Advanced Automated HVAC Fault Detection and Diagnostics Commercialization Program

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Deliverable D2.3b – Final Evaluation of Criteria for Selection Web-enabled FDD System

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Summary:

The MicroDataNet™ real-time data acquisition system was developed by Architectural Energy Corporation for use in buildings without existing Building Automation Systems (BAS). It uses a network of wireless sensors to send data from HVAC system components to an on-site gateway computer. The data are either stored in the gateway computer for periodic transmission via telephone, LAN, or wireless modems to a data server. The data collected may be used to summarize energy consumption and demand, as well as perform component or system Fault Detection and Diagnostics (FDD) using the techniques developed under the ENFORMA® brand fault diagnostic software.

As work progressed in predecessor research projects, it became evident that it would be valuable to extend the usefulness of the ENFORMA-based FDD to buildings with existing BASs. This would improve the robustness of the ENFORMA-based FDD by allowing access to status information within the BAS.

Thus, in order to use the MDN (MicroDataNet) as a platform for analyzing data for the purpose of ENFORMA-based system diagnostics, the MDN needs to be able to communicate with, and collect data from, any BAS (Building Automation System) on the market. The inherent challenge in such an endeavor is the fragmentation among manufacturers of these systems with regard to system architecture and data communication protocol.

This report outlines several methods to accomplish BAS data collection along with the advantages and disadvantages of each approach. It concludes with a recommendation to use an existing gateway product to allow access to data from existing BASs.

1.0 Overview of Strategies for Extracting Data from Existing BAS Systems

Outlined below are four strategies for extracting data from existing BAS systems.

1.1 Connect into EMS Ethernet via AEC Server.

This approach requires connecting into the Ethernet bus, picking up data traffic from controllers in the building communicating with the BAS, and intercepting packets of data and "unwrapping" them into usable data for the MDN DAS.

1.2 Connect Directly from MDN to BAS

This method utilizes a "roll your own" approach to data accumulation. Internally, AEC would create programming to translate the data stream from any BAS (using any protocol) into usable data and map that data for the use by the MDN DAS.

1.3 Extract BAS Trend Data

This approach would take advantage of the trending function present in most BAS systems and use the BAS system itself to define the capture of data output at specific intervals and exporting the data in a usable form for analysis and diagnostics.

1.4 Use a Gateway Protocol Translator with Appropriate BAS Drivers

This approach would use third party hardware and software to translate BAS I/O into usable data. These hardware/software packages function as a bridge from the Building Automation System's native protocol to a different protocol such as Ethernet. Many products are a fully functional TCP/IP network host serving as a multi-protocol data gateway to many different devices and a variety of 3rd party systems.

2.0 Advantages and Disadvantages of Strategies for Extracting Data from Existing BAS Systems

2.1 Connect into EMS Ethernet via AEC Server

Advantage:

From a physical standpoint, the hardware interface into the Ethernet bus is not difficult to accomplish.

Disadvantage:

While many of the newer BAS systems have a built-in Ethernet connection, older systems may not.

Each controller device located on the Ethernet has an individual IP address. Sometimes this traffic is encoded or encrypted for security. To intercept the traffic would require translating packets of data using the data structure native to the controller. Often, in newer systems, this is XML, a data structure that describes content, fields, and the labeling of those fields.

Another challenge to intercepting traffic on the local Ethernet is that what is being listened to on the Ethernet is high-level control commands and local control loop communications may not be transmitter over the Ethernet. For example, a VAV box may be controlled by set-point but the controller may have no requirement to report certain data to the control front end. If it was desirable to collect actual temperatures for example, those temperatures may not be available in the data stream when desired. For certain systems, this connection could be used to poll, rather than just listen to existing traffic. A significant issue with this approach is that the underlying network may not be able to sustain the polling rate required for the diagnostic method to be used.

2.2 Connect Directly from MDN to BAS

Advantage:

This approach has the advantage of controlling all hardware and software aspects of the data collection; from connection into the existing BAS, programming required to translate the BAS data communication protocol, to capturing and formatting the output of the data stream into the MDN.

Disadvantage:

The challenges of this approach are numerous. This could be a very labor intensive process. Open data protocols in the HVAC industry are Modbus, BacNet and LonWorks, yet many BAS manufacturers employ proprietary protocols for transmitting data. Although there may be different "flavors" of standard protocols like BacNet, for data collection these variances may not prove significant. Some systems have proprietary buss configurations varying from the standard RS-232 or RS-485 configurations. System architecture can also vary greatly with respect to the typology of the network, along with the application of master/slave controllers, peer to peer networks and stand alone controllers.

In order to begin to understand the complexity of the problem, it would be advisable to develop a matrix of BAS manufacturers along with the critical specifications and architecture issues as they relate to extracting a usable data stream from these systems.

Such a matrix should include (but not be limited to) the following parameters:

- Sensor error band (Accuracy of sensors used)
- 8 bit vs. 12 bit technology
- Type of sensors
- Stand alone or peer to peer controllers
- Sampling rates
- Protocol
- System architecture
- Format of trend data
- Data time-synchronization methodology
- Smallest recording interval for a given number of polled points
- A to D conversion specifications
- Web-enabled vs. Local BAS host computer

Additionally, there is a great deal of variance in complexity from small building automation systems like Trane Tracer (setup to control package rooftops) and more sophisticated packages designed for expansion and multi-discipline control like HVAC, fire, lighting and security.

Finally, each manufacturer may have several families of BAS controllers based on year of manufacture, price and application. Not every system marketed by the same manufacturer employs the exact same protocol or architecture. This practice results in the need for a number of unique gateway configurations that far exceeds the number of individual manufacturers out in the market.

2.3 Extract BAS Trend Data

Advantage:

The advantage to this approach is the low capitol and labor cost of using an existing BAS to collect trend data.

Disadvantage:

The disadvantage of this method could be the inherent BAS limitations with respect to sensor placement, sensor calibration, sensor coverage, the ability of the BAS system to setup trends, and storage limitations for collecting short interval data. Additionally there are challenges to retrieving the data (especially from a remote site) and reformatting it for imput into the MDN in a usable form.

2.4 Use a Gateway Protocol Translator with Appropriate BAS Drivers

Advantage:

This approach has the advantage of using current state-of-the-art technology and funded research bringing to market a product designed as a multi-protocol data gateway to many different devices and a variety of 3rd party systems.

A gateway is a hardware/software bridge that solves interoperability problems by translating the data stream coming from many different devices operating under a number of data protocol configurations. A gateway may also host an EMS and provide data storage.

Three gateway products were reviewed during our investigation. These products represent a sample of the major manufacturers of such devices and illustrate the industry's' approach and pricing to the end user in the marketplace. We examined gateway products from FieldServer, Enflex® and Tridium®.

The general configuration of the gateway is a hardware platform with imbedded software, which resides at the site and communicates with the BAS via a variety of options:

- ***COM Ports:*** (COM ports on a computer implement various flavors of serial communications using standards such as RS-232 and RS-485)

- ***LAN Connections:*** (A local area network (LAN) is typically implemented using the IEEE 802.3 communications standard called Ethernet)

Each gateway is capable of TCP/IP networking with a HTTP server for configuration, sensor mapping and data stream monitoring.

Each device has an on-board capability to communicate with Modbus, BacNet and LonWorks by imbedding software drivers (protocol translators) in the hardware platform. Extensive libraries of software drivers exist for the three products investigated. A summary of the three products investigated follows.

FieldServer is a pure translator product, in that data formats are translated using protocol drivers but data are not stored in the devices. This allows a facility with more than one BAS (e.g., a campus with buildings that have different BASs) to translate data and control signals from one BAS to another. A list of the manufacturers who supply drivers and support the FieldServer product are outlined in Appendix 1. BAS Drivers available from the FieldServer product is outlined in Appendix 2.

Enflex and Tridium both make gateway products that provide data procotol translation as well as act as a supervisory control systems. Both add network connectivity to existing BAS. Table 1 shows BAS and communication protocols compatible with Enflex and Tridium.

Table 1 Comparison of Enflex and Tridium Support for Communication Protocols and Legacy BAS

Enflex	***Tridium***
Modbus	Modbus
LonWorks®	LonWorks®
BACnet IP	BACnet IP
Andover	Schneider Electric (Tour Andover, CSI)
Honeywell	Honeywell WEBs
Johnson Controls	Siemens (Staeffa Talon)
Barber Coleman	Invensys (Barber Coleman)
Trane	CarrierOne
Novar	McQuay
PureChoice	ChemTrac Systems
Solidyne	
GE - Prosys LM	

For example, suppose a building owner has an existing BAS that does not have the ability to communicate via a TCP/IP network with a HTTP server, and the owner does not wish to engage in any further expansion or upgrades with their existing controls vendor. If the building owner wants to upgrade the system to be Web enabled and/or remodel a space, one course of action would be to gut the control system and start over. Rather than incur this large capital expense, these gateway products allow the owner to add state-of-the -art control elements to the system from another vendor at will, and blend them together into a unified Web-enabled front end.

Tridium and Enflex have software versions of their respective products that can be used on third-party computers. This facilitates use on a multiple building campus bound together by a common LAN. In a campus situation, rather than having a hardware platform installed in each building, communicating via a TCP/IP network with a HTTP server, a software suite is installed on a host computer somewhere on the site communicating directly with controllers via a common campus LAN controlling HVAC, life safety and security systems.

Disadvantage:

The disadvantage (or challenges) of this approach are found in the cost, software driver availability and setup. Each hardware platform has an initial cost of in the range of $2,500 to $4,000. Additionally any system that has a data protocol not compatible with Modbus, BacNet and LonWorks requires the purchase of a BAS system driver with an initial cost in the range of $500 - $800 each.

Not all system drivers are available from each of the gateway manufacturers. Some drivers are not available at all and some are proprietary and hard to come by. An example: If the Tridium system were utilized, the Johnson Controls N2 protocol is not available from Tridium and to do the job, one would need to purchase a hardware bridge from FieldServer with an N2 driver.

Another obstacle is that many manufactures require training and certification before these products can be purchased at a dealer or wholesale level. This can be overcome by purchasing through existing system integrators, which may have the added benefit of making available additional sites.

A further concern with protocol translators and TCP/IP network hosts is they are susceptible to attack by via Internet connections and could be infected with computer viruses.

All of the multi-protocol data gateway products require an I/P address to communicate with a computer front end. Modem communication may be adequate for smaller facilities, but it is likely to be too slow for large ones. The building must have the proper infrastructure to get Internet service to the device.

Finally, having a multi-protocol data gateway is only the first step. Each proposed site must be investigated to map the existing BAS system's sensor and status points into a database used for diagnostics.

3.0 Conclusions

It appears that the most cost-effective and least problematic approach to extracting data in a useful form for use in analysis and diagnostics would be to use an existing gateway or bridge product.

Based on our review, Architectural Energy Corporation has decided to adopt the Tridium Niagara platform to obtaining data. Buildings with existing Tridium installations will be our first focus for demonstrations of the ENFORMA® Pro FDD software. Ultimately the details and challenges involved in such an endeavor will be discovered through a demonstration project. To really understand the problem and potential solutions it may be advisable to identify a test building, purchase a gateway and driver and execute a pilot project.

Appendix A: Glossary of Terms

BACNET:

A data communication protocol for building automation and control networks. Developed under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), BACnet is an American national standard, a European pre-standard, and an ISO global standard.

ETHERNET:

A local-area network (LAN) architecture developed by Xerox Corporation in cooperation with DEC and Intel in 1976. Ethernet uses a bus or star topology and supports data transfer rates of 10 Mbps. The Ethernet specification served as the basis for the IEEE 802.3 standard, which specifies the physical and lower software layers. Ethernet uses the CSMA/CD access method to handle simultaneous demands. It is one of the most widely implemented LAN standards.

A newer version of Ethernet, called 100Base-T (or Fast Ethernet), supports data transfer rates of 100 Mbps. And the newest version, Gigabit Ethernet supports data rates of 1 gigabit (1,000 megabits) per second.

GATEWAY:

A protocol translator enabling data transfer between different devices and networks utilizing various protocols to promote interoperability with devices and networks used in building automation, HVAC, fire and process control industries.

LAN:

LAN (local area network) is a computer network that spans a relatively small area. Most LANs are confined to a single building or group of buildings. Each node (individual computer) in a LAN has its own CPU with which it executes programs, but it also is able to access data and devices anywhere on the LAN. This means that many users can share expensive devices, such as laser printers, as well as data.

The following characteristics differentiate one LAN from another:
1. topology : The geometric arrangement of devices on the network. For example, devices can be arranged in a ring or in a straight line.
2. protocols : The rules and encoding specifications for sending data. The protocols also determine whether the network uses a peer-to-peer or client/server architecture.
3. media : Devices can be connected by twisted-pair wire, coaxial cables, or fiber optic cables. Some networks do without connecting media altogether, communicating instead via radio waves.

LANs are capable of transmitting data at very fast rates, much faster than data can be transmitted over a telephone line; but the distances are limited, and there is also a limit on the number of computers that can be attached to a single LAN.

LONWORKS:

A protocol developed by the Echelon Corporation, LonWorks provides a set of services that allow the application program in a device to send and receive messages from other devices over the network without needing to know the topology of the network or the names, addresses, or functions of other devices. The LonWorks protocol can optionally provide end-to-end acknowledgement of messages, authentication of messages, and priority delivery to provide bounded transaction times. Support for network management services allow for remote network management tools to interact with devices over the

network, including reconfiguration of network addresses and parameters, downloading of application programs, reporting of network problems, and start/stop/reset of device application programs. LonWorks networks can be implemented over basically any medium, including power lines, twisted pair, radio frequency (RF), infrared (IR), coaxial cable and fiber optics. It requires a proprietary communications chip in each LON-enabled device.

MODBUS:

MODBUS® Protocol is a messaging structure developed by Modicon in 1979, used to establish master-slave/client-server communication between intelligent devices. It is a de facto standard, truly open and the most widely used network protocol in the industrial manufacturing environment.

PROTOCOL:

Rules and encoding specifications for sending data. Protocols also determine whether the network uses peer-to-peer or client/server architecture

TOPOLOGY:

A geographic arrangement of devices on a network. For example, many Ethernet configurations are a start typology - a center wiring out to many nodes.

Appendix 1: FieldServer Controls System Suppliers

* Alerton
* Allen Bradley
* American AutoMatrix
* Andover Controls
* Automated Logic
* Canatel
* Carrier
* Caterpillar
* Circon
* Cleaver Brooks
* Controlotron
* Cummins
* Cyberex
* Data Aire
* Delta Controls
* Echelon
* Edwards System Technology
* ES-USA
* Fike
* Fireye
* Gardner Denver
* GE Industrial
* GE Power Management
* Honeywell
* Intellution
* Johnson Controls
* Liebert
* Lutron Electronics
* Mammoth
* McQuay
* MGE UPS
* Mitsubishi
* Modicon
* Notifier
* Opto 22
* Plexus Technology
* Pneumatic Products
* PureChoice
* Russ Electric
* Secutron
* Siemens Building Technologies
* Siemens Cerberus
* Sierra Monitor
* Silent Knight

* Simplex-Grinnell
* Square D
* TAC-Americas
* TekAir
* T-Lon
* Trane Company
* United Power
* VeederRoot
* Veris
* Vision Systems (Vesda)
* Weightronics
* Wonderware
* York
* Zellweger

Appendix 1: FieldServer BAS System Drivers

Serial Drivers

* Allen Bradley DF1
* ATMI ACM
* BACnet MSTP
* BACnet PTP
* Canatal
* Carrier DataLink
* Carrier DataPort
* Caterpillar M5X
* CEI-ABI
* Cleaver Brooks (CB Link)
* DataAire DAP
* DataAire DART
* DNP 3.0
* Envirotronics System Plus
* EST3 ECP
* EST Quickstart
* Fike Cheetah
* Gamewell
* Gardner Denver
* GE MarkIV Speedtronic
* GE-SNP
* Grinnell TFX Minerva
* JBus
* Lutron Grafik 6000
* McQuay
* Metasys DX9100
* Metasys N2
* Modbus ASCII
* Modbus Daniels
* Modbus Omniflow
* Modbus RTU
* Modbus Tek-Air
* National Time & Signal FACP
* Notifier 1010/2020
* Notifier AFP 200/300/400/600
* Notifier INA
* Notifier Italia AM6000
* Notifier Onyx 640
* Notifier NFS 3030
* Opto 22 Optomux

* Pneumatic Products ADC
* Secutron
* Setra
* Siemens FireSafety MXL
* Siemens TIWAY 1
* Silent Knight
* Simplex 4100
* SMC 2450
* TAC I/Net
* Veeder-Root
* VESDA
* Weightronics
* WS3000 TABS
* YorkTalk
* Zellweger System 16

Ethernet Drivers

* Allen Bradley CSP
* BACnet Ethernet
* BACnet IP
* EtherNet/IP
* GE-EGD
* GE-SRTP
* Modbus TCP
* Omron FINS
* OPC
* SNMP
* TL1