating to LonWorks and BACnet. In this section, each topic from the table is discussed in further detail. This provides a better understanding of the difference and similarities between LonWorks and BACnet.

5.1. History

See section 7, *Appendix - History*, for further discussion.

5.2. Network Architecture

The BACnet and LonWorks network architectures differ greatly. The intrinsic difference is that LonWorks is an open protocol technology and BACnet is an open standard. This may sound like a difference of semantics, but in fact is the fundamental difference that sets the two solutions apart. All of the differences between LonWorks and BACnet stem from this.

LonWorks is an open protocol technology, which means that the network architecture is based on a single protocol - LonTalk. LonTalk is what every LonWorks device has in common, regardless of manufacturer, device type, processor, or communication media. Using a single protocol *enables* a flat network topology where all network devices are peers and any device can communicate with the operator workstation without requiring a gateway, supervisory controller, or other intermediary device.

LonTalk facilitates interoperability by creating a single set of network rules that apply to all devices and software. Manufacturers, system integrators and owners have recognized the benefits of device level interoperability and often characterize LonWorks as having a "bottom up" network architecture. LonTalk commonality provides manufacturers with a standard set of design requirements (which shortens product time to market) and enables system integrators to use products from multiple manufacturers without requiring specialized training or manufacturer specific software. It empowers owners to open their facility to competitive bids and multi-vendor installations, without compromising the integrity or maintainability of the network.

BACnet is an open standard, which means it defines a comprehensive set of rules for network architecture and product development that is not technology dependent. BACnet is processor independent, programming language independent and it supports 6 different protocols (each with specific implementation and media requirements). This empowers manufacturers with unparalleled flexibility in product development and solution architecture, which has resulted in a lack of commonality between devices and software applications. There are no design guidelines to set expectations.

BACnet is a "top down" network architecture that focuses on operator interface integration. As a result, in practice many BACnet based solutions focus on gateway integration at the operator interface. The network architecture consists of a BACnet compliant operator workstation connected to an array of gateways translating system data from various third party solutions. Other solutions, called native BACnet systems, apply BACnet elements at each solution level. Native BACnet systems employ multiple protocols, which creates a tiered architecture using either supervisory controllers or other intermediary devices to translate between protocols. These solutions are dependent on manufacturer specific software to install and maintain.

5.3. Network Management and Operator Interface Applications

LonWorks and BACnet each have a very different approach to network management and operator interface applications. Every control solution, regardless of the underlying technology, requires some form of operator interface and network management tool. Proprietary solutions typically bundle network management functions with the operator interface application. This makes network management functions transparent to the user and configuration is done automatically, creating a proprietary lock on the system.

There are several examples of LonWorks LNS and BACnet operator interface applications. Many BACnet solutions are focused on integration at the operator interface with gateways to various field level technologies. These solutions typically have a native BACnet operator interface application with a custom network database. There is no network database standard within BACnet. The typical LonWorks solution uses an LNS-based operator interface application with a standard LNS network database. The application can be native-LNS, use an LNS OPC connection, use a custom LNS communication driver or, most recently, use the OpenLDV unified driver with any application (provided the physical connection is an Echelon network interface product). Regardless of the LNS connection method, using LNS standardizes network commands from installation to installation. This ensures that owners receive essential maintenance features, like database backup and restore. The LNS operating system provides a common platform for interface development, which has accelerated the use of LonWorks at the operator interface level.

A network management tool is used on every LonWorks installation and they are almost nonexistent on BACnet installations. Every LonWorks LNS solution uses an LNS network manager to install, manage and expand the network, regardless of device vendor or media type. Many LNS network management tools present a graphical view of the network, which makes management intuitive and reduces configuration time. These tools are available from many developers and are independent applications that are not bundled with the operator interface application. There are a few network management tools for the high level BACnet protocols, but not the field level protocols. This limits device configuration options and device interoperability.

Both LonWorks and BACnet are successfully applied at the operator interface level, but only LonWorks is achieving success with network management tools. The LNS platform provides a common development environment for LonWorks interface development. This common approach has resulted in interchangeable LNS-based network management tools and leverages enterprise technologies (OPC, DDE). BACnet does not deliver the benefits of field level network management and does not offer a standard development platform, like LNS. The result is more required vendor specific software for a BACnet installation than for a LonWorks installation. The use of vendor specific software limits the owner's options to replace products or select a new integrator.

5.4. Design Guidelines and Certification

Design Guideline and Certification is an area of extreme divergence between LonWorks and BACnet. The LonMark Association establishes design guidelines for the LonWorks community and certifies devices against those guidelines. This provides repeatability by setting design expectations for manufacturers to meet. The BTL tests and lists products for the BACnet community, but does not set design guidelines. They verify that the manufacturer has implemented BACnet correctly, but they do not set design expectations for the manufacturers to meet.

In practice, this means that an integrator using a single tool is able to configure and commission LonMark certified devices into a building automation network with a significant level of confidence. In contrast, BACnet device interoperability is likely to require an installation tool specific to each device manufacturer. This fundamental difference can limit a system integrator's ability to create a multi-vendor, interoperable BACnet installation.

5.5. Devices and Diagnostic Tools

There are a variety of aspects to evaluate when comparing LonWorks and BACnet devices and diagnostic tools. Focusing on owner, system integrator and manufacturer issues presents three different comparisons. Each comparison has its merits and several key points are discussed in this section.

For manufacturers the BACnet standard offers more design flexibility than the LonWorks technology. Manufacturers can implement BACnet on processors they are using for their proprietary solution in a programming language they are familiar with, because BACnet is processor and programming language

independent. They can choose any one or more of the 6 supported protocols to implement, because there are no usage restrictions or guidelines to set expectations. Using the LonWorks technology, manufacturers must use the LonTalk protocol, but can choose to use the Neuron processor (with embedded LonTalk) or port LonTalk to a processor of their choice. Using the Neuron processor can reduce the time to market for LonWorks devices as compared to BACnet devices. Overall, manufacturers have more design freedom using BACnet.

System Integrators and owners are looking for a diverse array of products to address the comprehensive needs of a facility. The LonWorks technology offers greater product diversity and selection through an abundance of component manufacturers offering LonWorks product versions or options. This is evident when comparing the LonWorks product database (hosted by Echelon) and the BMA product database. Comparing these databases reveals a large disparity between the number of available LonWorks and BACnet products. Neither database represents all available products, but they represent the best available source of product information.

Diagnostic tools are used to address network issues and often to independently prove interoperability and network integrity. Because LonWorks uses the LonTalk protocol at all network levels and in every device, a single diagnostic tool can assess all network devices regardless of manufacturer or media type. Most LonWorks diagnostic tools are small hardware devices that an integrator can easily have on site and plug into the network. Software diagnostic tools (protocol analyzers) are available for LonWorks networks from multiple competitive vendors. By contrast, there are very few BACnet diagnostic tools available. They are all PC-based software applications that can only assess the upper level protocols and they require routine updates to include new BACnet objects and data types.

The vision for the field level of an Open System solution is an array of control devices from different manufacturers and disparate building systems. Achieving this is a function of obtaining the right products and using repeatable installation practices. The commonality of LonTalk simplifies LonWorks development and installation to one set of network rules and it speeds the delivery of devices and diagnostic tools to market. The flexibility that manufacturers gain from BACnet does not translate into more diverse products for owners or system integrators.

5.6. Protocols

Protocol usage varies significantly between LonWorks and BACnet. LonWorks is a single protocol technology, which uses the LonTalk protocol at all network levels and in every device. LonTalk supports various media types; each operates at a different speed based on the physical properties of the media. Network routers are used to change media and synchronize packet transmission between media speeds. LonWorks installations use LonTalk to create a flat topology where the media type is transparent to the network architecture. BACnet supports 6 protocols (referred to as data link layers), each with its own implementation and media requirements. Several of the protocols support multiple communication speeds. Many native BACnet installations use multiple protocols, creating a tiered architecture with supervisory devices translating between protocols.

BACnet Protocol	Reference	Speed
<i>BACnet/IP</i>	Internet Protocols	
<i>Ethernet</i>	ISO 8802-3	10 Mbps
<i>ARCNET</i>	ATA/ANSI 878.1	19kbps – 10Mbps; 2.5Mbps
<i>MS/TP (Master-Slave/Token Passing)</i>	EIA-485 (RS-485)	9.6kbps, 19.2kbps, 38.4kbps, 76.8kbps
<i>PTP (Point-To-Point)</i>	EIA-232 (RS-232)	9.6kbps – 56kbps
<i>LonTalk</i>	Version 3.0 (ANSI/EIA/CEA 709.1-B-2002)	32kbps – 5Mbps

Table 5.1 - BACnet Protocols

BACnet supports multiple protocols in an effort to address economic and network performance issues. The goal was to establish a low cost LAN option for field devices and a high performance LAN option for larger devices and operator interface connections. Each of the selected protocols is an industry standard protocol, except for MS/TP. The BACnet committee (SSPC-135) developed MS/TP as a low cost LAN for BACnet field devices. During the initial development of BACnet all available low cost LAN technologies were perceived as proprietary, which made them unacceptable for inclusion in the BACnet standard and fueled the development of MS/TP. MS/TP is now the field level protocol of choice.

LonTalk is included as a BACnet protocol option, but it is rarely used. It was included as an alternative low cost LAN option to MS/TP. Many of the manufacturers on the BACnet committee have an investment in LonTalk devices and wanted this option in BACnet. Regrettably, including LonTalk in BACnet does not provide a link between the two technologies. The BACnet and LonWorks data structures are incompatible. A device using BACnet objects over LonTalk cannot communicate with a device using LonWorks objects over LonTalk.

LonWorks Protocol	Media Type
<i>LonTalk</i>	Shielded/Unshielded twisted pair - free topology
	Shielded/Unshielded twisted pair - bus topology
	Fiber optics
	Radio frequency
	Infrared
	Power line carrier

Table 5.2 - LonTalk Media Types

The media supported by LonTalk can address a multitude of control network configurations. The twisted pair free topology option is the popular choice for field level building controls. It offers the most flexible network configuration and simplifies installation. Fiber optics and radio frequency are frequently used between routers to easily extend a network across long distances and wide areas. The infrared and power line carrier communication media are being applied for lighting control, alarming and remote control applications. The power line, free-topology and fiber optic signaling technology for LonWorks networks are ANSI/EIA standards 709.2, 709.3 and 709.4, respectively.

LonWorks and BACnet both support the Internet Protocols (IP). BACnet over IP is defined within the BACnet Standard and LonWorks over IP is defined in the EIA/CEA-852 standard. The EIA/CEA-852 standard, Tunneling Component Protocols Over Internet Protocol Channels, provides the basis to tunnel ANSI/EIA-709.1 (LonTalk) over IP. Supporting IP communications is becoming increasingly important as buildings adapt to unified, structured cabling systems based on IP.

LonTalk represents a simplified approach to network configuration and application over the BACnet protocols. The BACnet protocols attempt to balance manufacturing cost, existing design architectures, and installation familiarity; whereas the LonTalk protocol focuses on overcoming installation obstacles and creating a cohesive network that adheres to a single set of network rules.

5.7. XML, IP & Web Services

There is a growing demand for enterprise technology in building automation solutions. Enterprise technologies are opening new opportunities for system integrators and the diversity of enterprise applications is improving the owner's ability to administer and maintain an installation. As a result, for long-term success automation solutions must leverage XML, IP and Web Services to meet owner expectations.

The BACnet committee (SSPC-135) is addressing enterprise technology in building automation by forming a Working Group to investigate how best to incorporate XML into the BACnet Standard. Incorporating XML will enable BACnet manufacturers to take advantage of enterprise technology and reduce the time to market for XML-based BACnet products. The Working Group began this effort in 2002 and there is no published timetable for changes to the BACnet Standard to address XML and enterprise technologies.

The LonWorks community has already included XML and enterprise technologies in LonWorks products and solutions. The i.LON product series from Echelon provides the infrastructure for Web Services solutions. Several companies now produce web servers (similar to the i.LON) and EIA-852 devices. EIA-852 enables LonTalk tunneling over the industry standard Internet Protocol (IP) for router and gateway products. The LonMark Association is addressing the market shift to leverage enterprise technology by porting existing LonMark Functional Profiles (LFP) to XML format.

Enterprise technologies will continue to play a strong role in building automation. The success of a building automation solution will be based on how well it leverages the benefits and opportunities of enterprise technologies. The LonWorks community is already adapting to this market demand and is delivering solutions that leverage this technology and capitalize on new opportunities.

5.8. Distribution

No single manufacturer produces all products necessary for a comprehensive building automation solution that addresses all building systems. Manufacturers typically specialize on a specific building system. This makes access to products critical when creating a multi-vendor installation. Open Systems technology makes it possible for manufacturers to focus on their core competency and system integrators to select best-in-breed products. The easiest way for system integrators to obtain best-in-breed products is from independent distributors.

Nearly all LonWorks component manufacturers and many solution providers offer their product lines (or select products) through an independent sales channel. The largest US-based independent distributor of LonWorks products is Engenuity Systems. They represent over 1000 products from over 50 different vendors worldwide, including software, infrastructure and control devices for all aspects of LonWorks building automation. This level of independent product distribution is not seen in the BACnet community. BACnet products are typically only available as part of a complete solution and only distributed through the manufacturer's sales channels. There are a few BACnet component products and infrastructure products available independent of a complete solution, but these are the exception. Nearly every major device manufacturer offers a LonWorks product version, with BACnet product versions being less prevalent.

Independent distribution enables one-stop-shopping and it is a testament to interoperability and technology maturity. When a system integrator or owner purchases a product from an independent distributor they expect that product to come off the shelf and be easily integrated into their installation, with minimal or no support from the distributor. The LonWorks Technology has achieved this level of maturity, where third party off-the-shelf products can interoperate with any vendor solution.

5.9. Related Standards Qualifications

Standards organizations play an important role in building automation. They are a primary resource for architects, engineers and owners to obtain information and guidelines on the latest automation requirements and procedures. When a technology is maintained or listed by a standards organization it becomes available to a wide audience of industry authorities and becomes a typical component of building specifications.

BACnet was created and is maintained by the ASHRAE organization (American Society of Heating Refrigeration and Air-Conditioning Engineers). ASHRAE has been developing building standards for more than a century and is regarded as the preeminent resource of standards for buildings. All ASHRAE standards strive to be product neutral and to present a practical engineering guideline for system design in buildings. ASHRAE has also succeeded in establishing a rapport with many international and domestic standards organizations. ASHRAE's activities and reputation has positioned the BACnet committee (SSPC-135) to introduce BACnet to many standards organizations. Several standards organizations have

adopted or endorsed the use of BACnet with their membership. The most significant recognition of BACnet has been its adoption as ISO Standard 16484-5.

As an ISO Standard, BACnet is accessible to a larger community of users. ISO standards have little impact in North American building specification, but they influence specifications in Europe. European projects that previously did not have BACnet in the specification will now list it as an acceptable option. This will ultimately increase the number of European BACnet users and vendors.

Echelon created and independently maintained the LonWorks technology for many years. Over time the LonWorks technology and solution approach was adopted by several standards organizations (including IFSF – International Forecourts Standards Federation (EU petrol station controls); IEEE 1473 – In train controls; AAR – Electro-pneumatic braking controls; USA; SEMI – Semiconductor Equipment Manufacturer's Industry; Finnish Homes – Automation standard) and it also is part of the European community's standardization efforts (in conjunction with CEN TC247) for building automation projects in public buildings. The most significant recognition of LonWorks is the adoption of LonTalk as ANSI/EIA Standard 709. This provides continual maintenance for LonTalk to ensure that it meets the future needs of control networks. It also enables LonTalk to be implemented on any processor; it is no longer confined to the Neuron processor. The Neuron processor implementation of LonTalk remains the popular choice among control device manufacturers; however, some infrastructure devices are now using ANSI/EIA-709.1 on a non-Neuron processor. ANSI/EIA-709.1 has greatly improved the power, throughput and availability of LonWorks infrastructure devices.

LonWorks and BACnet have both achieved acceptance and secured continual maintenance within the standards community. In the area of specification development, BACnet has a clear advantage over LonWorks because it is an ASHRAE standard. ASHRAE standards are the most often used guidelines for specification development for buildings. This increases the exposure of BACnet to the specifying community. The LonWorks technology and LNS are not well represented in ASHRAE standards, primarily due to their product focus. As a result there is an increasing number of individual BACnet building specifications “on the street”, which has led to the perception that BACnet is better suited for building controls, when in fact both LonWorks and BACnet are equally capable technologies.

The LonWorks technology appears to have broader appeal when addressing total-building specifications and large multi-building specifications. This is primarily due to the diversity of LonWorks products, which covers the complete range of building automation systems. Where as, BACnet products typically focus on traditional (HVAC) building control systems. Recently a number of North American LonWorks based specifications have become available that each encompasses several hundred buildings. These include the US Army Corps of Engineers, New York City Public Schools, City of Chicago government buildings, Chicago School District, and State of Louisiana Government Buildings.

LonWorks and BACnet each have their strengths and exposure within the standards community. Specifiers can apply each platform to a variety of building applications. Their appeal varies depending on project scope and application. Because both are firmly entrenched in the standards community, LonWorks and BACnet will propagate through the industry for years to come as the primary choices for Open System solutions.

6. Appendix - Product Databases & User Groups

The information presented here is from publicly available industry sources. It is included to support statistics and discussions put forth in this paper. Each table is maintained by its respective authority and is subject to change without notice.

6.1. LonWorks Product Database

This database is hosted by Echelon and includes approximately 924 products from 155 manufacturers, worldwide. Products listed are not sold through Echelon. The database is provided as a resource for locating available LonWorks products and manufacturers. It does not represent all available products and services, but it is the best available source of information. www.echelon.com

Categories	#	Categories	#
Access Control	64	Actuators	42
Asset Management	5	Doors & Windows	22
Fire/Life Safety	29	Hospital Equipment	47
Human-Machine Interfaces	70	HVAC	186
Integration Components	126	Lighting Control	221
LonWorks Training	11	Mechanical	40
Monitoring & Security	115	Motor Control	29
Network Infrastructure	310	Network Management	44
OEM Components	49	Plumbing & Irrigation	10
Power & Energy Management	57	Refrigeration	49
Sensors	117	Software	62
Vertical & Horizontal Transportation	4	Wiring Devices	49

Table 6.1 - LonWorks Product Database Categories

6.2. Engenuity Systems Product Representation

Engenuity System is the largest US-based independent distributor of LonWorks products. They have approximately 1196 products from over 50 manufacturers worldwide listed for sale on their website.

www.engenuity.com

Product Category	#	Product Category	#
Access & Security	93	Accessories	75
Analog I/O	51	Analysis Software	10
Application Specific Controllers	47	Books About LonWorks	3
Combinations Of Products		Control Modules	27
Data Logging	9	Development/Debug Products	32
Digital I/O	77	Displays And Keypads	31
Energy Management Products	26	Fire & Life Safety	17
Gateways	182	GUI/HMI Software	8
Handheld Devices	4	IP Connectivity	41
Lighting Control	73	Mixed Analog & Digital I/O	41
Multi-Function Sensors	24	Network Interfaces	103
Network Managers	34	Occupancy Sensors	21
OPC/DDE Servers	15	Pressure Sensors	29
Programming Software	7	Protocol Analyzers	14
Repeaters	22	Routers	84
Schedulers	9	Services	31
Temperature Sensors	50	Terminators	17
Thermostats	13	Training Classes	20
Transceivers	15	User Interfaces	7
Wire	9	Written Documentation	16

Table 6.2 - Engenuity Systems Product Categories

6.3. LNO Database

The LNO (LON Nutzer Organization) of Germany is one of the oldest and largest LonUser organizations. The LNO maintains a database of LonWorks products, providers and services for Germany speaking countries. Products listed are not sold through the LNO. The database is provided as a resource for locating available LonWorks products and manufacturers. www.lno.de

Categories	#
Products	508
Providers	154
Applications	521
Services	98
Reference Stories	50

Table 6.3 - LNO LonWorks Database Categories

6.4. BMA Product Database

The BMA database lists 63 BACnet products by Device Profile, from BMA member companies. Products listed are not sold through the BMA. The database is provided as a resource for locating available BACnet products and manufacturers. It does not represent all available products and services, but it is the best available source of information. www.bacnetassociation.org

Device Profile	#
BACnet Operator Workstation (B-OWS)	3
BACnet Building Controller (B-BC)	3
BACnet Advanced Application Controller (B-AAC)	17
BACnet Application Specific Controller (B-ASC)	32
BACnet Smart Actuator (B-SA)	7
BACnet Smart Sensor (B-SS)	0
Miscellaneous BACnet Devices	1

Table 6.4 - BMA Product Database Categories

6.5. International Organizations - LonUser Groups

The LonUser Groups are organizations of LonWorks developers and users that promote LonWorks technology, organize marketing activities, provide a central place for information, and initiate cooperation between LonWorks developers and users. These groups work to provide up-to-date information on the LonWorks technology and promote best practices.

Organization	Website	Organization	Website
European LonUsers Web Portal	www.lonusers.info	LonUsers Italia	www.lonusers-italia.com
LonUsers Group Denmark	www.lonuser.dk	LonUsers Sweden	www.lonusersweden.org
LON Nutzer Organization (Germany)	www.lno.de	United Kingdom Open Systems Assoc	www.ukosa.org
LonUsers Norway	lonusers.hig.no	Belgian-Luxembourg Lon User Group	www.belon.be
Polish LonUsers Group	www.plug.org.pl	LonUsers France	www.lonusers.asso.fr
LonUsers Austria	www.lno.at	LonUsers Netherlands	www.lonteam.nl
LonUsers Finland	www.tpu.fi/lonusers	LonTech Thun (Switzerland)	www.lontech.ch

Table 6.5 - LonUser Groups and Websites

6.6. International Organizations - BACnet User Groups

BACnet User Groups are organizations of manufacturers, facilities personnel, system integrators, and consultants that promote the use of open systems using BACnet technology. These groups work to provide up-to-date information on the BACnet standard and promote best practices.

Organization	Website
BMA (BACnet Manufacturers Association)	www.bacnetassociation.org
SSPC-135 (The BACnet Committee)	www.bacnet.org
BIG-NA (BACnet Interest Group - North America)	www.big-na.org
BIG-EU (BACnet Interest Group - Europe)	www.big-eu.org
BIG-AA (BACnet Interest Group - AustraliAsia)	www.big-aa.org

Table 6.6 - BACnet User Groups and Websites

7. Appendix - History

LonWorks and BACnet have very different histories. Their histories are important because it shows the evolution of each technology through achievements and milestones as each adapts to market demands and enterprise technologies. Understanding their evolution and progression establishes a trend, which provides a glimpse into their future development and reaction to market demands.

The LonWorks Technology was developed and released in 1988 by what later became the Echelon Corporation in 1990. It was developed with the vision of creating a peer-to-peer control network managed through software. The initial release included several development tools for creating LonWorks devices including programming, testing, and network management tools. Manufacturers began developing devices but interoperability was difficult because most of these devices were a proprietary implementation of LonWorks.

To reinforce LonWorks interoperability, the LonMark Interoperability Association was established in 1994 to define guidelines for the LonWorks community and certify devices against those guidelines. LonMark is a user organization that develops and maintains the list of LonWorks data types (SNVT, SCPT) and the catalog of LonMark Functional Profiles.

With LonMark overseeing device interoperability, Echelon addressed the need for a better connection between the field devices and the HMI. In 1997 Echelon released the LNS (LonWorks Networks Services) network operating system and the LNS-based LonMaker™ network management tool. These products had a profound impact on the LonWorks community. LNS provided a uniform platform for developing HMI communications and it provided backup and restore features for the network database. LonMaker provided a graphical representation of the network, which is used to configure and manage the network. Together, LNS and LonMaker provided the LonWorks community with repeatability for network installations that was not possible before. Echelon had now created the necessary tools for End-to-End LonWorks solutions.

In 1999, Echelon turned its attention to maintaining the future of the LonWorks technology, by establishing the LonTalk protocol as an ANSI/EIA standard and releasing the first product of the i.LON series. Establishing LonTalk as an ANSI/EIA standard meant that it would be maintained by the industry to meet its changing needs and that it would be accessible to all. The i.LON product line was originally developed in conjunction with Cisco Systems and includes a series of infrastructure devices that provide IP connectivity and XML Web Services to LonWorks networks. These products enable the LonWorks community to seize upon enterprise technology opportunities, enabling them to meet ever-increasing owner expectations.

In contrast to the corporate-driven LonWorks history, BACnet began as an ASHRAE committee of manufacturers. In 1987 the ASHRAE origination formed the SPC-135P (Standard Project Committee) committee to develop an open DDC control standard for the building control industry, which ultimately became BACnet.

Part of the committee's initial approach was to include existing technologies and protocols that were being used in building automation. They did not want to create "another standard" that no one would use. They wanted to create a standard using technologies and techniques that the industry was comfortable with. This created an atmosphere of research and consensus. The committee needed to know what technologies worked well and then (through consensus) establish the best way to use these technologies in a single standard. The committee investigated and deliberated for eight and half years before releasing BACnet in 1995.

After its initial release, the SSPC-135 (Standing Standard Project Committee) committee was formalized to maintain and update the BACnet standard. The committee oversees the development and approval of addendum and errata to the standard.

Between 1995 and 2001, SSPC-135 received feedback and comments from manufacturers and industry professionals to enhance and improve BACnet. This led to several BACnet addenda, which specified numerous updates including establishing the BACnet/IP protocol, new Life Safety objects, the creation of BIBBs and BACnet Device Profiles, and several minor enhancements. Once each addendum was approved by ASHRAE, they were compiled with the initial release of BACnet and became BACnet2001.

In 1999 the BMA (BACnet Manufacturers Association) was established to address the commercialization of BACnet. It provides a forum for manufacturers to discuss application issues and perform interoperability testing workshops. The BMA complements the work of SSPC-135 and other BACnet-related groups whose charters limit their commercial activities. (ASHRAE standards are inherently product neutral. They are intended as design guidelines that can be applied generically. As a result SSPC-135 does not and cannot address BACnet commercialization.)

In 2000 the BMA addressed the need for BACnet product certification by establishing the BTL (BACnet Testing Laboratories). The BTL charter includes testing of all BACnet hardware and software products. They began testing and listing of low-level field devices in 2002 and plan to expand testing to include complex devices and software in the future.

SSPC-135 continues to maintain the BACnet standard through addenda and planning for future development. Several addenda to BACnet2001 have been drafted and/or are in the public review process. In 2002 they established an XML Working Group to evaluate how best to use the XML technology within the BACnet standard and in 2003 the BACnet Standard was adopted as ISO Standard 16484-5 (International Organization for Standardization). These addenda and events demonstrate the SSPC-135 committee's dedication to the future of BACnet.

These histories illustrate several market response differences between LonWorks and BACnet. The corporate driven LonWorks Technology reacts to market expectation faster than the committee driven BACnet Standard. This is evident from the fact that the LonWorks Technology was released years in advance of BACnet, LonMark was established prior to the release of BACnet and as the BACnet committee evaluates XML usage, Echelon and others have already released XML products to the LonWorks community.

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