Controls Integration and the Path to More Efficient Buildings

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Synopsis

Direct digital control (DDC) has revolutionized the operation and control of building HVAC systems. Many manufacturers of DDC systems have entered the market and there are numerous proprietary systems available today. Because building owners that operate a large portfolio of buildings often must work with proprietary DDC systems from a number of different manufacturers, building operators must be trained in each system and must establish accounts with several DDC vendors. The multitude of different products adds to the building operator's difficulty in seeing all of the building's systems from one central location.

This paper will provide an overview of common open protocols and discuss technology options that are available today for integrating different types of pre-existing DDC systems including Tridium and Richards Zeta systems. The paper will describe the benefits to the building owner of a centralized, integrated controls system. The authors will provide examples of controls integration projects that they have implemented and that demonstrate how the process of integrating control systems from different vendors can empower the building owner to operate their buildings both more effectively and more efficiently for the long term. The examples will cover several different types of DDC system and integration paths and will also include an example of using wireless technology to connect several buildings on one campus.

About the Authors

Jonathan Soper, P.E. is co-principal of Enovity, Inc., a San Francisco-based commissioning and energy engineering firm that also provides controls integration solutions, operations, and maintenance and repair (OM&R) services to the Federal Government. Among the firm's significant achievements in the area of controls integration is the management and expansion of the Government Energy & Maintenance Network (GEMnet). The firm is a leading provider of new building commissioning, retro-commissioning and persistence based commissioning services. Recent commissioning work has focused on projects for PG&E, federal and local governments, university campuses and private sectors. Mr. Soper has given professional seminars on a diverse range of topics related to commissioning, operations and maintenance topics and energy evaluations throughout his more than 15 years of experience in the construction industry. He is a Professional Mechanical Engineer, a licensed contractor and is a member of ASHRAE. Jonathan is a graduate of the University of Surrey in the United Kingdom with a degree in Chemical Engineering and holds a Masters from the Cranfield Institute of Technology in Energy Conservation and the Environment.

Tim Fackler is a Senior Controls Engineer based in Enovity's San Francisco office. Mr. Fackler is the lead controls engineer for Enovity's GEMnet controls integration project with GSA and is highly knowledgeable in the Tridium and Richards Zeta integration product offerings. Prior to joining Enovity, Tim was the BAS Network Administrator at the 4 million square foot University of Idaho, Moscow, Idaho (Land-Grant, Carnegie Doctoral/Research University). The University of Idaho's Campus DDC system includes more than 100 building control panels, on seven networks on RS-485, fiber optic, and Ethernet, over 38,000 control points, and is located on three sites state-wide. Tim was directly responsible for the entire DDC system from design, installation, programming, and maintenance.

The Value of Controls Integration in Commissioning

The role of DDC systems in building operation has significantly expanded beyond the systems' originally limited ability for scheduling and notification of critical alarms. DDC systems now have the capability of optimizing equipment operation, optimizing start, performance monitoring, point trending and data storage, and enabling of advanced algorithms for energy efficiency strategies. These capabilities make DDC systems a very powerful tool for the building operator and the commissioning provider. DDC allows systems to be evaluated in real time and equipment performance to be regularly reviewed using trend data over a period of hours, days or months. As such, they have become a critical and cost-effective instrument in commissioning and retro-commissioning activities. During their evolution, many different DDC systems were invented, installed, and expanded to fit the needs of the building operator. Each new generation of controls solved more problems but also created major communication challenges.

It is not uncommon for owners of multi-building portfolios to have to manage more than one brand of controls. Since controls upgrades and replacements are usually very expensive, owners are likely to keep existing systems until they are no longer functional or entirely obsolete. Although using different brands of controls systems often saves on first costs, maintaining these near-obsolete systems is problematic and time-consuming for the building manager. Controls integration offers a solution for some of these issues by allowing property owners to better manage their existing "legacy" DDC systems while allowing the owner to facilitate competitive bidding through an open protocol specification for new construction projects. Controls integration involves the implementation of software and hardware that can centrally collect and manage large quantities of building operating data within the constraints of controls hardware and limits of IT communication speeds. For the commissioning provider, integration solutions are becoming increasingly more popular. Developing an understanding of the technology and the opportunities that integration presents will be essential in the commissioning of open protocol single-building integrations or multi-building integrations.

Controls Integration Overview

There are seemingly as many control systems, protocols, tools, and languages as there are building types. Understanding what these different systems are and how they operate is the key to a successful integration project. A basic examination of a few control system platform types and how they communicate will help in this understanding.

Barber-Colman Network 8000 is a classic example of a durable, workhorse DDC system. It offers programmable devices and some trending capability but is limited by speed and has been replaced by more recent systems. The network speed on the original 84000 series Global Controller Module or GCM was limited to 9600 baud, while the newer 86000 series can run at a network speed of 19,200 baud. The system polls each device in the system at a set time interval to obtain “real-time” data, when in actuality you only see information that is one poll cycle old. On large networks this can significantly hamper the ability to effectively operate a site due to the time it takes to receive data. The only solution is to create more networks and reduce the number of devices on each network, which increases the workload from a networking standpoint for the control system operator.

Siemens pre-APOGEE (and APOGEE pre-BACnet systems) are examples of the next generation of DDC system. These systems are very robust and offer many features. Trending is easy and flexible and graphing features are built-in. There is even limited web-based control with the optional APOGEE GO module. The network will run on hardwire RS-485 or fiber optic cable between 9,600 baud and 115,200 baud or on Ethernet with the PowerPC processor. The network communicates using the attached computer resource network protocol or ARCNET, common on networks that use RS-485. ARCNET means that each panel is allowed to talk in numerical sequence for a specified amount of time; panel 1 passes information to panel 2 which talks to panel 3 and so on in a cycle. If a panel can’t pass all of the information it needs to in the specified token cycle, it must wait until it gets the token again to finish transmission. On large networks with a lot of distance between panels this can cause significant issues with timing on the network.

The third type of control system is what is considered the “modern system.” Systems such as Alerton Envision with BACtalk, Siemens APOGEE with BACnet, JCI Metasys, and Tridium, to name a few, are either “open protocol” or support one or more other protocols without the use of special hardware or tools. These systems are fully featured with high end graphics, trending and reporting options, and often have web-based interfaces and Ethernet support.

Communications Protocols

Another important aspect of DDC systems is the concept of “open” versus “closed” protocols. Open protocols allow communications and transfer of data between peer devices. Closed protocols are those that require special hardware or drivers to communicate with other peer devices. They also typically provide only limited functionality with the non-native device.

The building automation and control networking protocol, or BACnet®, is one of the three most common open protocol standards for commercial building applications. BACnet was developed by ASHRAE as Standard 135-2004 (current version) to help alleviate communications issues and define interoperability between control systems. It is a data communication protocol, meaning it gives a very specific set of rules on how devices will communicate, what the point properties are, and at what property address information can be found. It is up to the manufacturer of the control system to implement it properly. Three commonly used BACnet protocols have been defined by ASHRAE:

- BACnet over Ethernet, which follows IEEE 802 standards but not necessarily the Internet Protocol (IP) standards;
- BACnet over IP, which follows the IEEE 802 and IP protocol standards;
- BACnet MS/TP which defines the BACnet rules for Master Slave Token Passing (token ring or ARCNET).

In order to ensure the appropriate BACnet implementation, the BACnet Testing Laboratory (BTL) was created by several manufacturers so that a new product could be tested to be fully BACnet compliant.

LonWorks (LON) is another open protocol that allows peer device communications. It is the basis for the ANSI 709.3-1999 standard. While the standard provides some of the same type of rules as BACnet, it requires the device to have a computer chip supplied and licensed by Echelon for the device to communicate on the LON network. Each device can communicate either on a hardwired network at up to 78,000 baud or over Ethernet using the LON over IP standard. The network is constructed using the LNS network operating system.

Modbus is a third commonly used open protocol. Modbus was developed by Modicon as a serial communications protocol for programmable logic controllers (PLCs.) The three varieties of Modbus are:

- Modbus RTU which is the binary format of the protocol that is designed for machine use;
- Modbus ASCII, which is the same in function as RTU but is in human readable format;
- Modbus/TCP, which was created to allow implementation over today's Ethernet networks.

Modbus is not as well defined as LonWorks or BACnet and is not nearly as robust since it was written in the late 1970's for a different type of controller than today's controller.

Integration Methods

There are two primary methods of integration: hardware and software. For a successful integration, both hardware and software will often be required for various parts of the project. Hardware solutions such as the Richards-Zeta Mediator and Tridium Java Application Control Engine (JACE) are very useful tools. The hardware platform usually has multiple connection types to support Ethernet, MS/TP, RS-485 and so on. This allows for a single platform type to be ordered for many integration occasions. One drawback to some hardware platforms is the requirement to have a translation file in order to read the existing systems points. This translation file may actually be a requirement of the control system being integrated and not the integration hardware. Creation of the translation file can be costly, labor intensive and prone to errors. The ideal situation is to select an integration hardware platform that can reside on the existing network as a platform-specific device. The purpose of this hardware is to allow a communications conduit to a common front-end workstation in a common protocol.

A software integration tool such as Tridium's Niagara AX is designed to communicate with all of the three open protocols. Tridium's current JACEs have BACnet, LON and Modbus inputs. Niagara ships with customer selectable drivers for immediate use upon license activation, making it an ideal platform for integration. It uses an open source programming language (JAVA) to allow any necessary drivers to be developed by programmers who possess the requisite programming skills and controls knowledge. The disadvantage to the software-only platform is that other than the Ethernet port and possibly a PC after-market communications card, there is no physical connection to the control system.

The Integrator

The last and probably the most important integration requirement is the integrator. In today's rapidly changing controls technology market, the integrator must fully understand the existing control system, be knowledgeable enough to select the appropriate integration solution, and must also understand all of the IT requirements for remote operations and hardware and software connections. The integrator must also possess good troubleshooting skills, since smooth integrations are the exception rather than the rule.

Case Study of a Single Campus Controls Integration

The GSA operates the 350,000 square foot United States Geological Survey (USGS) campus in Menlo Park, California. Three different DDC systems serve buildings housing laboratory and office space, as shown in the table below.

USGS Campus Control Systems

Building Name	Proprietary System Name
Building 1	CSI
Building 2	CSI
Building 3	Johnson
Building 3A	Johnson
Building 15	Barber-Colman

Building engineers have their main office in Building 15 and had easy access to the Barber-Colman front-end that serves the building. Building engineers had internet access to the control systems in the other buildings using PC Anywhere, but the connection was often slow and cumbersome. It was not possible to see alarms unless an operator was logged into a specific building's control system. The interface to Buildings 3 and 3A was DOS based with no graphics.

A Tridium solution was proposed for the campus that would integrate all of the five control systems into a common platform. The solution replaced two existing JCI devices - a NCM 350 for Building 3 and a NCM Supervisory Controller for Building 3A - with two JCI Facility Explorer FX-40s, which allow for complete Tridium integration with enhanced Johnson Controls support via a JCI written application pre-loaded in the FX-40.

The Barber-Colman GCMs each have a JACE located nearby to transfer data over the Ethernet using a custom driver written for this purpose. The JACE installation was not required but helped with the slow network speed of the Barber Colman system. While the driver has the capability to run the Barber-Colman network directly from the server, this was not the chosen solution as this would require all GCM traffic to pass along an already slow network.

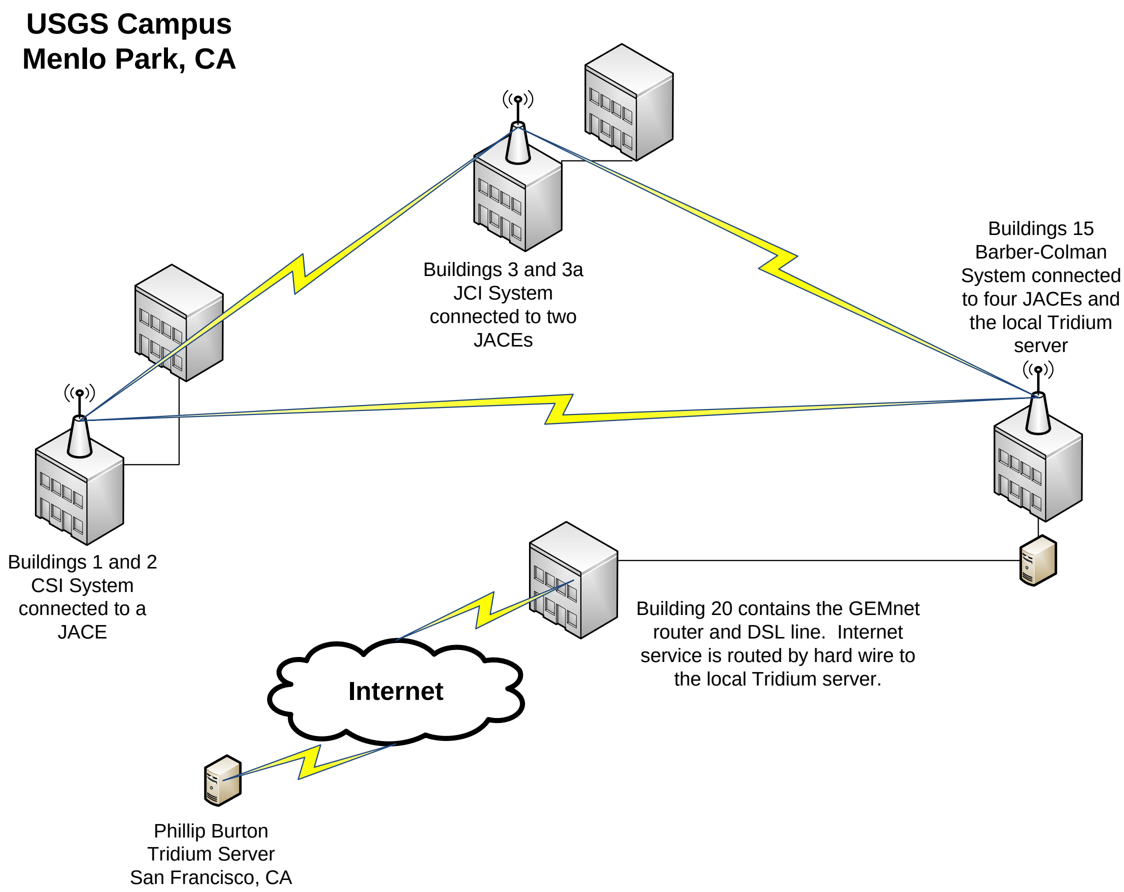
The CSI system has one JACE attached to the system at Building 1 and is responsible for transferring the data from both Buildings 1 and 2.

All JACEs communicate with each other and the front-end using a 5.8MHz wireless mesh network between the buildings. 5.8MHz wireless using the IEEE 802.1a standard with high gain antennas was chosen due to the high volume of 2.4MHz wireless traffic in the area that was already causing interference on that frequency.

This site was upgraded from three disparate control systems speaking three different languages using three front-end interfaces to a single network using one front-end interface. Programming tools for the proprietary systems must still be maintained, but all scheduling, alarming, trending, point monitoring and commanding take place from the single Tridium front-end. The user now has the entire site at their fingertips and all in one place. The campus is part of GSA's GEMnet system that is described later in this paper.

Through this integration, the site operators now have:

- A common set of graphics for all buildings with seamless networks
- A common front-end routing system for all alarms, including e-mail, pager and other notification choices for all systems
- Adjustable schedules and changeable setpoints
- Improved remote access capabilities using a platform that has native internet support
- Faster system response time to requests – nearly as fast on the internet as on the front end



Case Study of Multi-Building Controls Integration

The U.S. Federal Government's Energy and Maintenance Network (GEMnet) was initially developed in the late 1990s. GEMnet facilitates the management of more than 20 million square feet of federally-owned and leased space in GSA's Region 9. GEMnet is an integrated web-enabled suite of software tools that includes:

- Computerized maintenance management system (CMMS) to efficiently manage maintenance work orders across all Region 9 Buildings (CA, AZ, NV, HI)
- Remote monitoring of individual building automation systems (BAS) to reduce operational costs by improving energy efficiency and reducing peak demand GEMnet Phase I integrated the BAS in 10 buildings using ALC WebCTRL as the integration path
- Automatic enabling of CMMS work orders from building automation system alarms
- Monitoring of electricity and natural gas consumption and commodity unit cost data, to compare their building's energy consumption relative consumption to benchmark buildings
- An array of dashboards that are available for each building showing number of work orders for preventative maintenance, service calls, corrective maintenance and projects; this allows central office to keep track of their operations and maintenance contractor's performance

Enovity was contracted in 2006 to integrate the Building Automation Systems (BAS) of an additional eighteen 18 buildings. Rather than expanding the existing WebCTRL system, Tridium was selected as the integration solution. Tridium was considered a superior solution because many of the proprietary systems were not native BACnet and Tridium offered a more comprehensive solution and integration path for the diverse mix of existing proprietary systems. A central Tridium server was installed in GSA's Region 9 Headquarters at the Phillip Burton Federal Building in San Francisco.

Good cooperation was needed between Enovity, the controls contractor and GSA's Network Administrator. Enovity was responsible for all of the controls hardware and software installation. GSA's Network Administrator was responsible for ensuring that a reliable network was available for the integration. The table below provides a summary of the different proprietary systems that were integrated and the final protocols that were used.

GEMnet Integration Phase 2

Location	Proprietary Systems	Protocols Used
Sacramento	JCI	BACnet/IP, Niagara
San Francisco	Niagara	SQL
Fresno	Invensys	BACnet/IP
Van Nuys	Delta	BACnet/IP
Los Angeles	Delta, CSI	BACnet MS/TP, ModBus/RTU, Niagara
Santa Ana	ALC	BACnet/IP
San Diego	LonWorks	SQL
Calexico	LonWorks	ModBus/RTU
Menlo Park	CSI, Barber-Colman, JCI	Niagara
San Jose	Delta	BACnet MS/TP, Niagara
Reno	JCI	BACnet/IP
Las Vegas	Delta	BACnet MS/TP, Niagara

Each site contained old and new hardware and firmware sets making this a very complex project with unique challenges. Each site had to be evaluated for compatibility, available points, existing network issues, and potential for a specific integration path. Also, since each site is maintained by a different operations and maintenance contractor, the existing front-end had to remain in place with little or no degradation to system performance.

Calexico, Fresno, and Van Nuys were the sites that posed fewest problems. The local controls contractors for these buildings provided the connection information that was requested and, after opening some ports on the firewall at the individual buildings, the systems were easily integrated.

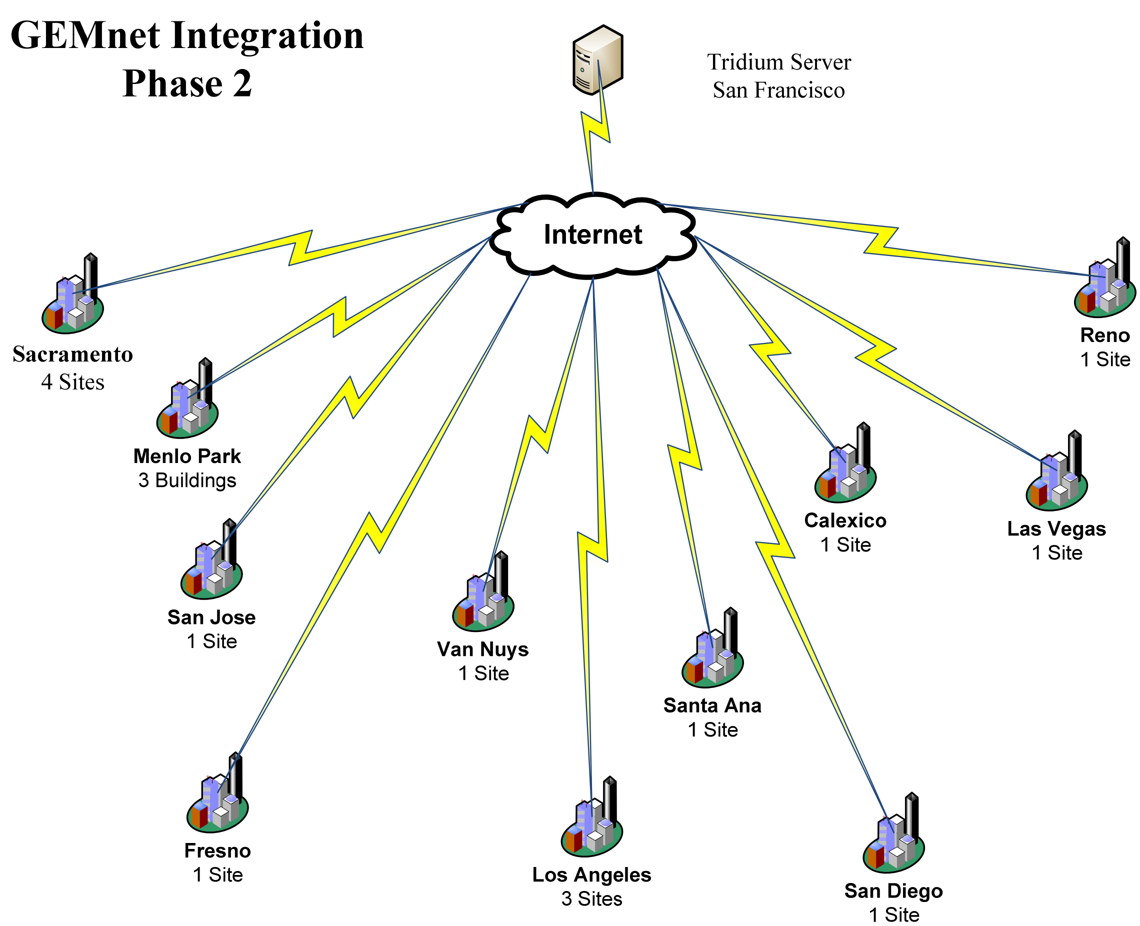
There were four buildings located in Sacramento; these offered unique challenges for integrations. Richards Zeta Mediators were used for three of the buildings where older Johnson systems were installed. A Tridium JACE was used to integrate the building with a newer Johnson system. The first Mediator building connected after convincing the Network Administrator that specific ports need to remain open in order for these devices to talk to the Tridium server in San Francisco. Once the ports were opened, the path was paved for opening ports at the rest of sites.

The second building had two issues: the first was a router that had only an intermittent connection to the Mediator. After replacing the router it was possible to connect to the Mediator, but data was not being passed. It was found that the translation file had not been correctly created for the older Johnson system. After correcting the problem, the translation files for the other Mediator sites were reviewed and corrected prior to trying to connect them.

At the third building, the Tridium server in San Francisco couldn't communicate with the Mediator. The communications port was found to be "locked up" on the device; this was a rare occurrence for this device and could not be corrected until a new Mediator was installed. The JACE building with the newer Johnson system should have been the easiest to integrate, but it was found to have a very intermittent connection with the server in San Francisco. After working with the Network Administrator it was found that the DSL line was at the extreme end of its speed range and had to be set at a slower speed.

Los Angeles, San Jose, and Las Vegas provided a perfect example of "what works in theory may not work in practice." All three sites feature modern Delta Orca systems updated to the latest firmware version. Delta fully supports BACnet as does Tridium and it should have been possible to connect the Delta system directly to the Tridium server without any additional devices. Enovity worked closely with both Delta Controls and Tridium corporate to troubleshoot why a connection could not be made. It was possible to only connect to the Delta RTR (BACnet router) but points could not be read from the field controllers. The final solution was to install a JACE as a BACnet MS/TP device on the Delta network and transfer the data to San Francisco as Niagara native information.

The main Tridium Server has also been connected to GSA's SQL Server database so that trend data for all the buildings can be exported from Tridium directly to the SQL database.



Conclusions

The integrations discussed above will enable GSA to perform a number of extremely useful tasks that could not be performed prior to the integrations. They included:

1. Implementation of a common demand reduction strategy for their Region 9 buildings that allows a response for a demand reduction request from one central location to be initiated.
2. Review of real time electrical demand and usage for each site through the integration of the main electric meter that is mapped to the local BAS and then through to Tridium.
3. Real time tracking of HVAC equipment performance; for example chiller kW and cooling tons can be viewed real time for any of the sites.
4. Collection of trend data from all GSA's Region 9 Building Automation Systems in a central location and ability to export that trend data to a database. Fault Diagnostic Toolsets can use that data to check HVAC system performance and generate deficiency lists for equipment that can be fed back to the Operations and Maintenance contractors for the individual buildings.