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Foundations is written by volunteers from the BACnet community for integrators/installers/applicers and specifiers/consultants. It complements the BACnet International Journal and the monthly newsletter Cornerstones.

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Although BACnet/IP is based upon the Internet Protocol (IP), it does not mean that BACnet devices are easily accessible from the Internet. This paper addresses the issues involved in accessing BACnet systems remotely, while proposing three possible solutions; direct connection, resident Virtual Private Network (VPN) and cloud-based VPN.

Managing Broadcast Messages — the Direct Connection Method

IP devices can easily be connected to the Internet. However, there are some issues when connecting BACnet/IP. The biggest issue is BACnet broadcasts — a message to all stations. This can be seen in the device discovery process. A client will send a global Who-Is broadcast and most BACnet devices will respond with an I-Am broadcast. This allows the client to discover the BACnet devices connected on the network. Also, some clients will send periodic Who-Is broadcast messages for each BACnet device. This is done to learn addressing information for the device and to make sure this information does not change. BACnet also supports Who-Has broadcast messages for discovering devices which have a particular object.

On the Internet, broadcast messages are not allowed because they cannot pass through IP routers.

This can cause a problem for most BACnet systems. However, BACnet supports a feature called BACnet/ IP Broadcast Management Device (BBMD). Each BBMD has a list of partner BBMD devices in its Broadcast Distribution Table (BDT) which must be configured at the BBMD. Another related feature is Foreign Device Registration (FDR). FDR is popular in client applications where only one BACnet/IP device may exist on a subnet. A subnet with only FDR devices will not need its own BBMD. In such a case, you configure the FDR device to register with the BBMD located on another subnet. At the BBMD, you do not need to configure FDR clients — making configuration easier.

How BBMD works is fairly simple. Each BBMD will receive all locally generated broadcast messages on its attached subnet then send them as directed messages to all BBMDs in its BDT and to all registered FDR devices — allowing them to traverse IP routers and, therefore, the Internet. The BBMD in-turn will re-transmit — as local broadcast messages — any directed messages it receives from its FDR devices or other BBMDs. The BBMD will also forward any messages from registered FDR devices to all BBMDs in the BDT.

Although this solves the broadcast issue, there is another issue. Most facilities connect to the Internet via a firewall. A firewall will block messages which originate from the Internet. This security feature can cause issues for BBMDs because the directed messages they share appear as originating messages. Fortunately, most firewalls support Port Forwarding. This allows any message (including originating) that is sent to one designated port (e.g., 47808 registered BACnet/IP port number) — to be forwarded through the IP router to one local device in the facility on the attached subnet. This will work in many applications, but this solution is limiting. Most BACnet/IP clients will only support one BACnet/IP port number. Thus, your IP router can forward messages to only one BACnet/IP device (see Figure 2). This would allow, for example, Internet communication for one BACnet/IP server device with FDR support — or — one BACnet/IP to MS/TP router with BBMD support. The BACnet/IP to MS/TP router could expose its connected MS/TP devices to the Internet — allowing communication to these devices. If you have multiple BACnet/IP devices or multiple BACnet/IP to MS/TP routers you wish to expose to the Internet for the same purpose, this becomes an issue.

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Using Resident Virtual Private Networks

Applying the above approaches, which relate to the direct connection method, can still leave your BACnet communications exposed because firewalls must be partially opened to make the direct connection work. A more secure approach is to use a Virtual Private Network (VPN) which encrypts TCP/IP communications so messages can be sent over a public network — such as the Internet. It will also restrict communications to authorized users — thereby limiting access. A simple VPN can exist between two end points. One is a VPN client. The other is a VPN server. Between the VPN client and server, the communications are encrypted — so only authorized devices can communicate over VPN, even if the VPN exists on the Internet. Sometimes this is called a VPN tunnel — so you can think of VPN communication as traveling over the public Internet while existing in its own (virtual) secure tunnel. Once the VPN connection is made, messages can originate from other side — eliminating the need for port-forwarding. Also, VPN servers wait for a connection — while VPN clients start the connection. VPN servers require public IP addresses, but clients can exist behind firewalls. There are two VPN solutions you can use — resident or cloud-based.

The first solution involves installing a VPN server onsite. This is the resident VPN. Many VPN servers are available on the market. These will require a static public IP address and a direct connection to the Internet. Normally, these are configured by IT professionals. On your PC, you install a VPN client application which comes from the manufacturer of the VPN server. Your PC can then connect to the VPN server over the Internet and make an encrypted connection to your network (see Figure 4). Some VPN connections will pass broadcast messages, so you may not need a BBMD — which is handy. If your facility has a VPN server already installed, this is a good solution. But if no VPN server is installed at the site, this could be an issue — since these can be somewhat difficult to setup for non-IT professionals.

Luckily there is a solution to this issue. With AHRAE 135-2010, BACnet was updated to support BBMD with Network Address Translation (NAT). Purists might call this Port Address Translation or PAT. NAT and PAT are firewall terms. The BBMD device — in our example a BACnet router — must support BBMD with NAT. With NAT, the BBMD device will route from one UDP port number to another UDP port number. For example, your BACnet/IP clients can communicate over the Internet with BACnet registered UDP port 47808 — but then use UDP port 47809 for your local BACnet server devices. The BBMD with NAT BACnet router will route BACnet messages from port 47808 to port 47809 (see Figure 3). The BBMD with NAT BACnet router will have a BACnet network number associated with the 47808 devices and a different BACnet network number for the 47809 devices. Any messages received from the Internet that are destined to the 47809 network number will be re-transmitted by the router — but now having a 47809 UDP port number. Your client can use 47808 and the local BACnet devices can use 47809 because the BBMD with NAT BACnet router will route between these two networks using these two UDP port numbers. Using a non-standard UDP port number on your Internet communications improves security because most hackers only know registered port numbers.
Cloud-Based Virtual Private Networks

The second option is a mediated VPN server or cloud-based VPN. Here the VPN server is on the Internet and is installed and maintained by a third-party. You load a VPN client application onto your PC and connect to the VPN server via an encrypted connection. The remote site you have another VPN client which is always connected to the VPN server via an encrypted connection. This provides an encrypted connection to the Internet, but you don’t need to install any equipment which requires a public IP address (see Figure 5). Because the cloud-based VPN server connects two VPNs, your PC will probably be on a different subnet than your BACnet/IP devices. In this case, you may need a BBMD at the remote site because the cloud-based VPN will not pass broadcasts from your PC to the site. But if the remote devices support FDR, no BBMD may be required — as shown in Figure 5.

Cellular Networks

Utilizing cellular networks for data communications can sometimes be easier to setup than other forms of Internet communications — especially if these connections are temporary. Connecting BACnet devices to a cellular network can provide a convenient method for gaining access to the Internet, but you typically will not have a public IP address for these devices. Normally, these devices will utilize a private address. This will allow your BACnet devices to send and receive data to the Internet but will block access from BACnet clients located on the Internet which want to originate a conversation with your BACnet devices. For example, if you want to monitor a BACnet system from a remote Internet location and this system is connected to the Internet via a cellular network, your BACnet client will not be able to address any of the BACnet devices because they have private addresses that are unreachable over the Internet. One solution is to utilize a cellular router which has VPN client functionality and can communicate with a cloud-based VPN server. As shown in Figure 6, the cellular router with a VPN client connects to the cloud-based VPN server. This allows the VPN client PC on the left to access the BACnet devices on the right which connect to the Internet via a cellular network. Here you can utilize a BACnet client application to communicate with all the BACnet devices. This also keeps your BACnet communications secure.
Summary

The direct connection method is the simplest approach for BACnet communications over the Internet. However, it is also the less-secure method because a hole in the firewall must be provided. Depending upon the approach taken, the number of BACnet devices supported can be limited — although the new BBMD + NAT option improves on this situation. With a resident VPN server your security is increased, but setting it up can be difficult if you don’t have an IT professional available. With a cloud-based VPN server, the setup is much easier and eliminates the need to maintain a resident server. The cloud-based VPN server also assists cellular connected BACnet devices. With any of the approaches, BACnet over the Internet is possible.

BACnet Takes the Voodoo out of Big Data for Buildings

by Terry Hoffman

Introduction

Over the past decade we have seen many advances in the automated management of buildings. Despite these advances, managers of facilities find themselves buried in volumes of data without the means to transform it into information of value. IT professionals have been confronting this problem for many years and have coined the term Big Data to describe the phenomenon. More directly, a major provider of business analytics software and services says, “Big data is a popular term used to describe the exponential growth, availability and use of information, both structured and unstructured. Much has been written on the big data trend and how it can serve as the basis for innovation, differentiation and growth.”¹

What has made data “big” is best described as a combination of three factors²:

• Velocity – Data has never come at us so fast or from so many directions. Users are finally listening to us as we tell them that data not collected is data that is lost forever. Now they are challenging us to do something constructive with it, deliver on the value proposition.

Is the concept of Big Data really a game changer for facilities professionals compared to other recent industry axioms like Convergence, Visualization or even that mysterious and vaporous Cloud that seems to surround us everywhere? The answer is no. Fundamentally, they all leverage technology to advance the art of management. They all contribute somewhat equally to an end game that allows building owners and management to optimize the performance of their assets. This optimization provides a combination of long and short term performance benefits along with conformance with government and industry mandates. Big Data is not a revolutionary concept, but rather a technology enabled evolutionary step in the direction of Building Intelligence; a progression to that end.

• Volume – The growing number of intelligent devices connected to our networks provides a steady stream of data whether it comes from tweets or t’stats.

• Variety – Differences in source and function mean that data types are inherently different and must be normalized to take full advantage of mash-up synergies.
Whether we say that Big Data solutions for buildings are in their infancy or perhaps early childhood, there are some applications that are making a dent in the data bucket. These applications include:

- **Fault Detection and Diagnostics** – One application from a major Building Management System provider collects data from large mechanical and electrical equipment connected to their BACnet based BMA as well as those supplied by others. It uses a remote cloud services platform to store that data and to apply task specific analytics in order to expose operational abnormalities.

- **Enterprise Energy Management and Reporting** – Advanced reporting systems now apply comparative analytics on data from similar facilities in order to provide performance judgments that formerly required the Energy Manager’s time and knowledge. That time can now be used on other tasks that may result in greater value to the organization.

- **Central Plant Automation** - This application uses Big Data in another way that was really not accessible to our industry just a few years ago. Not only does this app look at past performance, it performs analytics on real-time data that is in motion and adjusts system parameters continuously to optimize performance. This requires careful integrity checks so that decisions are not made with inputs that are outliers or not reporting correctly.

- **Facility Focused Data Analytics Engines** – Several of these tools have become available in the recent past as either new offerings or technology updates to legacy software. They take advantage of advances in network convergence, user experience and the availability of cloud resources for storage and analysis.

Compared to some of the applications currently in use by consumer marketers that scan billions of pieces of data to form conclusions about market trends these may seem to be basic or even trivial, but for our industry they are a first step toward delivering on the promise of advanced intelligence in buildings. And, each of the applications listed here have been implemented using data collected using BACnet as the primary source protocol.
Convergence, Visualization, Cloud

Dealing effectively with Big Data offers positive rewards as evidenced by the available applications that meet specific needs of facility managers and owners on a local scale or across an enterprise, but what about the other foundational concepts referred to previously?

A working definition of convergence calls it “the act of moving toward union or uniformity” 7. We think of it as the ability to merge data from multiple sources and to normalize it into a format that is standardized and useful for managing assets and processes. The three critical components of effective convergence as it applies to the networks we use in managing buildings are critical if Big Data solutions are to be implemented. All devices must connect to the network. The network allows systems to share data. The network allows users to optimize traffic flow and access to information.

The cloud provides services, storage and computing capacity for the amount of data required and the analysis of that data. It also provides security in the form of automated back-ups and availability, due in great part to the virtualization of large data centers. It is not feasible for most facilities to have their own computing infrastructure that is capable of handling all of the Big Data applications that are becoming available.

Finally, visualization of the information from these apps is critical to communicating their impact and value. Dashboards are fine for a quick look at operating efficiency or for use by stakeholders as positive proof of desired actions or conformance to regulations but lack the depth required by specialists. Think about the obvious analogy between a car and a building. The car has a dashboard that relays basic operational information to the driver but it is most often insufficient for troubleshooting problems with the vehicle. So, the mechanic at the dealer connects the car’s network to an analyzer that provides an in depth look at maintenance costs as a drain on profitability.

By now most of you who read this publication regularly are nodding your head and saying to yourself, “I can see how BACnet could make the challenges of working with Big Data a lot easier.” That’s right! BACnet facilitates convergence, visualization and cloud based solutions. As BACnet professionals many of the benefits are obvious. Let’s review them:

- BACnet provides a complete networking solution at the facilities level with accommodations for data transfer and storage at the enterprise level and/or in a cloud computing environment. BACnet MS/TP, IP and Wireless media solutions drive this completeness along with BACnet Web Services.
- BACnet is relevant to virtually all tasks inherent to the management of buildings. This can be attributed to the availability of a wide variety of standard objects tailored to the tasks at hand as opposed to other general purpose protocols or protocols designed for other applications. (A great example of this is the recent addition of BACnet objects for meeting special needs that have been identified as unique.) BACnet services are similarly tailored to those activities dictated by building control functions and mechanical/electrical devices.
- BACnet is interoperable and compliant with IT standards. It is continuously evolving to meet the needs of a changing technology universe. BACnet is dynamic, not static. It has seen numerous updates and expansions since adoption in 1995. Compare this to many industrial and general purpose protocols that have not changed with the times. As a reflection of the engineering community that developed it, BACnet is a talented protégé in the eyes of its proud parent organization. It is not the orphan of a corporate entity that developed it decades ago and looks at maintenance costs as a drain on profitability.

Additionally, most BACnet building systems use a standard database with published data formats to facilitate the transfer of historical data that is to be cleansed and integrated before it is analyzed. The application of these advanced analytics in a near real-time control environment can lead to significant improvements in efficiency.

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Issues for Facility Managers to Consider when Selecting Effective Energy Dashboards
By Grant Wichenko, P. Eng.

Energy Dashboards are becoming very popular with Facility Managers, Senior Managers and the public at large who want timely information on energy demand and consumption in the Facility Domain (the building, campus or military base). There are numerous dashboard products on the market. This article outlines guidelines for how to select Energy Dashboards to meet the needs of the various users of energy data in the Facility Domain.

Why Should You Buy Energy Dashboard Software?
An Energy Dashboard provides the user with timely information on the Facility Domain energy consumption and demand. Users or occupants in the building want to know how much energy they can save through their own actions such as turning off lights or changing space setpoints. Senior management wants a simple window into the Facility Domain to determine if the organization is meeting its energy and sustainability commitments. Energy Dashboards and the information they make public are a practical and reasonable approach to implementing the organization’s sustainability goals.

Choose your Energy Dashboard Carefully
All Energy Dashboards will record and graph utility (gas, electricity, water, oil and propane) meter data. While this is an important first step to managing utility consumption and demand, knowing how much energy was used six months ago without having comparable data during the same time period on the operation of building equipment, it is of limited value to the Facility Manager. It is like knowing that you gained 10 lbs six months ago without knowing what you ate or how much exercise you did.

There is normally only a one way flow of information from the BAS Front End and the BACnet device network to the Dashboard. This is because the dashboard only consumes meter data and graphs it. A dashboard does not control equipment. This is the purview of the BAS Front End software. While it would be nice to have the Dashboard identify the problem and then have a link to the relevant piece of equipment to fix the problem, this is not practical. A 10% change in consumption in energy or water within a day or a week could be due to one or more pieces of equipment malfunctioning or running outside of their normal operating schedules.

Some Energy Dashboard suppliers suggest that one can see energy consumption and demand savings in real time by turning off equipment while reading the building utility meters. This sounds like a good idea in theory but it is time consuming and impractical to implement. Turning off HVAC equipment during the day may disrupt operations. Such activities require the time to do this work and to record the results. Facility Managers are too busy with other tasks to allocate staff resources to this antiquated way of determining equipment level consumption and demand.

The best source of information on how the facility is performing is the Building Automation System (BAS). Combining the operational data from the BAS with meter data allows the Facility Manager to determine how much energy was used by a piece of equipment under various operating conditions. For example, knowing the kW and kWh as well as the operating conditions of a piece of equipment such as a chiller or boiler helps the Facility Manager determine how much energy is consumed when the chiller is running at a specific setpoint. The next logical step is to change the setpoint slightly (from 42 deg F to 43 deg F) to see if there is an energy saving without creating comfort problems. Returning to the diet metaphor, most diet plans recommend keeping a food and exercise journal as well as weighing yourself regularly so you can see what behaviours cause weight gains or losses. Unlike a food journal where records are kept manually, the BAS Front End will automatically log changes in consumption and demand when setpoint or other control programming changes are made.

BACnet-based Energy Dashboards are the Best Choice for Facility Managers
The solution is to buy an Energy Dashboard that can read BACnet object property values from the BAS. The Dashboard should be able to read BACnet Trend Logs or BACnet object data from meters, VFDs and other devices that contain valuable energy and runtime data.

Here is a simple example of why a BACnet-based Energy Dashboard is the best option. Variable Frequency Drives (VFDs) now provide kW and kWh represented as BACnet AI or AVs. VFDs also have objects that indicate running status and drive speed. A BACnet-based Energy Dashboard can read these objects simultaneously; the Facility Manager can then know how much energy is consumed when the drive is running at a particular speed. The next question is how much energy can be saved by running the VFD at a lower speed. It may be possible to run the pump or the fan at a lower speed in moderate weather and save money. This savings data can then be used by the Facility Manager to ask for funds to add speed drives to existing constant speed fans and pumps. A BACnet-based Energy Dashboard facilitates this type of analysis.
Author Biography

Grant Wichenko is President of Appin Associates, a Mechanical Engineering firm that specializes in designing and specifying BACnet-based BASs. Mr. Wichenko is a voting member of SSPC-135, the BACnet Committee and SGPC-13, the BAS Specification Committee. He is a non-voting member of SPC-201P, the Facility SmartGrid Information Model (FSGIM) Committee.

Options for Buying an Energy Dashboard

There are two options for buying Energy Dashboard software. The first is the traditional purchase of software that is installed on a facility-resident server. The second is Software as a Service (SaaS). Under the SaaS option, the user accesses the Energy Dashboard software via the public Internet. The interface under both options is normally a web page that is accessed using a web browser. There is normally no additional software on the user’s computer (the client). The user can view the energy and other data from a menu of pre-created graphs, tables or other displays.

If the Energy Dashboard product is BACnet-based, the software will likely read a BACnet Trend Log but will subsequently store the data in its own database. The critical issue with the SaaS model is how does the Facility Manager retain ownership of the data if he decides to end the annual agreement? If the data is in the form of BACnet Trend Logs, is the data stored in some “standard database format” that can be accessed using for example SQL reporting tools?

The Dashboard license is normally purchased either based on the number of users or the number of “meter” points to be presented in the software. If the license is by meter point mapped into the Dashboard program, it is important to resolve what constitutes a meter. Returning to the VFD example above, are the four BACnet AVs – kW, kWh, status and speed – counted as one “meter” point or four?

A Facility Manager may start with an Energy Dashboard on one system or one building. If the implementation is successful, the Manager will likely add more buildings or systems. If the Energy Dashboard software is licensed on a per “meter” point basis, the pricing schedule needs to be negotiated up front and should be based on bundles of 10 to 100 points. Rarely will one add just one or two points from a building or system. There also is setup work required for mapping in one point or 50 points that will inflate the single point price.

Desirable Energy Dashboard Features

Following is a list of the important features of a Dashboard:

1. The dashboard should be able to present data in a wide range of formats including graphs, radio dials, pie charts and other display options.
2. An important feature is that the Dashboard needs to support are XY graphs where the X-axis is something other than time. The graph below shows the relationship between outdoor air on the X axis and boiler Hot Water Return temperature for a condensing boiler on the Y axis. The data shows that the boiler temperature is below the 140 deg F condensing temperature threshold for the majority of the winter period. This graph allows a Facility Manager to evaluate the BAS control strategy of the condensing boiler plant and conclude that the greater the time the boiler plant is in condensing mode (below 140 deg F) the greater the efficiency of the plant.

Graph of Outside Air Temperature vs Boiler Hot Water Return Temperature. Source: Appin Associates
3. The Dashboard should be able to present data to a wide range of users from senior management to equipment operators who have differing interests and focus. Senior Management is interested in the overall building consumption and how the building compares to other buildings in the same category.

4. If the Dashboard is a standalone, separate product, is it possible for a graphic created in a Dashboard be linked to a graphic on the BAS Front End. If the BAS Front End does not support XY graphs per point 2 above, can the graph be created in the Dashboard and then dynamically linked to a graphic in the BAS Front End?

5. Does the Dashboard support Automated Fault Detection and Diagnosis (FDD)? FDD is more than an alarm. FDD uses a set of rules to determine if the fault on the chiller, VAV box or AHU is serious or is minor. Currently only a few Energy Dashboard products on the market support the use of FDD. The National Institute for Standards and Technology (NIST) is working on software tools that will be available for use by Energy Dashboard software suppliers. FDD enabled Energy Dashboard will become more popular once this happens.

6. Security is a very important concern when selecting an Energy Dashboard. Some dashboards use Cloud services. A Cloud-based service is where the service provider hosts both the application and the data on a server that is not on the Enterprise LAN and is not under the jurisdiction of the IT department. The benefit is that the end user is free to use the service from anywhere. The issue from an IT perspective is that such remote access represents a potential security hole. IT needs to be satisfied that any SaaS option is secure. If the software is installed on an Enterprise server, does the software support Microsoft Active Directory so access by a wide range of users can be easily managed by IT?

7. Can the Energy Dashboard generate alarms when the consumption exceeds a threshold? This may not be an important feature as the Facility Manager may want the alarm to be processed through the BAS Front End alarm software. The next question can the Energy Dashboard pass an alarm back to the BAS Front End? This may only be possible with a BACnet-based dashboard product that is tightly integrated into the BAS Front End.

8. The Energy Dashboard software needs to have the necessary graphics tools to present the data in a simple manner that the user can readily understand what the savings are by quickly looking at a large TV screen. The software may be part of the Dashboard offering or may be a separate application. This feature is important because once the Energy Dashboard is implemented successfully, Facility Managers will want to have the energy data and the savings that have resulted made publicly available as part of a “Sustainability Awareness” campaign. Under such a campaign, the energy data would be presented in real time on a TV screen in the building lobby or posted on the employee web site to show the Facility Management's support of Enterprise-wide green or sustainability initiatives.

The Energy Dashboard will mandate new BAS Front End Graphics

Senior Management will want to see an Energy Dashboard installed as it will let them see how the building is performing. Some Facility Managers may see this is as intruding on what was the sole purview of the Facilities Department. The last thing a Facility Manager wants are constant calls or emails from management asking why are we spending so much money on energy today?

The primary purpose for traditional BAS graphics are to allow the user to find out if a specific room or zone is too hot or too cold. These room level graphics are not helpful when trying to pinpoint problems identified by the Energy Dashboard as many pieces of equipment may be the cause of high energy consumption or demand.

Facility Managers need new energy-related graphics to determine quickly if one or more spaces are driving the boiler and chiller operations. The graphics may point to the need to add heat in an entrance that is requiring the boiler plant to operate outside of its condensing mode in cold weather. There may be a conference room that requires spot cooling when fully occupied to keep the chiller plant from running extensively just to satisfy one room a few times a week.
Here are some sample graphics that will help deal with these inquiries.

This first graphic shows the color relative to the recommended zone setpoint, not relative to the user’s setpoint. This allows Facilities Operations to determine which spaces are outside of the recommended temperatures. The graphic shows the heat and cool counts so Facilities Operations can determine which space is driving the chiller or boiler plant to run excessively. Often there are only a few spaces that drive the plant operation.

The comparison of the actual airflow to the setpoint indicates which spaces are getting enough air or too much air. With this graphic, Facilities Operations has the ability to adjust the airflows to the spaces. The RED space is not getting enough air and the CYAN space is getting too much air.

These graphics allow Facilities Management to turn a question such as why are we spending so much money on energy today into a request for modest capital improvements to solve a clearly identified problem (an overheating conference room that needs independent cooling for high occupancy conditions).

### Part 2: Energy Dashboards Value in a SmartGrid World

Energy Dashboards in a SmartGrid world will need to show the shifts in electricity supply in peak periods. This is different from the traditional role of an Energy Dashboard which is to show savings in consumption and demand.

Energy Dashboards that are BACnet-based can read and record not only energy and demand information from the meter but information on equipment operating status. This information, when combined with energy data, will tell the user if the equipment is performing as best it can.

Conclusions

Energy Dashboards are a useful software tool for visualizing energy consumption and demand. Dashboards will be used by many people in the Enterprise from senior management to the building operator.

A Dashboard that only records meter data is of limited use as one needs information on equipment runtimes and the percentage speed or capacity in order to determine if the equipment is performing at peak efficiency.

Energy Dashboards that are BACnet-based can read and record not only energy and demand information from the meter but information on equipment operating status. This information, when combined with energy data, will tell the user if the equipment is performing as best it can.
Moving Up From Protocol Revision 4

What is Needed to Go To Higher Protocol Revisions?

by Duffy O’Craven

The role of BTL Testing in keeping the community interoperable

To keep the community of BACnet implementations all communicating and adhering to one interoperable standard, it is desirable for implementations to stay within a narrow band of similar Protocol Revisions of the standard. Over time, the behaviors mandated by the standard may drift apart slightly, but the differences accumulate. BACnet International, through its BTL testing, encourages everyone to make their devices Protocol Revision 7 or 9 or even higher.

In most devices, moving up to Protocol Revision 7 or higher involves just a few small changes in property values, and Error code responses. That’s all it takes. This document lays out the entire slate of needed property value changes at various Protocol Revisions.

List of changes needed to move up from Protocol Revision 4

For all devices

I. The Protocol_Revision property in the Device object needs to be at the right value to match the Protocol_Revision.

II. The length of Protocol_Object_Types_Supported property value changes at various Protocol Revisions.

III. The length of Protocol_Services_Supported property value changes at various Protocol Revisions.

<table>
<thead>
<tr>
<th>Revision</th>
<th>Size</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>21</td>
<td>Added Averaging(18), Multi-state Value(19), Trend Log(20)</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td>Added Life Safety Point(21) and Life Safety Zone(22)</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>Added Accumulator(23) and Pulse Converter(24)</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>Added Structured View(29), and reserved bits for several other objects in review.</td>
</tr>
<tr>
<td>6</td>
<td>31</td>
<td>Added Load Control(28), Access Door(30)</td>
</tr>
<tr>
<td>7</td>
<td>31</td>
<td>Added Event Log(25), Global Groups(26), Trend Log Multiple(27)</td>
</tr>
<tr>
<td>8</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>38</td>
<td>Added Access Credential(32), Access Point(33), Access Rights(34), Access User(35), Access Zone(36), Credential Data Input(37), and reserved bits 31 for a future object type</td>
</tr>
<tr>
<td>10</td>
<td>51</td>
<td>Added Network Security(38), BitString Value(39), CharacterString Value(40), Date Pattern Value(41), Date Value(42), DateTime Pattern Value(43), DateTime Value(44), Integer Value(45), Large Analog Value(46), OctetString Value(47), Positive Integer Value(48), Time Pattern Value(49), Time Value(50), and reserved bits 51 for a future object type</td>
</tr>
<tr>
<td>11</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>53</td>
<td>Added Notification Forwarder(51), Alert Enrolment(52)</td>
</tr>
<tr>
<td>14</td>
<td>55</td>
<td>Added Channel(53) and Lighting Output(54)</td>
</tr>
</tbody>
</table>


There is nothing more. Just making the above two changes, makes the device Protocol Revision 7 or 9, if the values chosen are those for Protocol Revision 7 or 9.

For devices Protocol Revision 10 or higher

III. There is permission to accept UTF-8 strings on the B-side, at any Protocol Revision. The UTF-8 capability is intended to be largely backward compatible, and BACnet wants its uptake to be as wide as possible. For devices Protocol Revision 10 or higher, that permission becomes a requirement to accept UTF-8 strings on the B-side to support CharacterString properties. The SSPC-135 specified supporting the UTF-8 capability with no requirement that the recipient evaluate or validate it in any way. Just accept and store and return the bytes, if character-set 0 (formerly known as ANSI X3.4) is indicated in the string value, even if some or all of the content bytes have bit 7 set.

There is now a test for UTF-8. Devices claiming Protocol Revision 9 or lower may either accept requests writing CharacterString properties with valid UTF-8, or return an error to those writes, if some or all of the content bytes have bit 7 set. If there is no difficulty in your implementation to just accept and store and return the bytes, without validating in any way that is the more interoperable choice.

What a device does when presented with non-valid UTF-8, if the content bytes have a pattern that is not valid UTF-8, is a local matter. There is no BTL testing attempted with invalid UTF-8.

For devices with BIBBs, DS_RPM-B, DS-WPM-B, DS-COV-A, DS-COV-B

III. The required Error code for a ReadProperty/Multiple of any property which is not readable starts to be enforced in Protocol Revision 7, in tests 9.20.1.7, 9.20.1.8, and 9.20.1.9 which are tests of ReadProperty/Multiple with the special BACnetPropertyIdentifiers: ALL, OPTIONAL, and REQUIRED. The entry in ReadAccessResults for each such property shall contain ‘Error Class’: PROPERTY and ‘Error Code’: READ_ACCESS_DENIED for that property.

IV. If a WriteProperty/Multiple_Request contains an entry which produces an error later than the first entry, it is now enforced by test 9.23.2.X1 that the IUT does not send a BACnet-Reject-PDU after applying the writes from earlier entries. It is still permissible to return WriteProperty/Multiple-Error, indicating the entry where the error was observed, after applying the writes from all earlier entries. Only the returning of a BACnet-Reject-PDU, after applying the writes from any earlier entries, is the situation which is forbidden.
XI. Any device capable of external Trending, i.e. T-VMT-E-B or T-MVVM-E-B, must demonstrate that execution of the ReadRange service performs properly for each data type supported.

For devices with Trending BIBBs

VII. The length of the BACnetLogStatus in ReadRange-ACK responses, when reading the Log_Buffer property of logging objects, will vary depending upon the protocol revision to which the device was implemented.

<table>
<thead>
<tr>
<th>Revision</th>
<th>Size (bits)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 6</td>
<td>2</td>
<td>log disabled (0), buffer purged (1)</td>
</tr>
<tr>
<td>7 - 14</td>
<td>3</td>
<td>Added log interrupted (2)</td>
</tr>
</tbody>
</table>

VIII. If there is a Trend Log object, these two properties go from forbidden when Protocol_Revision < 7, to required when Protocol_Revision >= 7.
- logging-type: [197] BACnetLoggingType
- status-flags: [111] BACnetStatusFlags

IX. If there is a Trend Log object, these two optional properties become available when Protocol_Revision >= 7.
- align-intervals: [193] BOOLEAN
- interval-offset: [195] Unsigned

Both properties are required to be present if the object supports clock-aligned logging.

X. If ReadRange execution is supported, then three negative tests yielding the expected Error codes are required. Any list properties are present in the device, then a positive test, reading each list property which is present in the device, shall succeed.

For devices with DM-LM-B and/or DM-OCD-B BIBBs

XII. The required Error code for AddListElement Failure Part Way Through a List was defined in Protocol_Revision 7, and starts to be enforced in Protocol_Revision 7, in test 9.14.2.3

XIII. The required Error code for RemoveListElement Failure Part Way Through a List was defined in Protocol_Revision 7, and starts to be enforced in Protocol_Revision 7, in test 9.15.2.2

XIV. The required Error code for Attempting to Create a non-Supported Object Type was defined in Protocol_Revision 10, and starts to be enforced in Protocol_Revision 10, in tests 9.16.2.X1 and 9.16.2.X2

For Workstation and Operator Display devices

XV. In Workstations there are two object types defined in Protocol_Revision == 7, which result in additional requirements applicable to Workstations when Protocol_Revision >= 7. There are additional A-side requirements in BIBB T-V-A to interact with Trend Log Multiple, and for B-AWS there is a requirement to also support Trend Log Multiple in DM-OCD-A.

XVI. In Workstations claiming Protocol_Revision >= 7, there is an additional requirement of the AE-ELVM-A BIBB.

XVII. Twelve additional object types are defined in Protocol_Revision 10, which results in additional requirements applicable to the Workstations BIBBs for Data Sharing - View - A and Data Sharing - Modify - A when Protocol_Revision >= 10. When Protocol_Revision >= 10, workstations are also required to accept and execute the ConfirmedEventNotification and UnconfirmedEventNotification formats produced by the new event algorithms.
Test Package-12.0 is the right Test Package for nearly everyone. The exception is that Test Package-9.0 is the right Test Package for B-OWS and B-AWS that are less than Protocol_Revision 10. There is nothing additional that Test Package-12.0 requires of B-OWS and B-AWS that are less than Protocol_Revision 10. But it expresses a lot of new requirements for B-OWS and B-AWS which are Protocol_Revision 10 or higher, and then says: except that if less than Protocol_Revision 10, then you don’t have to do this. It probably makes reading Test Package-12.0 in that respect harder than simply staying with Test Package-9.0, and adds that complexity for no additional benefit, and no additional testing. There will probably not be a Test Plan-14.0 until at least 10 or more months from now, so you should plan testing against Test Plan-12.0.

If something does not comply with testing requirements or there is a Failure in the test, what’s the procedure?

Every applicant so far at the lab has had to update some part of their implementation to comply with requirements after initially failing some test or tests. The expectation is that testing will primarily be performed on the first revision sent, but then a revised version that corrects observed defects will be field-upgraded into the device. Then the failed tests are restested to verify that the remedy resolved the defect, along with restesting of related tests where the change may have affected the result. There is no “all-or-nothing” testing. There is instead: incremental improvement until the implementation is a fully conformant implementation of BACnet.

XVIII. There is an additional requirement in DM-BR-A, for Workstations claiming Protocol_Revision >= 10, to respect the Backup_Preparation_Time et al. if the other device, the one implementing DM-BR-B, is Protocol_Revision 10 or higher. This is an area of some awkwardness, because Workstations claiming Protocol_Revision < 10, are not tested to see whether they respect the Backup_Preparation_Time since those properties were first defined in Protocol_Revision 10. If possible in your implementation, for interoperability it would be better to respect the Backup_Preparation_Time and/or any other properties that devices using DM-BR-B require. The B-OWS and B-AWS that are Protocol_Revision 10 or higher must respect those properties. If B-OWS and B-AWS that are Protocol_Revision < 10 are to respect those properties, then you must checkmark the box for that property, and test for its compliance. This requirement applies to Workstations claiming Protocol_Revision >= 10, and does not apply to Workstations claiming Protocol_Revision < 10.

The Device Profiles in terms of the BIBBs

ASHRAE 135-2010 in Annex L describes the requirements of the various Device Profiles in terms of the BIBBs, and in Annex K, the BIBBs are described in terms of their individual requirements. If you are reading ASHRAE 135-2008, that Annex K and L have been superseded by the requirements in http://www.bacnet.org/Addenda/Add-135-2008l.pdf. Look there for additional Device Profiles and BIBB definitions, and in some cases added or changed requirements.

Test Package-12.0 is the right Test Package for nearly everyone

The BTL Checklist sections correspond with the BIBBs. A Base Requirements line at the top of each section has a conformance code R for Required. You must checkmark Base Requirements, if you checkmark the section at all. Some sections have additional lines of optional functionality. In those additional lines, most have a conformance code O for optional, but note that some have an R, BTL-R, or BTL-C conformance code, drawing attention to additional functionality that is also Required in that BIBB. Each line item corresponds to some testing that is conducted within those BIBBs, when the line is check marked.

Author Biography

Duffy O’Craven is the BTL Manager at BACnet International. He supervises the BACnet International sponsored SoftDEL testing lab in Pune, India, and chairs the BTL-WG, a working group continuously improving and extending the Test Plan for BACnet interoperability.
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