BACnet in an Internet of Things (IoT) World
Learning Objectives – BACnet’s Role in Implementing IoT for Facility Managers

1. Explain how BACnet data can be used in a Facility from the Device to the Domain level.
2. Describe how an Energy Analytics tool can analyse whole Building meter bill data with BACnet Device level data.
3. List the improvements to BACnet that will help a Facilities Manager (FM) implement a BACnet-based IoT strategy.
4. State why good relations with the IT department is critical to the FM Department’s BACnet-based IoT implementation strategy.
Introducing Appin and Grant Wichenko

Appin Associates is a 37 year old consulting firm that specializes in:

• **Building Automation System (BAS) Design** including specification and commissioning with emphasis on BACnet-enabled controls.

• **Mechanical Systems Design** (HVAC, Boilers, Chillers) paying particular attention to the needs of the FM.

Grant Wichenko is a Professional Engineer. He is a member of:

- ASHRAE SSPC-135 (BACnet committee – voting member),
- SGPC-13 (BAS Guideline Specification committee – voting member)
- ASHRAE 201P (SmartGrid committee - member.)

Appin Associates was the first Engineering firm to join BACnet International.
IoT is the latest buzzword you hear everywhere…. but what does it mean to you?
BACnet data can be used from the Domain to the Device levels

**Domain:** BACnet Data is normalized for weather so it is comparable. Cost data is used for budgeting.

**Campus:** Bldg KPIs (energy/sf and kW/Ton) and costs are reported to Senior Management and the Board.

**Building:** FM reports Building performance to VP of Finance using an Energy Dashboard tool.

**System:** Operator/FM use BACnet data in a BAS Dashboard to monitor the Devices in the System.

**Device:** Blgd Operator Uses BACnet data to manage a single Device on the BACnet network.
Using BACnet IoT data at the Device level

- The IoT Device reports energy information and fault information to the operator using BACnet objects and services.
- This data can be provided without having to add additional meters as most BACnet Devices now have onboard real time meter data.
- Runtime data can be manually or automatically added to the Facility Dept. PM System. Fault data can be analysed by an FDD software package.
- Energy, power and shed rate data may be used for developing Device-specific Demand Response load shedding strategy.
- Operators now make “virtual rounds” on the Front End. The days of walking around with a clipboard to check out Devices, are over.
- **BACnet Devices have IoT data onboard. Specifying the BACnet Device data/networking requirements in projects is critical to your IoT strategy.**
If specified properly, BACnet-based VFDs can come with a built-in kWh meter and fault codes.

You need to check the data!!

BAS Front End screenshot

VFD display screen
Using BACnet IoT data at the System level

System:

- A System - chiller or boiler plant - is a collection of Devices.
- We sum up the energy and power information from each Device and then we calculate Key Performance Indicators (KPI) to show System performance.
- kW/ton is a KPI for a chiller plant. With BACnet, the kW data for each Device in the System can be added together to get total kW. A BACnet flow meter can provide chiller plant GPM. We calculate kW/ton.
- The Operator and the Facility Manager use KPIs like kW/Ton to assess System performance in real time or on a daily basis.
- We can compare this System to other Systems in the Building or Campus.
- A well designed System level Dashboard in the BAS that reports on energy and Device health, needs to be accessible from the Domain level down.
The chiller plant consists of a plant controller BACnet Device that controls the BACnet Devices (chillers and VFDs), stick built sensors and other Devices.

The BAS only sends a setpoint and enable signal to the System, not the individual Devices.
The Chiller System will have both Networked BACnet and Stick-built Devices.

All three chillers are BACnet Devices.

VFDs are BACnet Devices.

Cooling Tower and other points are stick-built.

Refrigerant monitor and water treatment controller are BACnet Devices.
Chiller System power for each Device is monitored in real time via BACnet without having to install extra meters.

- **Chiller Power**: 130.00 kW
- **+ CHWP Power**: 13.50 kW
- **+ CWP Power**: 45.02 kW
- **+ Cooling Tower Power**: 21.10 kW
  
  **= Total CHW System Power**: 209.62 kW

- **System Tonnage**: 289.23 tons

- **Power ÷ Tonnage = 0.72 kW/ton**

Real Time kW/Ton
Chiller Plant BACnet data is ACTIONABLE – Real time tons, kW, kW/ton, GPM
Equipment Meter Data via BACnet is ACTIONABLE – Weekly kWh data from Chiller Plant

<table>
<thead>
<tr>
<th></th>
<th>Monday kWh</th>
<th>Tuesday kWh</th>
<th>Wednesday kWh</th>
<th>Thursday kWh</th>
<th>Friday kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chiller 2</td>
<td>1786</td>
<td>1515</td>
<td>1589</td>
<td>1868</td>
<td>1992</td>
</tr>
<tr>
<td>Chiller 3</td>
<td>1989</td>
<td>1532</td>
<td>1795</td>
<td>2055</td>
<td>1918</td>
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<tr>
<td>CHWP 1</td>
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<td>138</td>
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<tr>
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<td>148</td>
<td>136</td>
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<td>171</td>
<td>167</td>
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<tr>
<td>CT 1</td>
<td>66</td>
<td>40</td>
<td>43</td>
<td>75</td>
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<tr>
<td>CWPs</td>
<td>802</td>
<td>717</td>
<td>775</td>
<td>825</td>
<td>902</td>
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<tr>
<td>Total</td>
<td>5107</td>
<td>4149</td>
<td>4583</td>
<td>5292</td>
<td>5206</td>
</tr>
</tbody>
</table>

Total Week CHWS Energy Usage: 24338 kWh x 0.08 = $ 1947.00

Using $$$ makes it real!!!
Using BACnet IoT data at the Building level

**Building:**

- The energy information from the various Building Systems is then summed up and compared to the Building meter data to do a *sum of the parts* analysis.
- The Facility Manager and the VP of Finance can summarize and review this data through the Energy Dashboard so it can be compared on an energy cost/sq. ft. basis with other Buildings.
- Comparing Buildings that perform to expectations to non-performing buildings helps to set funding priorities for upgrades.
- The building could have Energy Dashboard TV kiosk in the Building lobby to show the occupants and the public how the Building is performing on a daily basis. Make sure the data is accurate before you do this.
Modbus Trip Unit data provides data on Building components like lighting, elevators, plug loads so you can do a “sum of the parts” comparison to the Building utility meter.
Building Level Meter Data is CONFIRMATORY – It lets you determine project priorities and then confirm that the changes worked.

- Boiler plant changed in 2011 to condensing
- Owner negotiated a better gas price in 2012
- CO₂ Emissions declining
Using the Energy Analytics software to track utility costs as well as consumption

- Posting meter data that includes costs and consumption allows you to track utilities accurately.
- The Energy Dashboard is a General Ledger. *Currency* is kWh, therms or gals.

<table>
<thead>
<tr>
<th>Meter</th>
<th>Supplier</th>
<th>Start Date</th>
<th>Bill Date</th>
<th>Bill Type</th>
<th>Total Consumption</th>
<th>Expected Total</th>
<th>Billed Total</th>
<th>Difference %</th>
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<tbody>
<tr>
<td>031-GAS-024-UTILITY METER</td>
<td>North Shore Gas</td>
<td>10/31/2015</td>
<td>11/30/2015</td>
<td>Bill</td>
<td>15,800.00</td>
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<td>$ 7876.78</td>
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<tr>
<td>031-GAS-024-UTILITY METER</td>
<td>North Shore Gas</td>
<td>10/1/2015</td>
<td>10/30/2015</td>
<td>Bill</td>
<td>5,800.00</td>
<td>$ 2823.19</td>
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<td>0.00 %</td>
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<tr>
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<td>031-GAS-024-UTILITY METER</td>
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<td>Bill</td>
<td>5,064.00</td>
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</tr>
<tr>
<td>031-GAS-024-UTILITY METER</td>
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<td>4/30/2015</td>
<td>Bill</td>
<td>12,640.00</td>
<td>$ 9053.45</td>
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<tr>
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<td>29,158.00</td>
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<tr>
<td>031-GAS-024-UTILITY METER</td>
<td>North Shore Gas</td>
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<td>1/31/2015</td>
<td>Bill</td>
<td>36,560.00</td>
<td>$ 20270.14</td>
<td>$ 20270.14</td>
<td>0.00 %</td>
</tr>
</tbody>
</table>
Equipment Meter Data via BACnet is ACTIONABLE – Chiller Plant is at .7 kW/Ton, plant is off on weekends

<table>
<thead>
<tr>
<th></th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
</tr>
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<tbody>
<tr>
<td>Chiller 1</td>
<td>0 kWh</td>
<td>0 kWh</td>
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<td><strong>4583 kWh</strong></td>
<td><strong>5292 kWh</strong></td>
<td><strong>5206 kWh</strong></td>
</tr>
</tbody>
</table>

No need to include all this data in the Dashboard
Equipment Meter Data via BACnet is ACTIONABLE – Floors 06, 07 and 08 are on July 4 – the lighting schedule needs to be fixed
Using BACnet IoT data at the Campus level goes beyond the FM Department

- The energy information from the various Buildings can then be summed up and reported to management on a Campus-wide basis.
- The Campus Utility Department can use the data to implement a Demand Response program. Loads in selected Buildings are shed in a sensible manner and the commercial utility pays the Campus for the savings.
- The Utility Department may also use the data to negotiate bulk buys of electricity or natural gas to save money.
- The benefits of PV array and solar thermal projects can be tracked in real time. PV Devices can be part of the Campus-wide Demand Response plan.
- The Construction Department can use the data to commission a new project and then to evaluate the performance of A/E consultants’ designs over time.
Well designed Campus level BAS graphics let you drill down to a Building, a System and a Device

### Building Level Status Page

<table>
<thead>
<tr>
<th>Building nnn</th>
<th>Occ</th>
<th>Alarm Count</th>
<th>Avg. Temp</th>
<th>Energy Cons</th>
<th>Demand</th>
<th>CO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building nnn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Building nnn</td>
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<tr>
<td>Building nnn</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Click to get to the Building Alarm Log**

**Building within Energy and Demand Targets**
Well designed Building level BAS graphics let you drill down to a System and a Device

<table>
<thead>
<tr>
<th>Building Equipment</th>
<th>Status</th>
<th>Alarm</th>
<th>Supply Temp</th>
<th>Mixed Temp</th>
<th>Return Temp</th>
<th>Pump Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU1</td>
<td>ON</td>
<td>OFF</td>
<td>55.3</td>
<td>62.1</td>
<td>74.2</td>
<td>ON</td>
</tr>
<tr>
<td>Chiller</td>
<td>ON</td>
<td>OFF</td>
<td>42</td>
<td>N/A</td>
<td>100</td>
<td>ON</td>
</tr>
<tr>
<td>Paint Booth</td>
<td>ON</td>
<td>ON</td>
<td>65</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Mr. Slim</td>
<td>OFF</td>
<td>ON</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Space Conditions</th>
<th>Avg. Temp</th>
<th>High Temp</th>
<th>Low Temp</th>
<th>Space Static</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>72</td>
<td>76</td>
<td>67.3</td>
<td>.12</td>
<td>850</td>
</tr>
</tbody>
</table>

| Outdoor Air Temp  | 80        |
| Blgd Interior RH  | 55        |
| Blgd Op Mode      | Clg       |

<table>
<thead>
<tr>
<th>Electrical Demand</th>
<th>Current</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>75.2</td>
<td>123.6</td>
</tr>
</tbody>
</table>
Using BACnet IoT data at the Domain level

Domain:

- The Domain is a collection of Campuses. The Domain could be in one state or a collection of Buildings and Campuses around the world.
- Data is in summary report form and is normalized for weather (degree-days).
- The gas, electricity and other fuel data is converted to Energy Use Intensity (EUI) numbers so the total energy use can be reported and analyzed.
- Senior management and funding agencies use summary data for capital and operating cost planning. Plant operations are normally not their focus.
- Good Energy Dashboard software tools will allow you to drill down to lower levels you can look at the data for yourself. Transparency is critical.
- Data at this level is normally posted on a 24 hour basis. Meter bill data is normally posted monthly or quarterly.
BACnet Front Ends

BACnet Data posted to Energy Analytics Software

Summary Data To Domain Analysis Tool

Whole Building Meter Data posted to Energy Analytics Software

<table>
<thead>
<tr>
<th>Start Date</th>
<th>Bill Date</th>
<th>Bill Type</th>
<th>Total Consumption</th>
<th>Expected Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/31/2015</td>
<td>11/30/2015</td>
<td>Bill</td>
<td>15,800.00</td>
<td>$7876.77</td>
</tr>
<tr>
<td>10/1/2015</td>
<td>10/30/2015</td>
<td>Bill</td>
<td>5,800.00</td>
<td>$2823.19</td>
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<tr>
<td>9/1/2015</td>
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<td>442.00</td>
<td>$585.44</td>
</tr>
<tr>
<td>8/1/2015</td>
<td>8/31/2015</td>
<td>Bill</td>
<td>39.00</td>
<td>$492.86</td>
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<tr>
<td>7/1/2015</td>
<td>7/31/2015</td>
<td>Bill</td>
<td>50.00</td>
<td>$564.4</td>
</tr>
<tr>
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<td>6/30/2015</td>
<td>Bill</td>
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<td>$1285.05</td>
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<tr>
<td>5/1/2015</td>
<td>5/31/2015</td>
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<td>4/1/2015</td>
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<td>$20270.14</td>
</tr>
</tbody>
</table>
How BACnet helps you implement IoT from the Device to the Domain

Domain:

Campus:

Building:

System:

Device:
How BACnet helps you implement IoT – Application Profiles (AP) and Semantic Tags

• BACnet AP-WG is preparing a dictionary of tags to give objects semantic meaning. Determining what an object means is now a time-consuming manual process. You have to read the object list to find the heating setpoint.

• Front Ends can discover BACnet devices and objects now. With tags the Front End can get the meaning of the Device and its objects. We can build graphics automatically as we know that the Device is a VAV box with a damper and a fan. O&M, BIM and other data can be embedded in the Device and discovered.

• An Application Profile will define minimum object and tag requirements for a Device like a chiller, VAV box or a VFD.

<table>
<thead>
<tr>
<th>Building System+</th>
<th>Control</th>
<th>Control Modifier+</th>
<th>Item Modifier+</th>
<th>Item Type</th>
</tr>
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<tbody>
<tr>
<td>Temperature Sensor</td>
<td>hvac;</td>
<td>processValue;</td>
<td>continuous;</td>
<td>controller;</td>
</tr>
<tr>
<td>DEVICE</td>
<td></td>
<td></td>
<td>group;</td>
<td></td>
</tr>
<tr>
<td>AI1 – RoomTemp</td>
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<td>processValue;</td>
<td>continuous;</td>
<td>sensor;</td>
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<td></td>
<td></td>
<td></td>
<td>selfControlled;</td>
<td></td>
</tr>
<tr>
<td>AV1 – HtgRoomSetpointOcc</td>
<td>hvac;</td>
<td>setPoint;</td>
<td>continuous;</td>
<td>whenOccupied;</td>
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The Structured View Object (SVO) will allow you to represent a VAV box or other Device as a collection of BACnet objects, but with a structure.

The semantic tags in the SVO give Front End the information to manage these components without having any prior knowledge from a Submittal:

The tags would describe:
- The fan in a fan powered box,
- The damper,
- The reheat coil,
- The thermostat,
- External Devices like a lighting System occupancy sensor or room radiation.

How BACnet helps you implement IoT – Structured View Object and Semantic Tags

Structured View
Subordinate Tags
Subordinate Tags
Tags

VAV Box SVO And Semantic Tags that describe the Device.

BACnet Object Tags
Fan B. O. and Tags

BACnet Object Tags
Damper A. I. and Tags
How BACnet helps you implement IoT
- BACnet Web Services (WS)

BACnet RESTful Web Services

- You used Web Services when you booked your trip on Expedia or Trivago.
- The address of the point is an http:// URL that allows another Device to talk to that point using standard IP technology. But it is still BACnet data.
- The non-BACnet software packages that collect data from the BAS Devices can use Web Services to bring BACnet point data into a database at the Domain level.

REST stands for Representational State Transfer.
It relies on a stateless, client-server, cacheable communications protocol – and in virtually all cases, the HTTP protocol is used. REST is an architecture style for designing networked applications.
How BACnet helps you implement IoT - BACnet/IT and other enhancements

• BACnet/IT will eventually replace BACnet/IP. It is backwards compatible to BACnet/IP but there is no longer a need for a BBMD.
• BASs can then be managed by the IT department like any other computer.
• BASs will use standard IP security techniques that IT departments prefer.
• BACnet/IT supports DHCP, Active Directory and TCP/IP (not just UDP).

• Other IT level enhancements by BACnet:
  • The new Network Port object allows for simple network visible IP configurations.
  • The standard also supports IPv6.
How do we implement a BACnet-based IoT strategy

• FMs must be involved in the entire design and construction process.
• Too often we have seen FMs being involved only after the Building is turned over to the Facilities department.
• There should only be 2-3 FM-approved BAS vendors. Having more than 3 vendors is a maintenance nightmare. You need to have an approved procurement process to allow this.
• In a IoT world, FMs also need to limit the selection of common equipment such as VFDs, lights, chillers, boilers, switchgear to reduce training and maintenance costs.
• Ultimately FMs must have control over the BAS spec and the graphics or getting a BAS that meets FM needs, WILL NOT HAPPEN.
• **Finally Devices must be designed and specified to come with BACnet-based IoT data as adding this capability after the fact is expensive and complex.**
FMs must ensure that the BAS design permits equipment level metering

- Equipment level metering is essential for FMs to maintain proper performance over the life of the System…not just to save energy.
- Most pieces of equipment – VFDs, chillers, CRACs, Trip Units – now have onboard metering via BACnet or Modbus.
- While this meter data is not revenue grade per ANSI C 12.19, daily metering will tell the FM how the chiller, boiler, AHU and other Systems are doing.
- This data can be aggregated and posted to a BACnet-based Energy Dashboard or TV kiosk to provide reporting to support the Enterprise’s GREEN strategy.
- Present meter data in dollars not just kWh or therms to make costs real to FM staff.
To have the Internet of Things...

Things must be on the Internet!!
To more BACnet Devices

BACnet/ IP Cable by Div 27

VAV box BACnet MS/TP Connection by Div 25

Fire Alarm

LAN

BACnet/IP Connection

Server

Client

Meter
IT Support is Essential to a Successful FM IoT Strategy

- Most FMs must rely on IT for access to the Enterprise LAN. IT must become “your new BFF (Best Friend Forever)”.
- IT must be involved with the BAS integration when the job starts, not a week before commissioning begins.
- Other than BACnet/NS Devices that are secure, BACnet Devices and networks are secured by IT means. We must follow IT security rules.
- IT security also includes no open connections in public areas, physical security to rooms where BAS equipment is installed and mandatory FM staff/contractor security clearances or background checks.
- Servers, switches and IP cabling infrastructure are to IT standards…no more unmaintained computers and rogue hubs in Mechanical Rooms!!
- Many Energy Dashboards and FDD tools are SaaS-based. They need remote access to a cloud server. IT may allow this if security rules are followed. **New DoD CyberSecurity rules will not allow remote access.**
Following IT rules is critical to implementing a Successful IoT Strategy

- Having separate computers with Front Ends for each job are no longer required. More computers create extra patch management work for IT.
- The servers should be provided as Virtual Machines that are maintained by IT, not FM nor the BAS vendor.
- Give IT plenty of time to provide switches, patch panels and IP addresses.
- BAS must follow IT cabling installation standards or cabling is done by Division 27. Only BACnet MS/TP and Modbus cabling is by the BAS vendor.
- There should only be one network connection from the BAS Device network to the Enterprise LAN. This allows for a functioning BAS network until IT completes the certification and accreditation process (ATO for DoD).
- BASs are now commissioned using the IP infrastructure. IT may be asked to allow a temporary wireless network so MEP and finish their work. This would be removed once the Building it lit up and online.
BACnet is your IoT Solution from the Device to the Domain

- If you have BACnet-Devices that you have networked, you have a wealth of data already. You can analyse data with the BAS Front End you have now.
- The software tools that analyse the data at each of the five levels may change to suit the needs. The data structure may change from a BACnet Trend Log to a database record, but the data source is BACnet.
- If you read your meter electronically, this pulse count data is BACnet-based. This meter data may be aggregated by other tools at the Campus and Domain levels, but it is still BACnet data.
- New developments in BACnet will support your IoT strategy from the Device to the Domain.
- **THE BOTTOM LINE**: Don’t get locked into proprietary software that converts all your BACnet data to some proprietary format and you are tied to single vendor. Specify networkable BACnet Devices and use your Front End to create the System and Building level dashboards.
Implementing IoT successfully will require changes in your FM department

- IT support is critical to a successful IoT strategy...IT is your new BFF!!
- Once this data is public (outside the FM Dept.), users will want this data. You need to have the staff or outside resources to meet this demand.
- Build Device, System and Building Dashboard virtual rounds into your Operator’s schedule. Encourage discussion of problems at shift changeover.
- Equipment must function or the data is useless. Running fans in hand rather than through the VFD increases energy consumption. Check your lighting system to make sure daylighting is enabled and the schedules are correct.
- **Finally, Check the Data, Check the Data, Check the Data.**
  - A smart IoT strategy lets the FM Dept. shine. Wrong data will hurt you.
  - Showing buildings that are not performing or there were problems (devices running in hand), is reality. Own up to mistakes and move on.
  - You can use the data to justify upgrades to fix the problem.
THANK YOU FOR YOUR TIME.

Questions???

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