WHITEPAPER

Adesto

Adesto Partner, Western Allied, Implements Fully Interoperable Multi-Protocol Field Bus Solution

White paper illustrates the benefits of combining LonWorks® and BACnet, two of the most popular communications protocols for Smart Buildings, in a single network

We hope you enjoy this paper from Adesto's long-time partner, Western Allied. Western Allied is a premier designer and builder of A-grade commercial and industrial HVAC systems with a long and successful history of direct digital control (DDC) installation and support. Western Allied was the first mechanical contractor to achieve LON® System Integrator status in Southern California.

Through Adesto's acquisition of Echelon Corporation, we are the originators of the LonWorks networking platform, a powerful, pervasive solution for today's advanced control-networking systems widely used in building automation, industrial controls and municipal networks. Now maintained by the LonMark organization, it's the foundation for open connected systems in which products and solutions from multiple vendors are combined in an interoperable implementation integrating diverse types of devices into one complete solution. Hundreds of thousands of LonWorks based systems and hundreds of millions of LonWorks devices have been installed worldwide.

While LonWorks solutions offer myriad benefits, we believe that a multi-protocol approach to building automation systems offers an even greater upside for integration projects. A multi-protocol bus, based on Adesto's Free Topology (FT) technology can not only enable best of breed features and prevent the need to rip and replace existing systems, it can also deliver the most flexible, error free and cost effective implementations. That's why we are supporting Western Allied's innovative approach to next-generation integration in Smart Buildings that harnesses FT technology to combine BACnet and LonWorks building automation products and optimize network performance. This paper explains how.

Contact Adesto at embedded-iot@adestotech.com for more information on multi-protocol FT smart transceiver, or contact Western Allied at aslabodkin@wasocal.com for more information on project implementation using this technology.

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Echelon by Adesto

Multi-Protocol Field Bus in Building Automation Applications

WESTERN ALLIED CORPORATION

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I. Introduction

This document was written to support the multi-protocol controller demonstration board. It will show that interoperability, reliability, performance, and cost of installation improve when either BACnet or LonWorks, or both protocols, are transported over a Free Topology (FT) bus.

This document will model a typical BACnet network and a typical LonWorks network to offer a comparative analysis on capabilities and performance. Each network can be further optimized by a knowledgeable system integrator that has a deep understanding of the control applications installed (HVAC, lighting, process, etc.) and the respective trade-offs introduced by these optimizations. Therefore, this document will focus solely on typical network configurations.

II. Audience

This document is intended for building owners and operators, specification engineers, and system integrators who are faced with challenges in designing, building, or maintaining open building automation control systems.

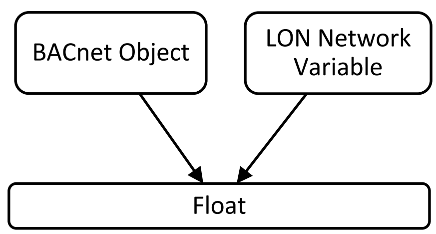
III. Primitives and Data Objects

A data object on a multi-protocol controller can be represented as a BACnet Object, LON Network Variable, or both object types simultaneously. The ability to natively support both BACnet and LON communications on multi-protocol controller offers some unique advantages. To understand these, it is important to first look at how data objects are implemented.

In traditional systems, data objects are typically viewed as LON Network Variables or BACnet Objects. The truth of the matter is that under each of these constructs are well understood, standard data types known as bits, integers, and floats, generally known as *primitives*. Primitives are protocol agnostic and are used universally throughout computing systems.

- Bits are Boolean values consisting of a 1 (true state) or 0 (false state).
- Integers are whole number values, such as 10 or -1.
- Floating-point ("floats") are decimal number values, such as 70.51 or -1001.98.

Traditional control systems add further data constructs, such as LON Network Variables or BACnet Objects, which simply reference primitives, therefore it is not difficult to conceive that a control application that defines both a LON Network Variable and a BACnet Object could simply reference the same primitive:



For example, consider a temperature sensor connected to an input on a controller and defined in the control application as a float primitive type. The float can be assigned to BACnet Object Analog Input 1 (AI1) `Temperature` data object, LON Network Variable `nvoTemp` data object, or both. Any action taken on that float is reflected in the protocol data objects.

Note that this occurs without the use of "proxy points" whereby a secondary object mirrors the original data object.

Writable data objects such as setpoints are represented in the same manor. When writing to the data object in either BACnet or LON the value is written directly into the primitive and reflected in the protocol data objects.

IV. Messaging Mechanisms

Messaging on a multi-protocol controller can be implemented using traditional polling communication or peer-to-peer push messaging.

BACnet networks are generally implemented as polling networks, where a master device continuously requests information from a slave device and the slave responds with the relevant information. Polling is generally inefficient in three ways:

1. For every poll, there are two messages sent – a request message and a response message – therefore more network traffic.

2. Because the master does not know if the information has changed, it must frequently and repeatedly request the information from the slave. The information may have not changed, which means the request and response messages were unnecessary load on the network.

3. Polling is done at fixed intervals, e.g. every 10 seconds. Therefore, if the information changes rapidly the master may not receive the new information until the next poll, e.g. 10 seconds later.

LonWorks networks can also be implemented as polling networks, however they are more commonly implemented as publish-subscribe “push” networks. In a push network, devices use the concept of a “binding” to connect to information on other devices. Each connection is known as subscription. When a device’s information changes, it is responsible for notifying or “publishing” to all its subscribers. Push networks are more efficient than polling because (1) no request messages are made therefore reducing network traffic, (2) only changes are sent therefore eliminating unnecessary traffic, and (3) information is sent immediately on a change therefore creating a much quicker responding network.

BACnet networks can be implemented as push networks as well, using a mechanism called COV (change of value). However, BACnet COV is designed for pushing information to supervisory SCADA servers for data collection and should never be used for device-to-device communication. It makes no guarantees on the delivery of a message and should be used only when reliability is not a concern.

Care must be taken when implementing polling and push networks in both BACnet and LonWorks networks as they each introduce their own limitations. For example, scaling polling networks requires increasing network bandwidth or slowing poll rates. On a push network, if a device goes offline it will simply stop communicating on the network. Its subscribers will simply interpret this as no information has changed state. LonWorks applications may implement “heartbeat” and “max receive time” mechanisms to detect offline devices but generally require a knowledgeable LonWorks integrator to configure these.

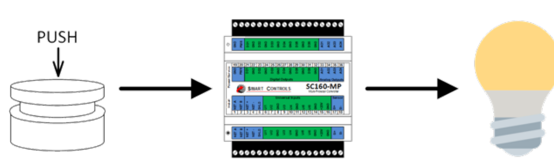
V. Performance of Direct Messaging

Using the multi-protocol controller demo board, a simple lighting control network has been created to show the performance of Direct Messaging using a peer-to-peer LonTalk binding versus standard network polling.

The network consists of:

- (1) Smart Controls SC240-MP: Button controller. Reads button presses and messages light controller over various protocols.
- (1) Smart Controls SC160-MP: Light controller. Accepts button press messages over various protocols and turns lights on and off accordingly.
- (1) Vykon JACE-8000: BACnet MS/TP master
- (1) Vykon N4 Supervisor: BACnet/IP master
- (1) Echelon IzoT Router: BACnet/IP Ethernet-FT router
- (2) Push buttons labeled “local” and “network”
- (4) LED lights, one for each – LonTalk/FT, BACnet/IP, BACnet MS/TP, and local

The local button is hardwired to the light controller. When the local button is pressed, an associated “local” light turns on/off as depicted to the right. The local button and light are used to demonstrate a traditional hardwired control light switch and the negligible on/off switching time (latency) associated with that configuration.



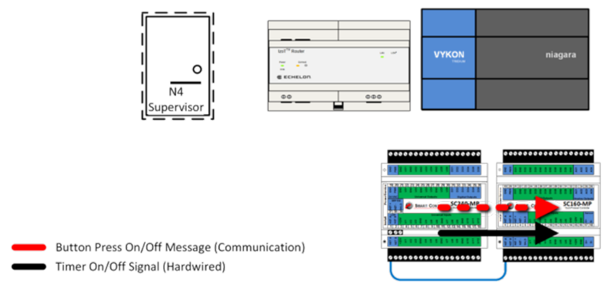
The network button is hardwired to the button controller. When the network button is pressed, two events occur:

1. The button on/off state object changes. This is represented in LON as network variable `oButton` and in BACnet as AI0 `Button`.

2. The button controller signals the light controller to start timers for LonTalk/FT, BACnet/IP, and BACnet MS/TP communications.

When the button on/off state object changes, the lighting controller receives the button on/off state value and turns on a series of lights.

In the case of FT, the button controller sends a message from network variable `oButton` *directly* to the light controller network variable `iFTCmd` using a binding.

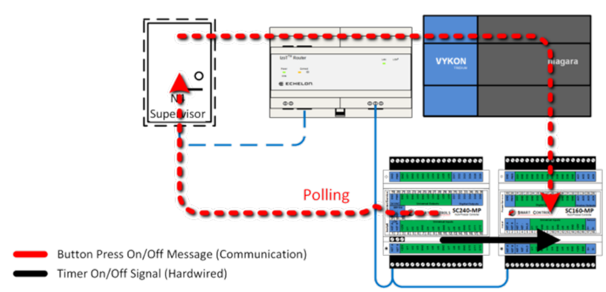


Because a binding is used, no master device is required to manage device-to-device communication. Instead light controller `iFTCmd` subscribes to `oButton` and whenever `oButton` changes state `iFTCmd` <u>immediately</u> receives an update.

If `iFTCmd` receives an On state, the FT light will turn on and the FT timer will be stopped. If an Off state is received, the FT light will turn off and the FT timer will be reset to 0.

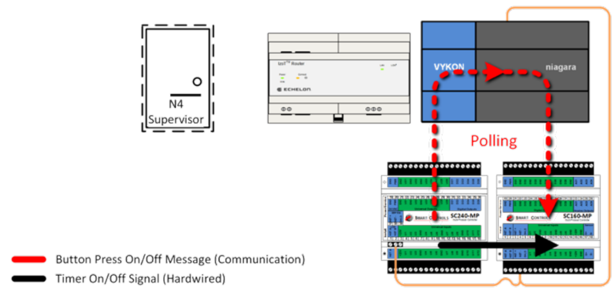
In the case of BACnet MS/TP and BACnet/IP, master devices poll the button on/off state object AI0 `Button` and write the state value to their respective AO1 `MS/TP Command` and AO2 `IP Command` objects on the lighting controller.

The BACnet/IP master in this case is a Tridium Niagara 4 supervisor. During a poll, a BACnet "ReadProperty" request for the button controller AI0 `Button` object state is emitted on the Ethernet network. The IzoT Router routes the request from Ethernet to FT, whereby the button controller receives the request. The button controller responds with the current state of the button, which is traversed back through the network routing from FT to Ethernet.



The supervisor then emits a "WriteProperty" request for the light controller `IP Command` object. The request is routed over the network, whereby the light controller receives the request, and updates its `IP Command` object state accordingly. If an On state is received, the IP light will turn on and the BACnet/IP timer will be stopped. If an Off state is received, the IP light will turn off and the BACnet/IP timer will be reset to 0.

The BACnet MS/TP master is a Vykon JACE-8000 running a Tridium Niagara 4 station. Because MS/TP implements a token-ring network, all communications rely on the use of a messaging "token". The token is passed from master to master in a round-robin fashion. The master that currently holds the token is the only device allowed to talk. During a poll, the master waits for the token to be passed. Once the token is received a BACnet "ReadProperty" request for the button control AI0 `Button` object is emitted on the MS/TP network. The button controller receives the request and responds with the current state of the button.



The JACE then emits a "WriteProperty" request for the light controller `MS/TP Command` object. The request is routed over the network, whereby the light controller receives the request, and updates its `MS/TP Command` object state accordingly. If an On state is received, the MS/TP light will turn on and the BACnet MS/TP timer will be stopped. If an Off state is received, the MS/TP light will turn off and the BACnet MS/TP timer will be reset to 0.

After several rounds of testing, the typical latency of Direct Messaging with FT is under 10 ms, which is indistinguishable from a hardwired local switch. Latency from polling via BACnet/IP or MS/TP are typically 2 seconds at best and often longer. In conclusion, BACnet networks gain the amazing performance of Direct Messaging via LonTalk bindings when they are combined with FT.

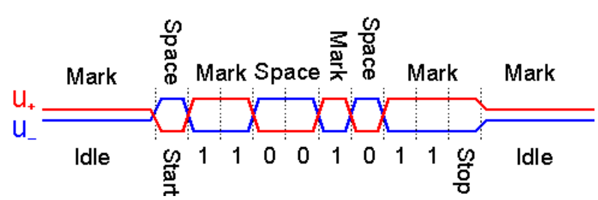
VI. Benefits of FT and Differential Manchester

Free Topology (FT) offers several benefits in performance and cost of installation partly due to Differential Manchester encoding. Before these are discussed, it is important to understand the capabilities and limitations of the most popular BACnet field bus – BACnet MS/TP.

BACnet MS/TP uses RS-485. RS-485, also known as EIA-485, is a polarity sensitive and noise sensitive electrical encoding standard specified in ANSI/TIA/EIA-485-A-1998. It requires a 3-wire shielded cable in a bus-only topology; the use of star, ring, or any other topology is strictly prohibited. RS-485 has a max cable length of 4000 feet. Much attention must be paid during installation to ensure conductor polarity is correct, shields are correctly terminated, end-of-line terminators are used, and the bus is correctly grounded. Installing a RS-485 network is often referred to as a "black art". Floating grounds are a very common issue and often troubleshooting RS-485 requires the uses of an oscilloscope.

A RS-485 transceiver can put up to 12kΩ resistance on the bus, known as unit load (UL), and therefore adds load on to the bus. Bus loading limits the maximum number of allowable devices on the bus and is a major factor in scaling an MS/TP network.

RS-485 relies on amplitude modulation whereby the data is signaled by varying the DC voltages of two waveforms across a center line. The typical voltage range is -7V to +12V. Failure to stay within this range will result in signal corruption. Because RS-485 varies amplitude and electrical noise varies amplitude, RS-485 is not ideal for noisy environments and several measures must be taken to ensure the data signal is not corrupted.



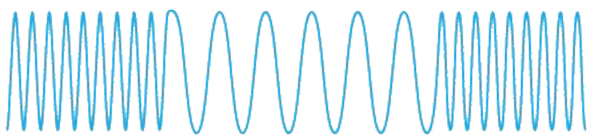
Below is an example of how noise can interfere and corrupt data signal:

Clean RS-485 Signal

Noisy RS-485 Signal

By comparison, Free Topology uses a 2-wire non-shielded cable in any topology: bus, star, ring, or free. Using 22 AWG cable, FT has a max cable length of 4600 feet in a bus configuration or 1640 feet in free topology. The use of repeaters or 16 AWG cable provides for much longer cable runs. Due to its use of Differential Manchester encoding it is non-polarity sensitive and noise tolerant. Differential Manchester encoding is an electrical encoding standard specified in IEEE 802.5.

In Differential Manchester encoding, a fixed clock speed is used and data is signaled via frequency modulation. As shown below, the waveform starts at a high frequency, shifts to low frequency, then back to high frequency again. The high frequencies represent a binary value of 0, whereas the low frequencies represent a 1:



In general, electrical noise affects the amplitude of the waveform, therefore making Differential Manchester encoding ideal for noisy environments.

In summary, the benefits of using FT with Differential Manchester encoding are many:

	RS-485	FT	Notes
Number of Conductors	3	2	FT is less expensive to install
Non-shielded Cable	No	Yes	FT is less expensive to install
Polarity Insensitive	No	Yes	FT reduces installation error
Bus Loading	Yes	No	
Noise Tolerant	No	Yes	FT works well in noisy environments
Affected by Floating Ground	Yes	No	FT is more reliable
Max Cable Length – bus topology	4000 ft	4600 ft	
Max Cable Length – free topology	0 ft	1640 ft	Not possible with RS-485
Max Number of Devices	32 [1]	64	

[1] Varies by manufacturer. A maximum of 32 devices is very common and understood as the safe limit.

VII. Benefits of a Multi-Protocol Field Bus

The benefits of using a multi-protocol field bus include improvements in flexibility, scalability, performance, and overall lower installation cost. The points can be summarized as follows:

Better Flexibility

- Supports multi-drop IP communication – the first instance of truly device-to-device daisy-chain IP communications without the use of switches.
    - Traditional Ethernet IP networks require home running communication cabling to a central network switch.
    - Some controller manufacturers have attempted to implement multi-drop IP buses by incorporating network switches into their devices. This ultimately produces a more expensive device, adds complexity to the network, and can create network outages should the device fail.
- Supports free topology (FT) – the ability to connect IP devices using any network topology (bus, ring, star, etc.) without network switches.
    - Traditional Ethernet IP networks typically use hierarchical star network topology with a network switch at the center of each star.
    - BACnet MS/TP network must use bus topology.

Better Scalability

- Supports a maximum bus network cable length of 4600 ft compared to 4000 ft on BACnet MS/TP.
- Supports a maximum free topology network cable length of 1640 ft compared to 328 ft on CAT6 Ethernet star networks.
- Supports a maximum of 64 devices per network segment compared to 32 on most BACnet MS/TP networks. Note that Ethernet IP networks support the greatest number of devices, up to 16,777,214 devices on a class A network, e.g. 10.0.0.1.

Better Network Performance

- Peer-to-peer Messaging – the ability to truly message directly from device to device without the use of masters.
- Direct Messaging – the ability for a device to immediately publish/send a message to subscribers when a change of state occurs without being requested for the information and therefore providing extremely low network latency.

Lower Installation Cost

- Free Topology (FT) uses 22 AWG non-shielded wire which is less expensive than both traditional CAT6 cable for BACnet/IP over Ethernet and RS-485 cable for BACnet MS/TP.
- Requires less IP cabling overall due to the ability to daisy-chain devices versus homeruns.
- No network switches required to communicate.