



# Building Automation System Basics

EngineeringAdvantage™ Program

Presented by Brendan Cox

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# Course Description

## **Building Automation System Basics (BAS101)**

Most buildings designed and built today have some means of managing and controlling building systems through a Building Automation System (BAS). This presentation will cover basic terms and components comprising a typical commercial building system.

## **Learning Objectives**

- Learn about the basics of Building Automation Systems
- Understand the concept of a BAS Point
- Be able to identify various components
- Recognize how the components and controllers form a BAS Control System

# Course Outline



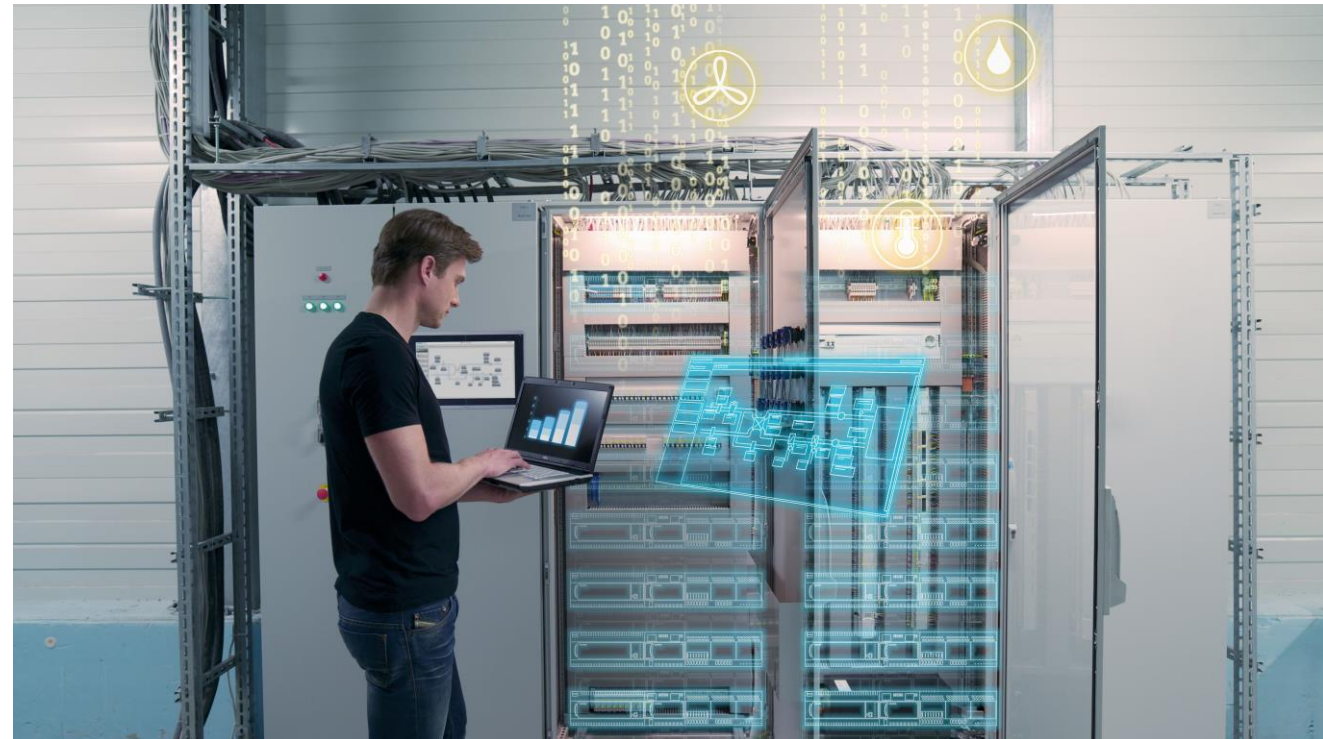
- Background
- Control Fundamentals
- Key Elements of BAS System
- Trends
- Wrap-up

# Defining a Building Automation System (BAS)

## Building Automation System

A built combination of electronic hardware, instrumentation, low-voltage cabling, data, and software that control and monitor a building's systems to keep occupants comfortable, healthy, and safe.

### Division 23



# Defining a Building Automation System (BAS)

Interconnected

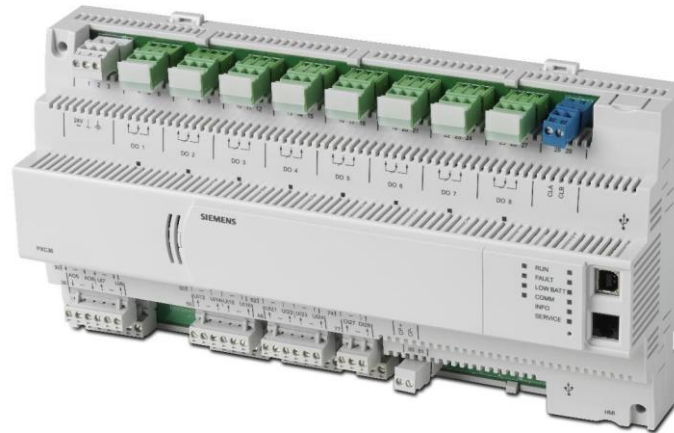
DDC Controls

“Front end”

Automated

## Criteria

- Utilizes Direct Digital Controls (DDC)
- Has a central user interface (“front end” or “head end”)
- Multiple building systems/equipment are interconnected
- Automated to maintain building conditions to design criteria with minimal human intervention



```
7 string sInput;
8 int iLength, iN;
9 double dblTemp;
10 bool again = true;
11
12 while (again) {
13     iN = -1;
14     again = false;
15     getline(cin, sInput);
16     system("cls");
17     stringstream(sInput) >> dblTemp;
18     iLength = sInput.length();
19     if (iLength < 4) {
20         again = true;
21         continue;
22     } else if (sInput[iLength - 3] != '.') {
23         again = true;
24         continue;
25     } while (++iN < iLength) {
26         if (isdigit(sInput[iN])) {
27             continue;
28         } else if (iN == (iLength - 3)) {
29
30
31
32
33
34
35
```

## Defining a Building Automation System (BAS) - examples

Scenario:

Package rooftop unit (RTU) with manufacturer's standalone, digital, programmable thermostat

- Uses DDC?
- Has a user interface?
- Interconnected?
- Automated?

This system could be tied into a larger BAS, but is not in itself an “automation system” per se.



## Defining a Building Automation System (BAS) - examples



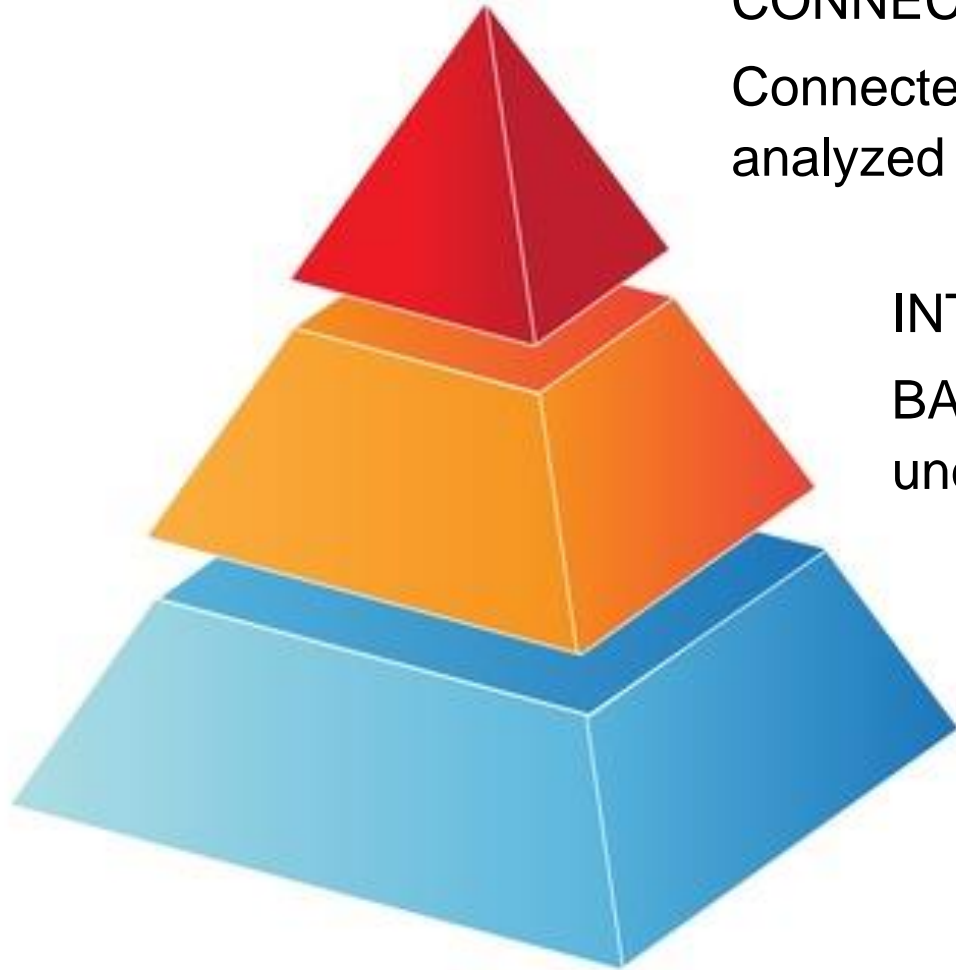
Scenario:

Large chiller plant utilizing microprocessor-based controls with “front end” workstation accessible by facilities director in his office. The director can change setpoints, schedules, setbacks, etc., remotely.



- Uses DDC?
- Has a user interface?
- Interconnected?
- Automated?

## Three tiers of BAS capabilities



### CONNECTED

Connected to digital/data tools and continuously analyzed to optimize efficiency

### INTEGRATED

BAS is monitoring other systems not directly under its control; operators gain insights

### CONTROLLED

Processes are under control to create desired conditions in the building

## Three tiers of BAS capabilities - example

### CONTROLLED

- “Hardwire” connected to BAS for on/off and speed control, and general alarm

### INTEGRATED

- BACnet card is connected to BAS and advanced points (kWh, runtime, specific alarms)

### CONNECTED

- Advanced, custom alarms alert owner of unusual energy usage compared to trends, e.g.
- Predictive maintenance recommended based on analysis of data and historical performance

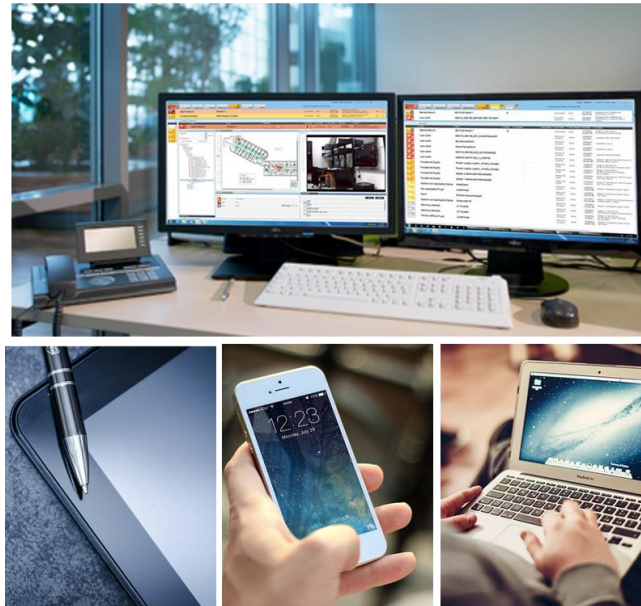


# BAS Basics – Yesterday to Tomorrow

Building Evolution

Technology Evolution

User Needs



# BAS Basics – Yesterday to Tomorrow

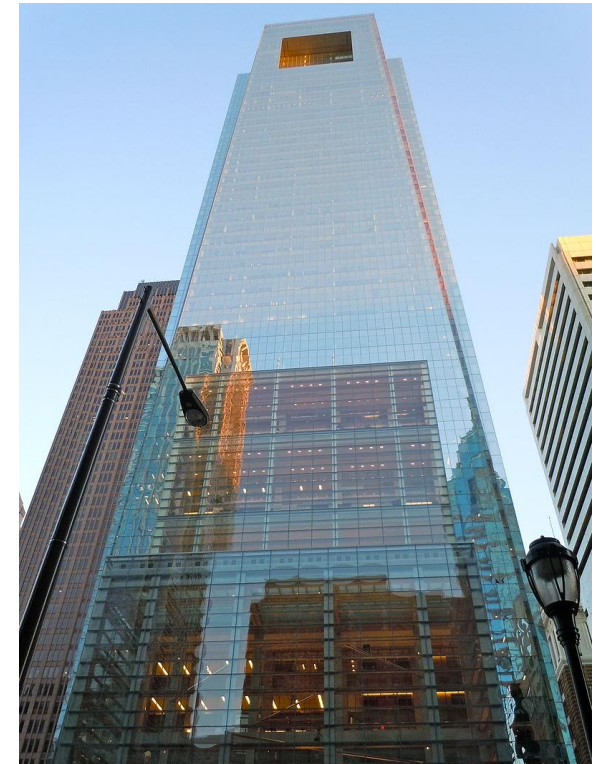
Building Evolution

Technology Evolution

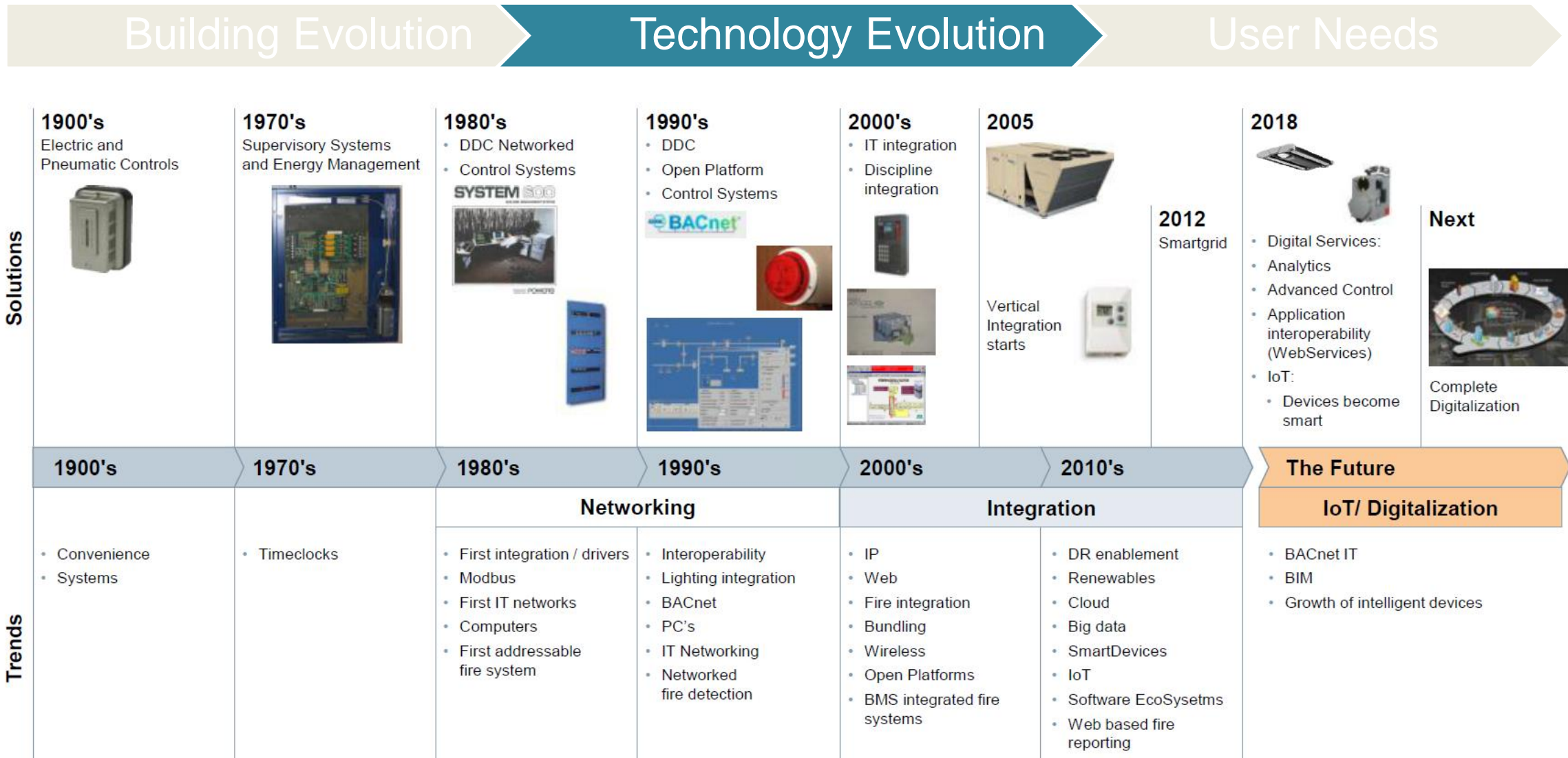
User Needs



- Net-Zero & Bioclimatic
- Offices to flexible workspace
- Bed Towers to Treatment Centers
- Classrooms to High Tech Learning
- Server Rooms to Data Centers



# BAS Basics – Yesterday to Tomorrow



# BAS Basics – Yesterday to Tomorrow

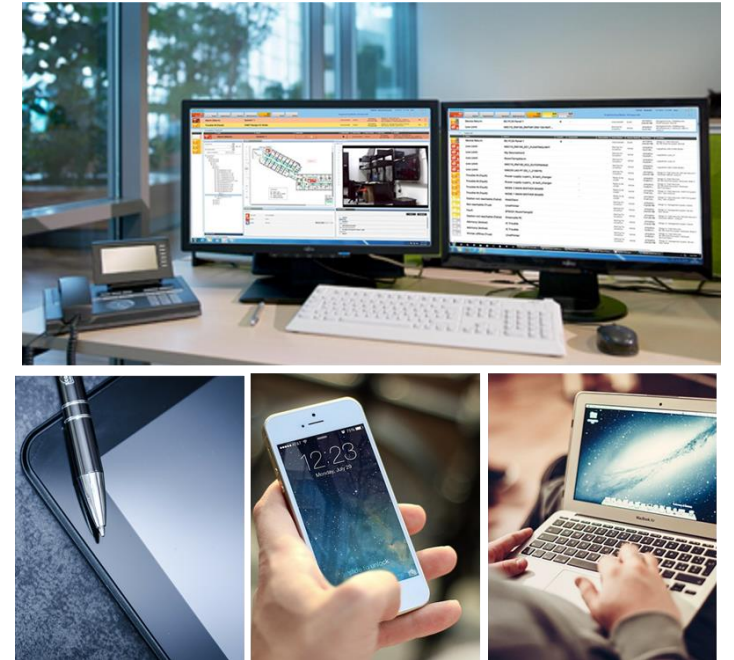
Building Evolution

Technology Evolution

User Needs



- Environmental Quality
- Precise Control
- Complex Energy Management
- Data Collection
- Flexible Data Media
- Mobile Data
- Paradigm Shift – IoT, Wireless, Big Data



The background features a perspective view of a tunnel formed by concentric rings of binary code (0s and 1s) that recede into the distance. At the center of this tunnel is a bright, glowing white sphere. Overlaid on the right side of the image is a solid teal circle with a white border. Inside this circle, the text "Control Fundamentals" is written in a clean, white, sans-serif font.

# Control Fundamentals

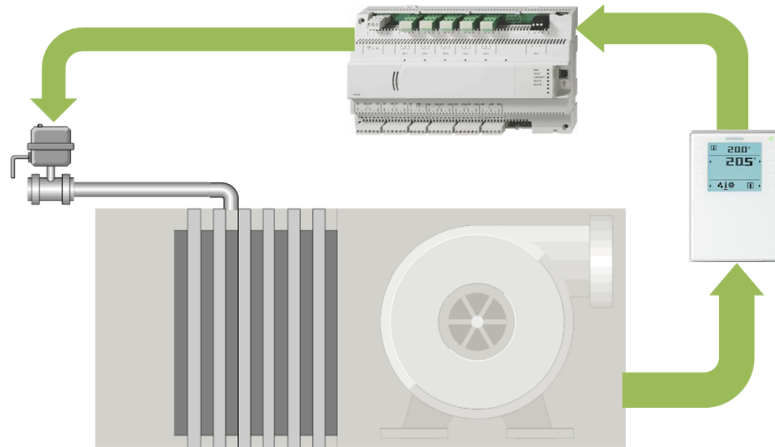
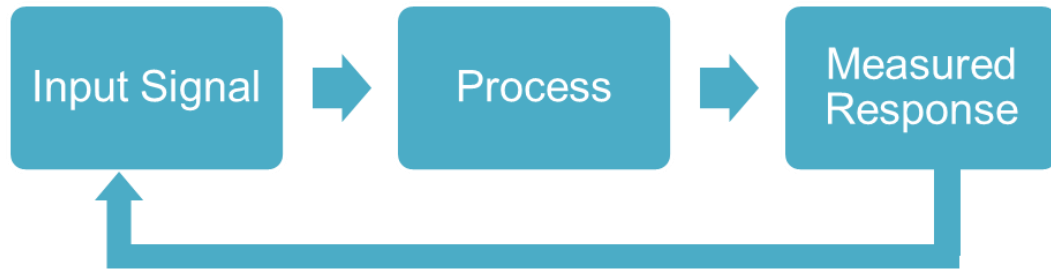
## Control Fundamentals – Basic Control Loop



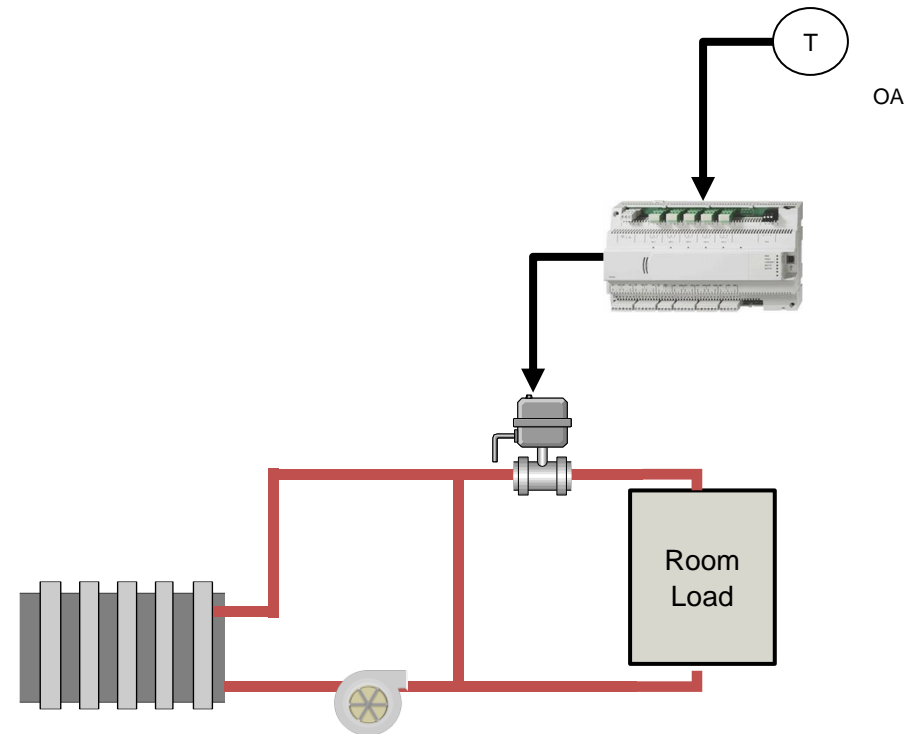
Basic Control Loop

# Control Fundamentals – Basic Control Loop

## Closed Loop



## Open Loop

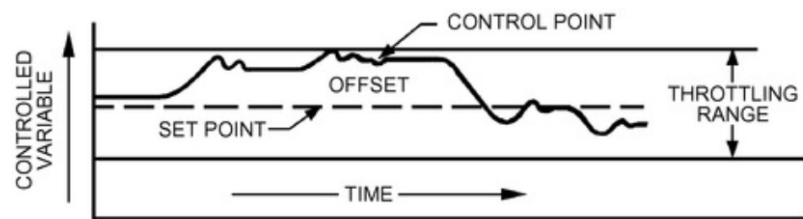


## Direct Digital Control (DDC) Control Loops – PID Loops Defined

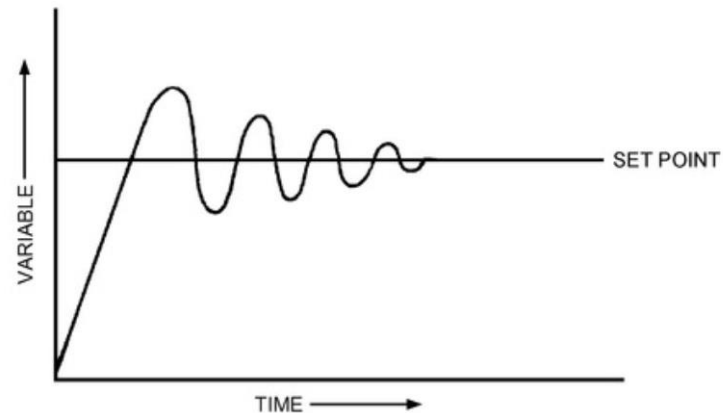
**P** Proportional control = variable output change in proportion to the varying input (direct or reverse)

**I** Integral add = measures offset over time and adjust until zero

**D** Derivative add = predictive element by measuring slope of response (*rarely used*)



Proportional Control



Proportional + Integral Control

### Results:

P Loop settles with an error from setpoint

PI Control variable offset close to setpoint, output maintained

PID Gets there faster

# Control Fundamentals – Typical Control Responses

Two – Position: Same as "digital"; switch; on-off; open/close

Proportional: Analog or variable output in proportion to varying input; direct or reverse acting; range converted to volts or amps (e.g. 0-100%, 0-10V, 2-10V, or 4-20mA)

Pulse Width Modulation (PWM): Form of analog, range is converted to time pulse (e.g. 50% open = 25ms pulse); monitors a timed closure of a set of contacts

Floating – Form of “analog”, range is converted to time, two outputs increase or decrease with a dead band between. Requires Slow actuator/Fast responding sensor

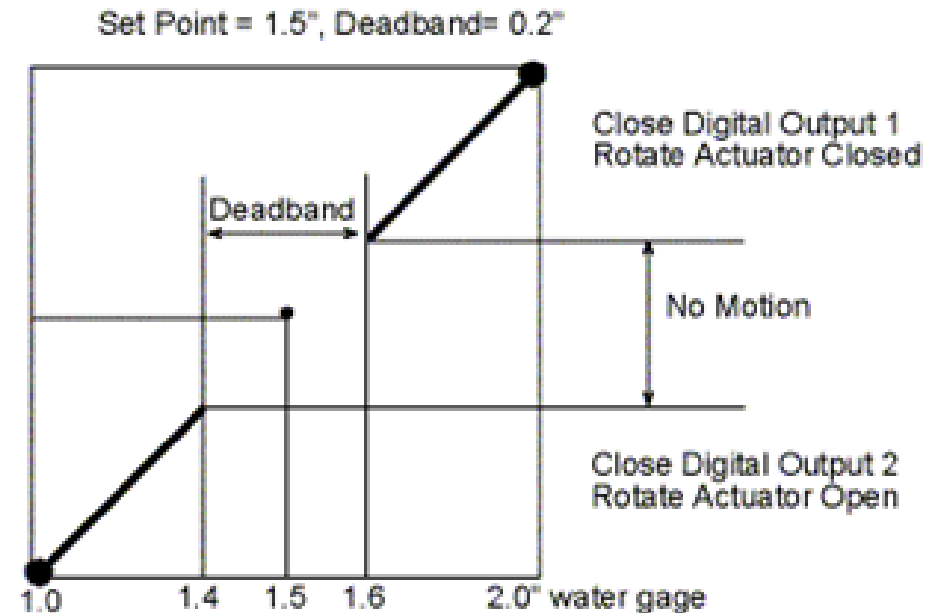
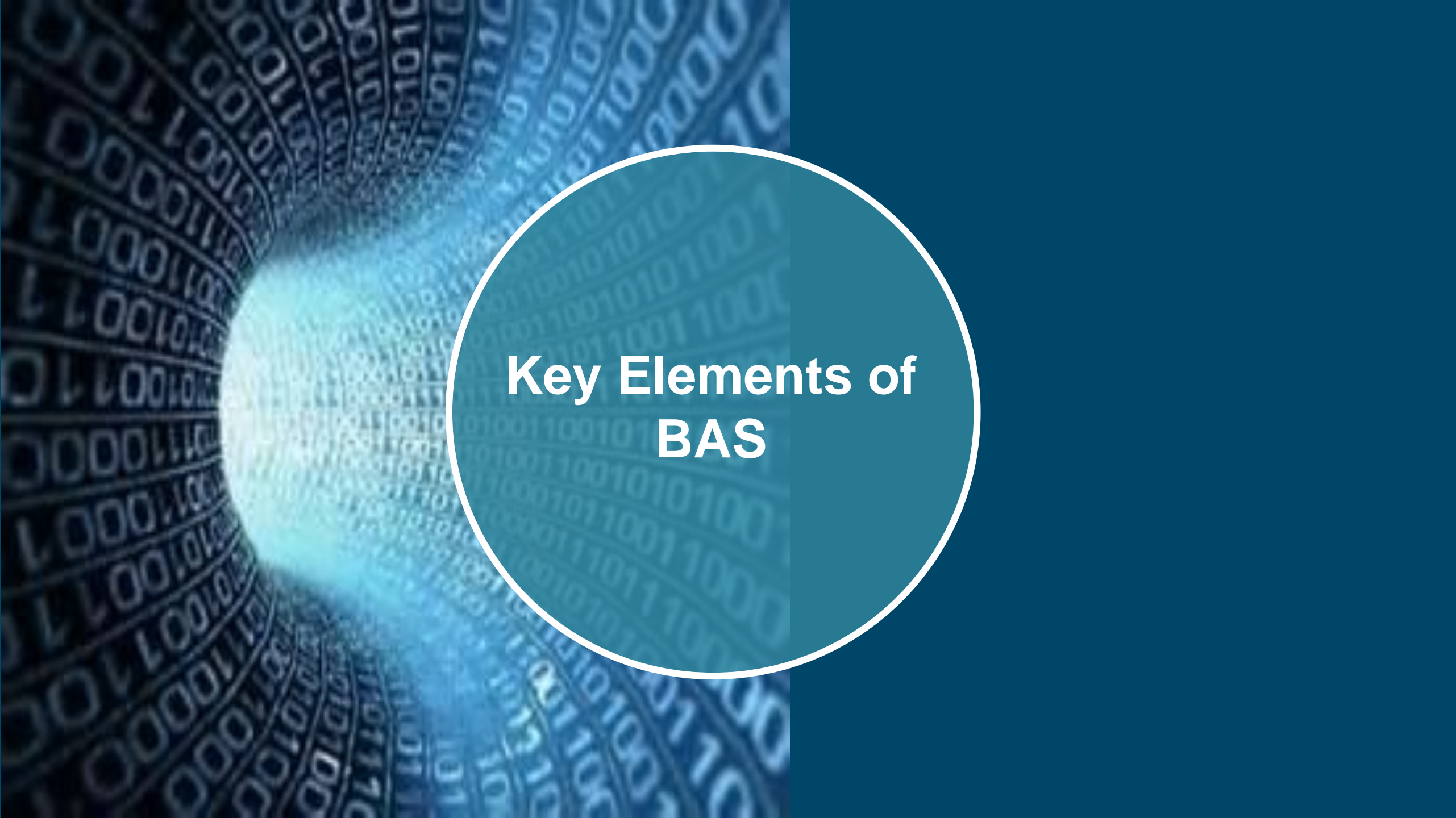


Image credit DDC-Online



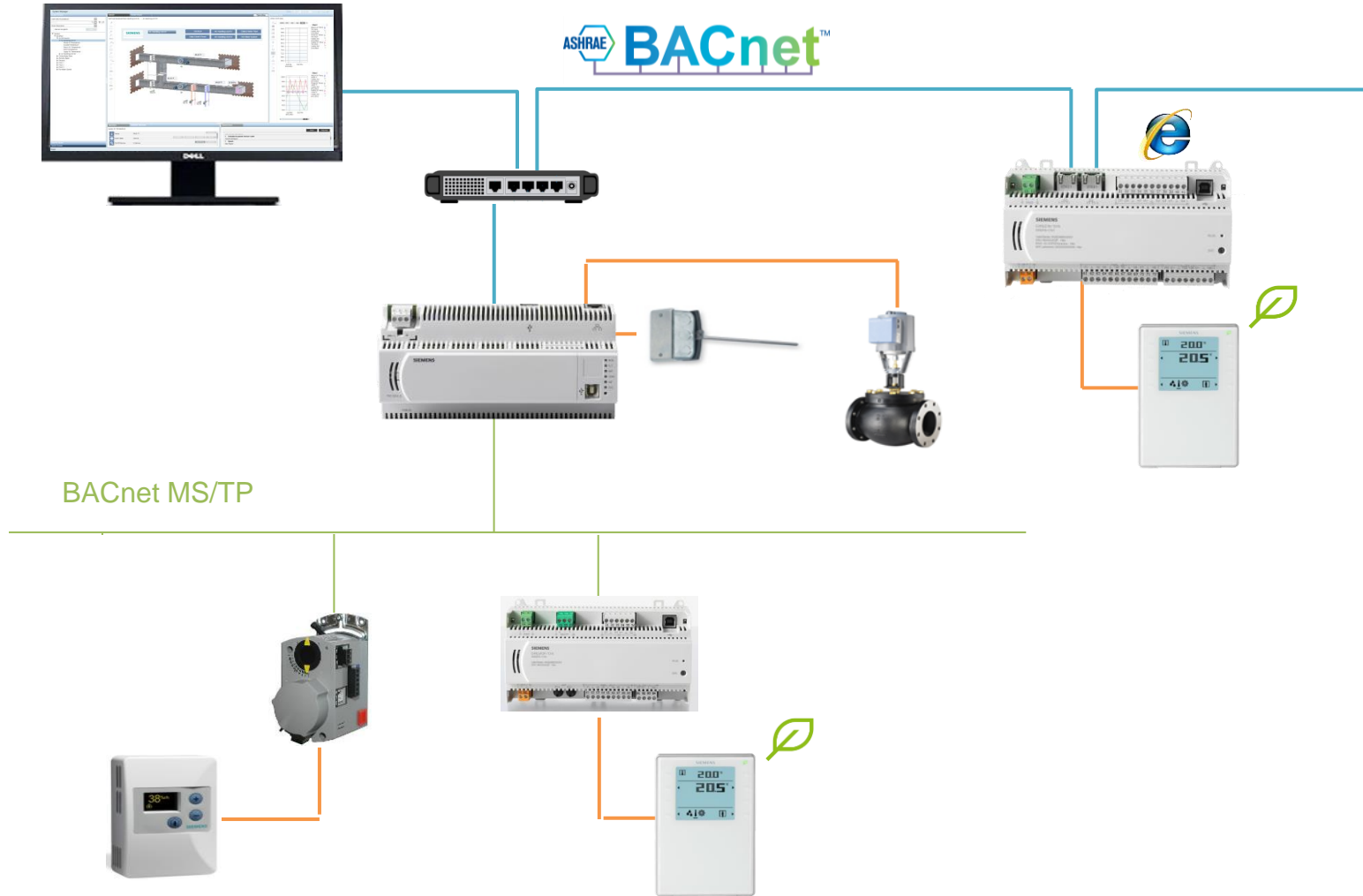
**Key Elements of  
BAS**

# BAS Key Elements

Management Level

Automation Level

Field Level



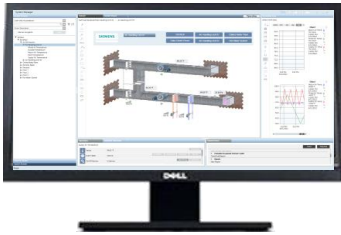
Communication Network

BAS Hardware

Field Devices

# BAS Key Elements – Field Devices

Management Level



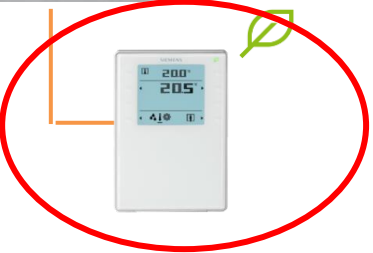
ASHRAE BACnet™



Automation Level

BACnet MS/TP

Field Level



Field Devices  
Or  
Control Components

# Field Devices DDC Points (Hardwired) – Data Type and Data Flow

Analog Input (AI)



Variable information such as temperature, humidity, pressure, flow, power

Digital Input (DI)



Two state information generally indicating status such as safeties, on/off

Analog Output(AO)



Modulating control, such as dampers, valves, VFDs

Digital Output (DO)



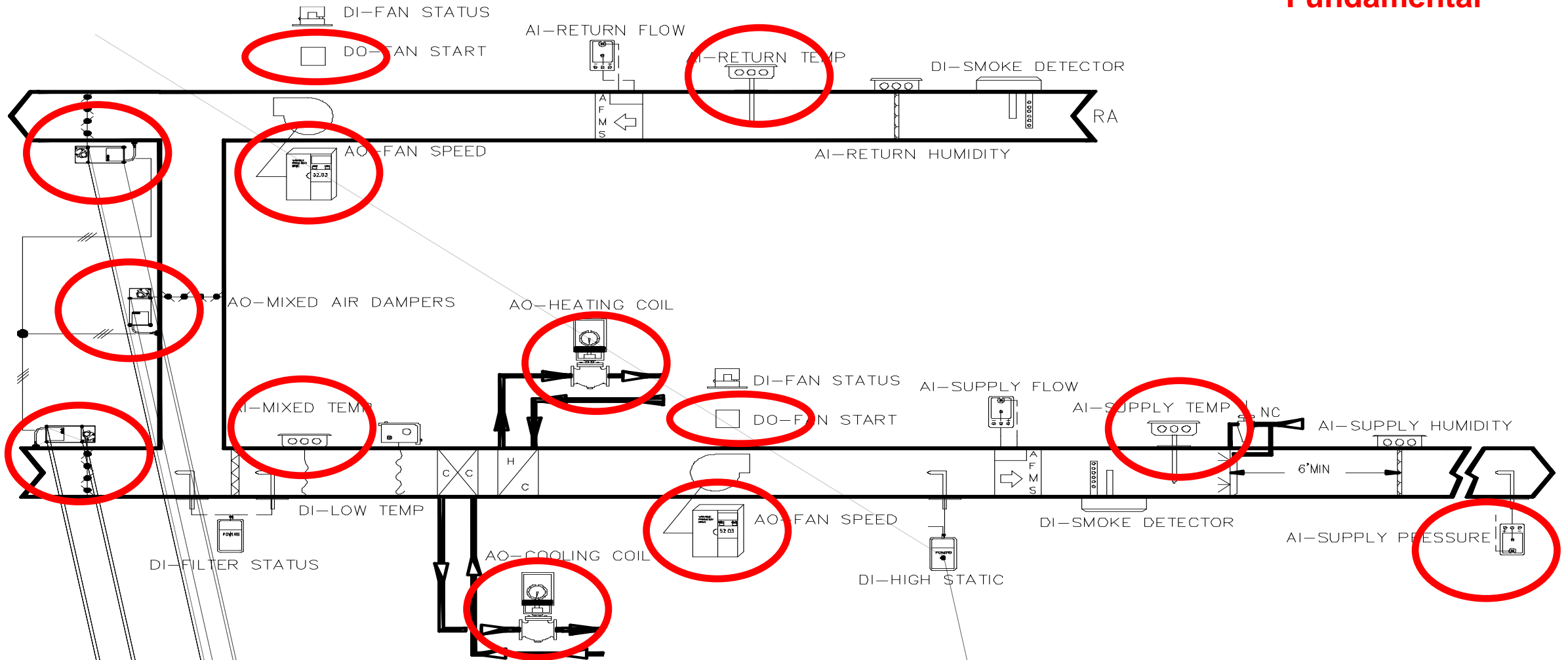
Two state control changing/maintaining status such as on/off, open/close

Inputs and Outputs are relative to the controller

\*Digital Points are also referred as “Binary” and sometimes used interchangeably.

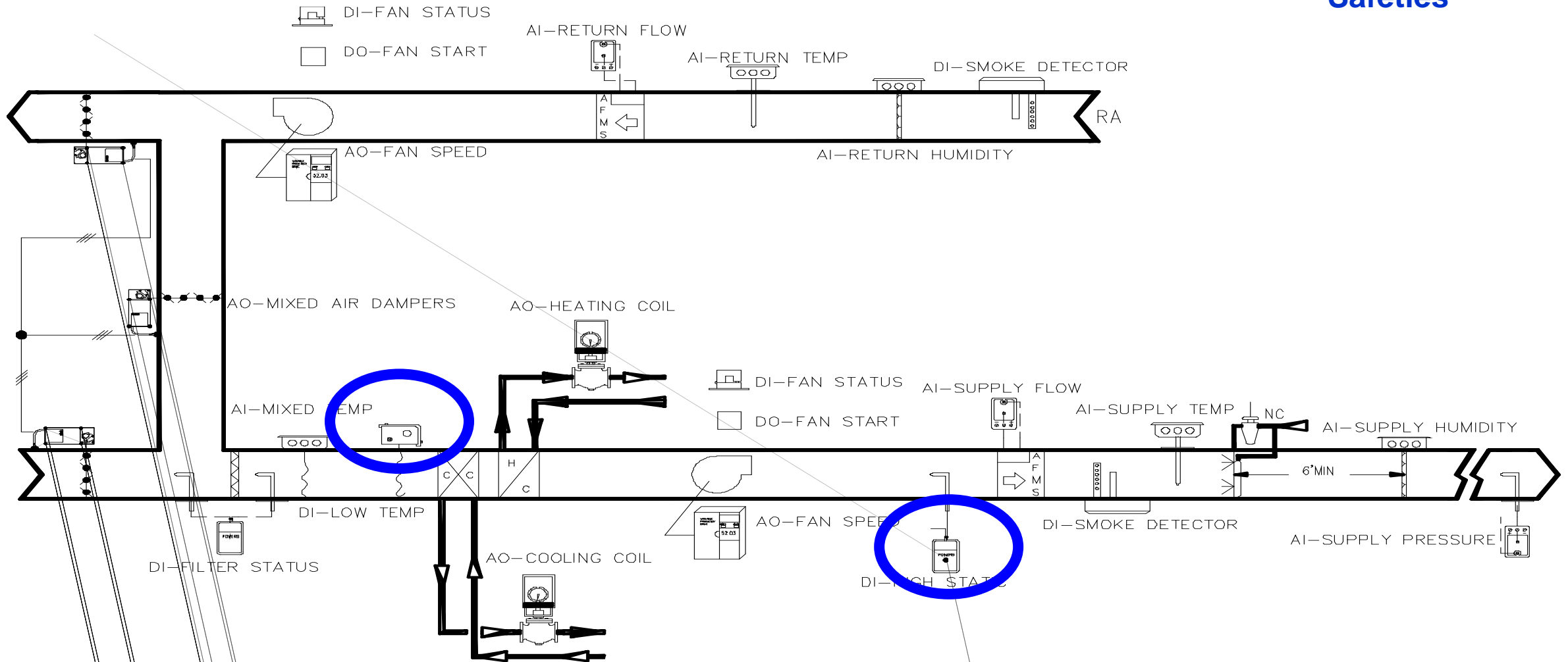
# Instrumentation Drawings

Fundamental

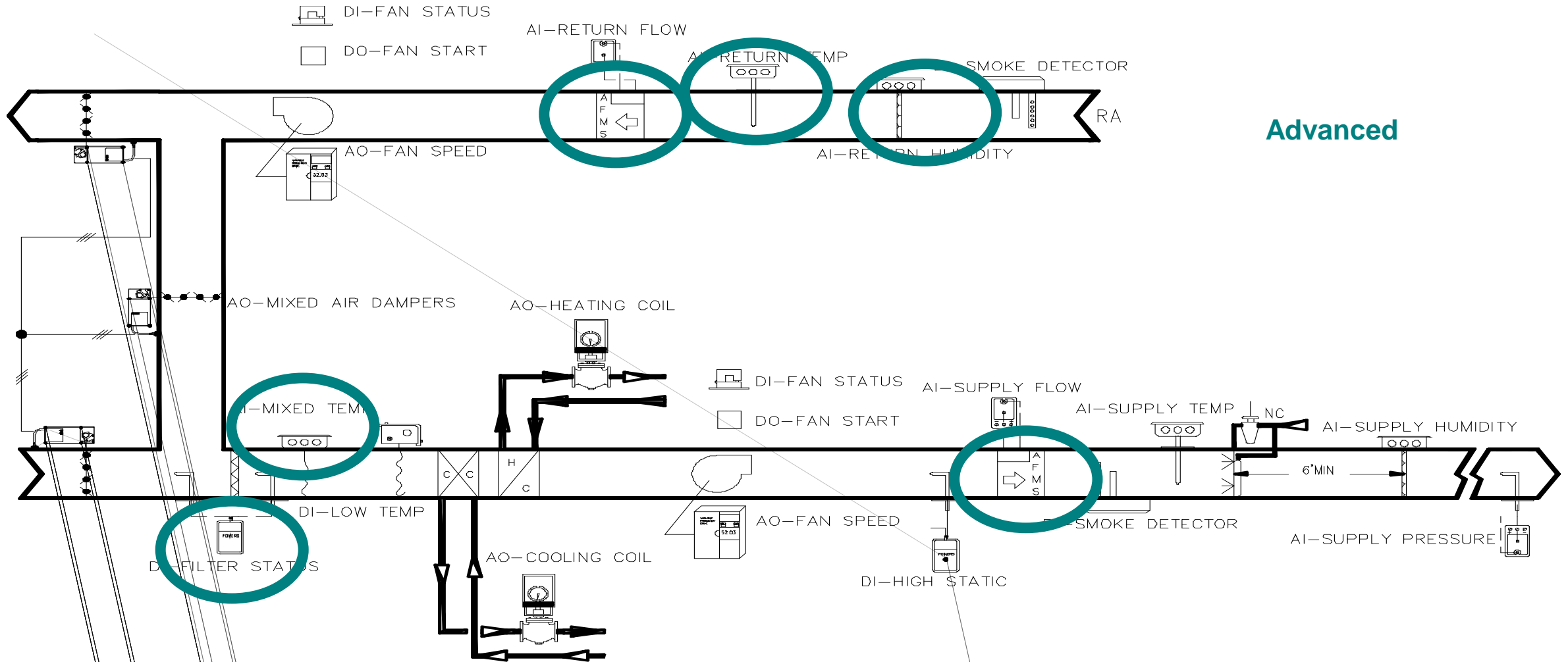


# Instrumentation Drawings

## Safeties



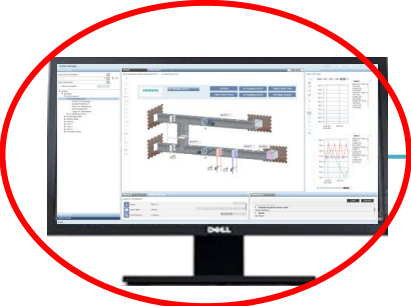
# Instrumentation Drawings



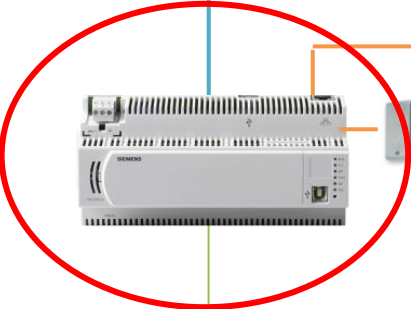
Advanced

# BAS Key Elements – DDC Hardware

Management Level



ASHRAE BACnet™



Sensor



Control Valve



Rom Unit



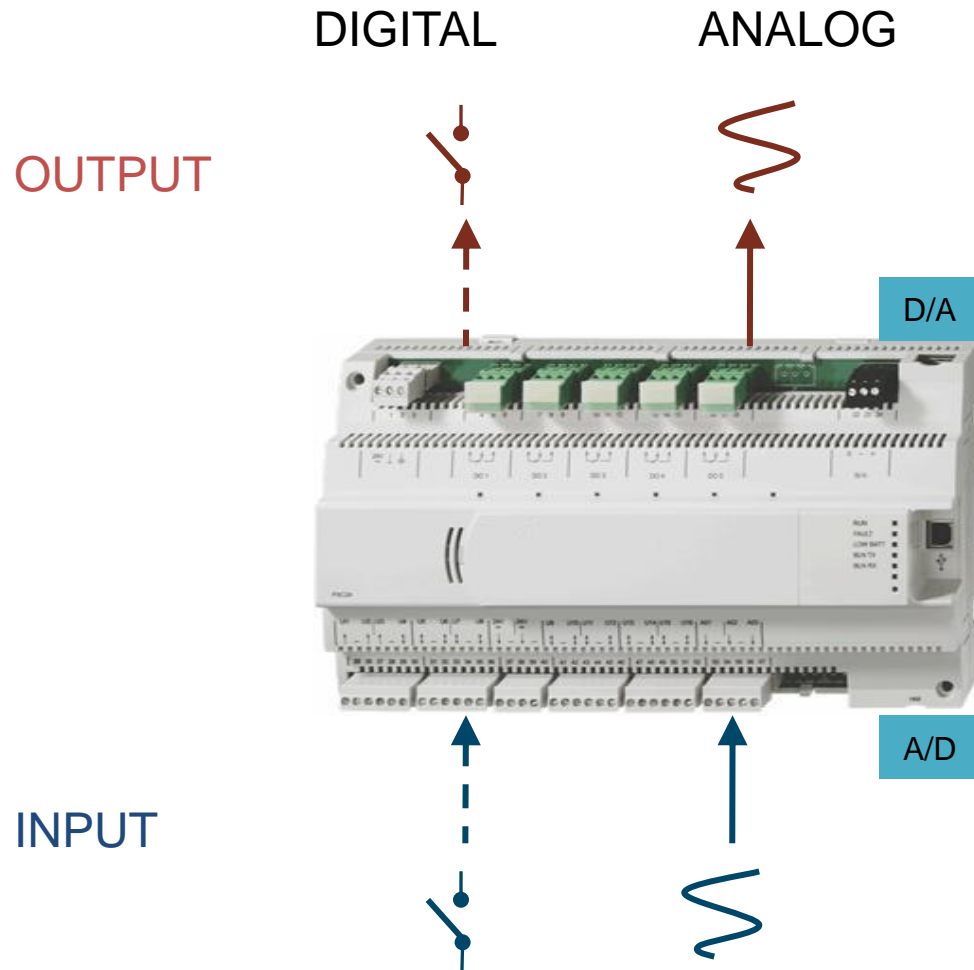
Automation Level

BACnet MS/TP

Field Level



# DDC Controller Basics – Points (Type, Flow, Source)



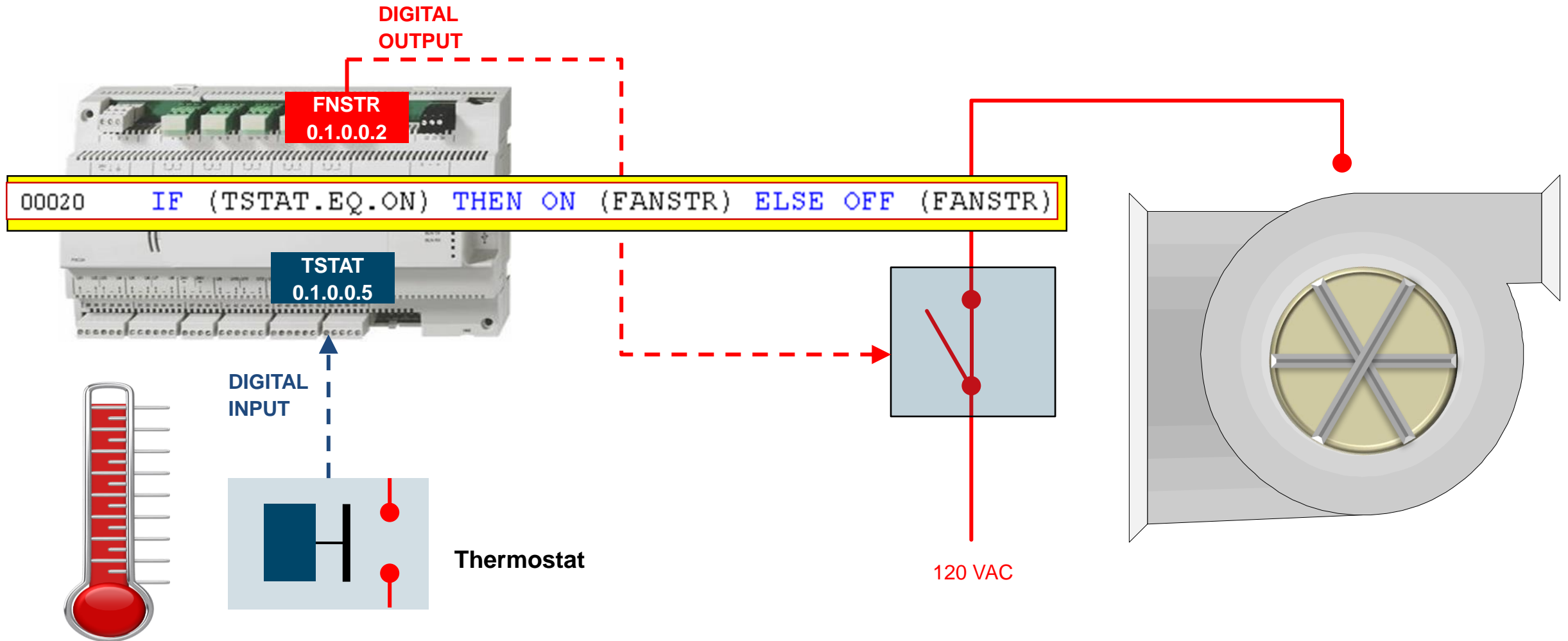
- POINT = Digital Representation of Signal
- Data Type: digital, analog, or accumulating
- Data Flow: input or output of component
- Data Source: External (hardwired), Internal (virtual/software)
- Source: Real (Hardwired) or Virtual (Software)
- Real: DI, DO, AI, AO
- Virtual: DV, AV

**FANSTR**  
**0.1.0.0.2**

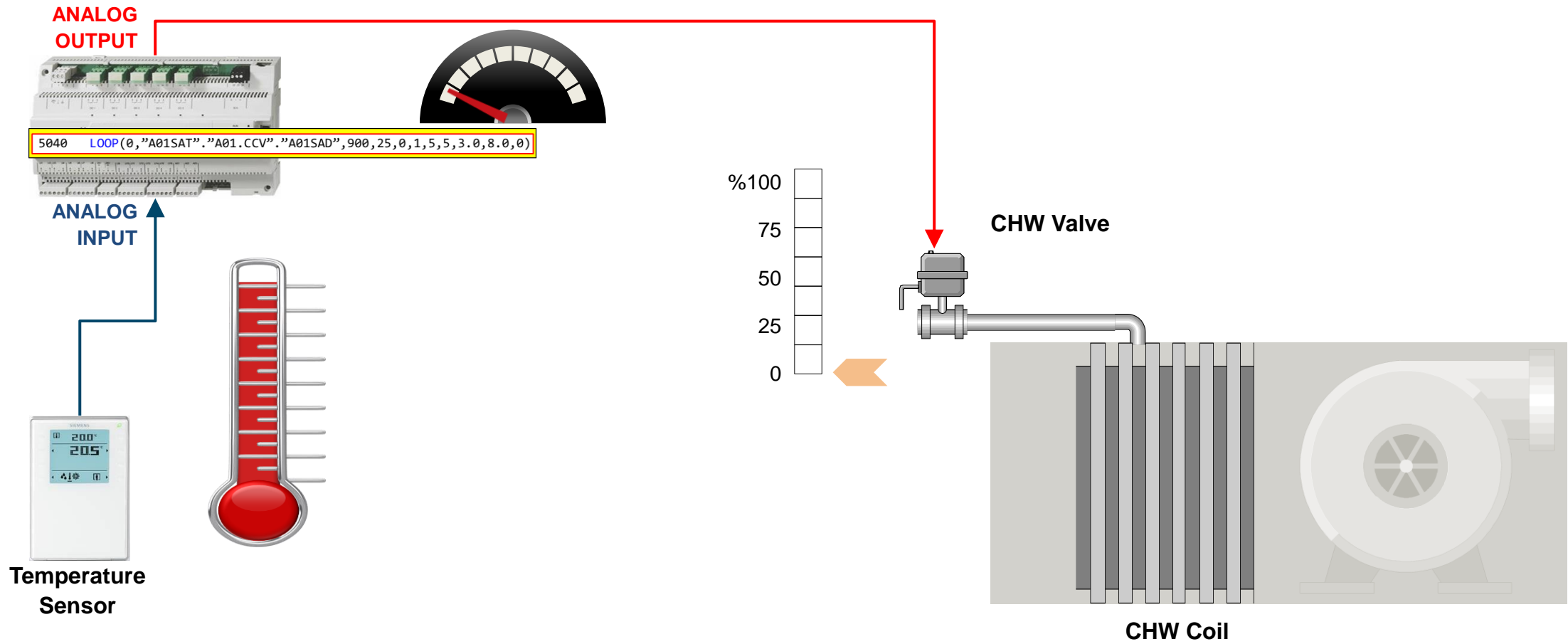
Point Name  
Point Address



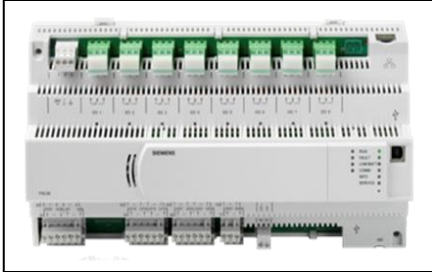
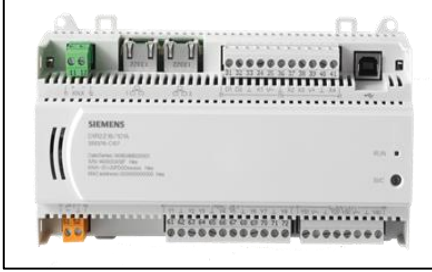

# DDC Controller Basics - Digital Points Data Flow



# DDC Controller Basics - Analog Points Data Flow



# DDC Controller Basics – General Controller Types and Functions

Controller Type	Typical Functions	Typical Applications
<p>Building Controller</p> 	<ul style="list-style-type: none"> <li>• Completely Stand-alone</li> <li>• Global Commanding</li> <li>• Network Management</li> <li>• Device Management</li> <li>• Custom Programming</li> <li>• Data sharing</li> <li>• Trending and Scheduling</li> <li>• Alarm Management</li> <li>• Event Management</li> <li>• Inputs/Outputs (opt)</li> <li>• Protocol Gateway</li> </ul>	<ul style="list-style-type: none"> <li>• Central Plants</li> <li>• Air Handling Units</li> <li>• Complex Room Control</li> <li>• Network Controller</li> </ul>
<p>Custom Application Controller</p> 	<ul style="list-style-type: none"> <li>• Stand-alone to perform its application (database)</li> <li>• Built in programs/applications</li> <li>• Custom programming</li> <li>• May have some level of scheduling</li> <li>• May have some level of trending</li> </ul>	<ul style="list-style-type: none"> <li>• Air Handling Units</li> <li>• Heating/Cooling Eqpt</li> <li>• Integrated Room Control</li> <li>• Complex Room Control</li> </ul>
<p>Application Specific Controller</p> 	<ul style="list-style-type: none"> <li>• Stand-alone to perform its application (database)</li> <li>• Built in program</li> <li>• Configurable</li> <li>• May have some level of scheduling/trending but relies primarily on higher level</li> </ul>	<ul style="list-style-type: none"> <li>• VAV boxes</li> <li>• Fan Coil Units</li> <li>• Heat Pumps</li> <li>• Unit Ventilators</li> <li>• Unit Conditioners</li> </ul>

# BAS Key Elements - Workstation



Graphics

Data Exchange

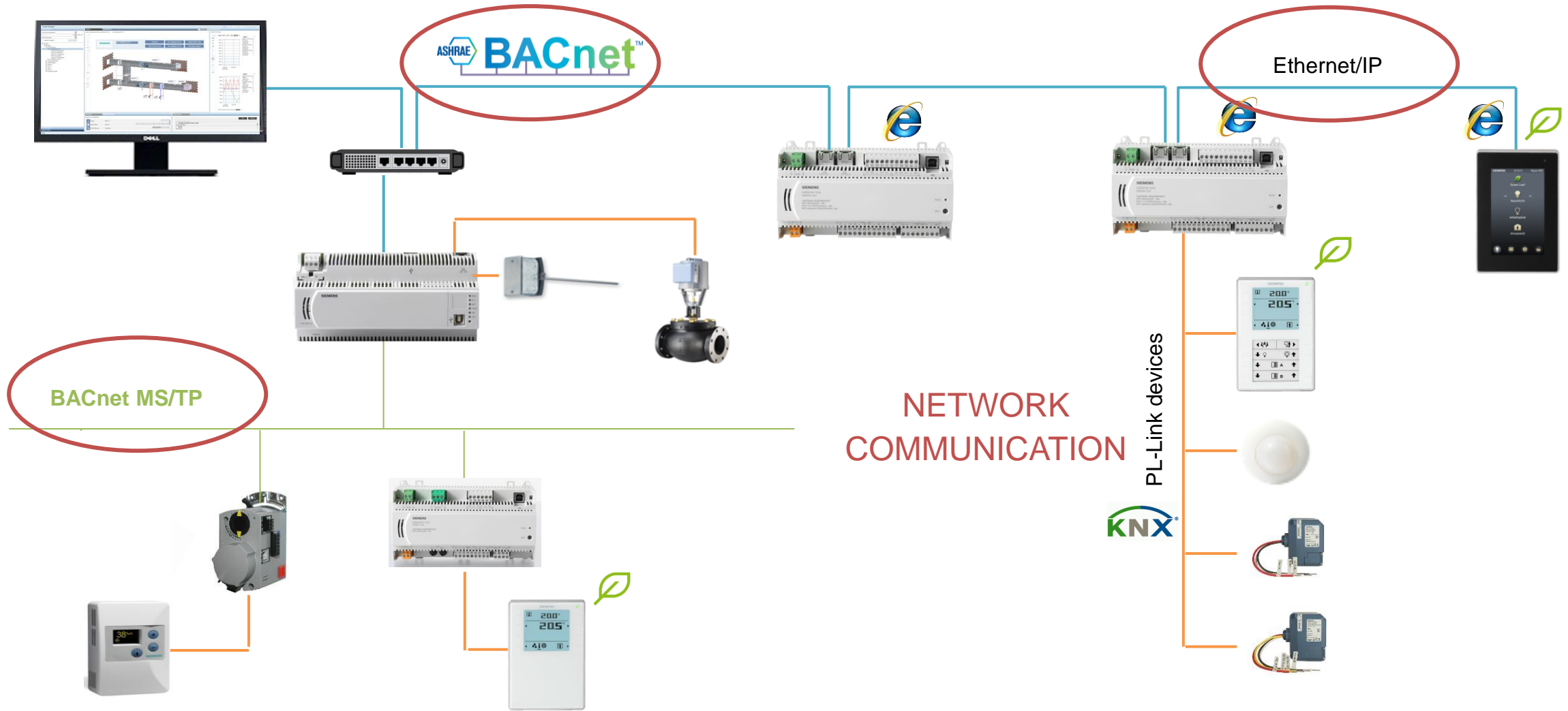
Scheduling

Trend setup and storage

Alarms setup and history

Reports setup and storage

# BAS Key Elements – Network Communication



# Network Communication - Protocols

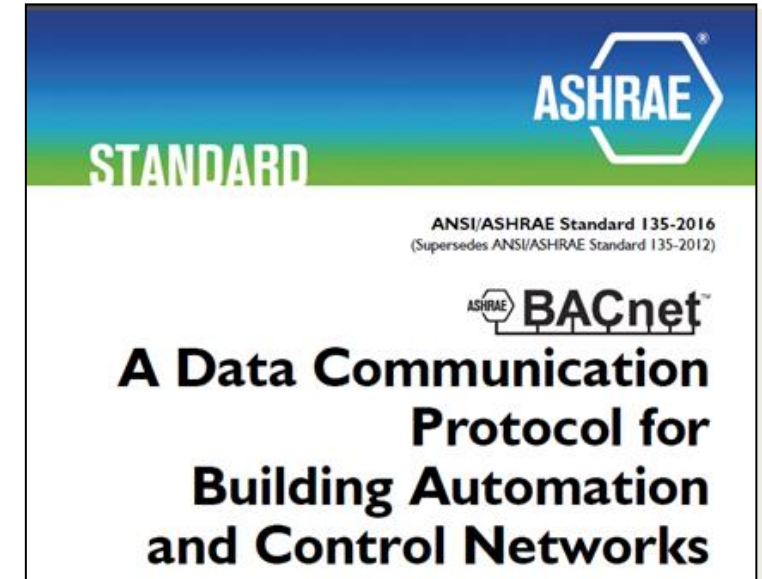
- Protocol – Set of rules to follow to exchange data; agreed upon format to send and receive messages between computing devices – Standard, Public , Private

- Standard – Published and controlled by a standards body (e.g. BACnet, html, xml)

- Public – Published and controlled by a private organization. Can be used by anyone freely or via license (e.g. LON, Modbus)

- Private or Proprietary – Unpublished and developed/controlled by a private organization

→ Open

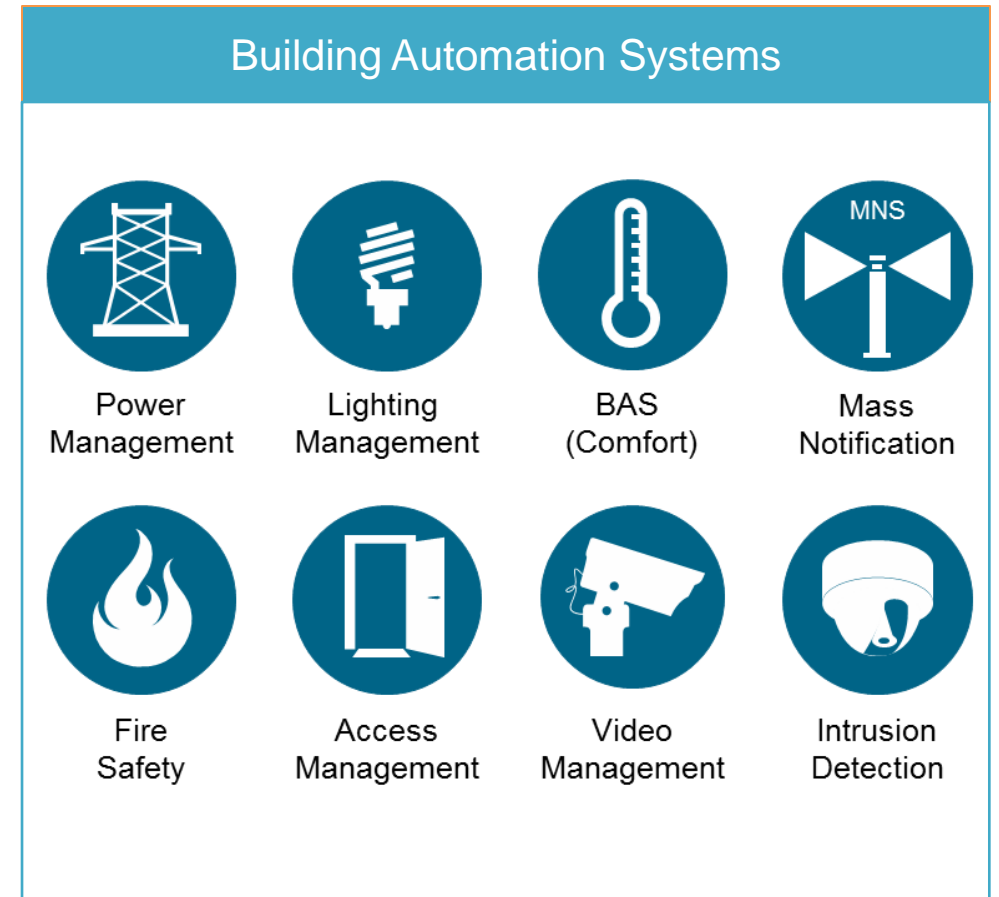


# Network Communication - BACnet

BACnet - A standard protocol published by a standards organization (American Society of Heating, Refrigerating and Air-conditioning Engineers or ASHRAE). It is a specification that defines what is required to conform to the protocol.

**B**uilding  
**A**utomation and  
**C**ontrol  
**n**etworks

Designed to provide communication and **interoperability** between **building** automation devices and applications



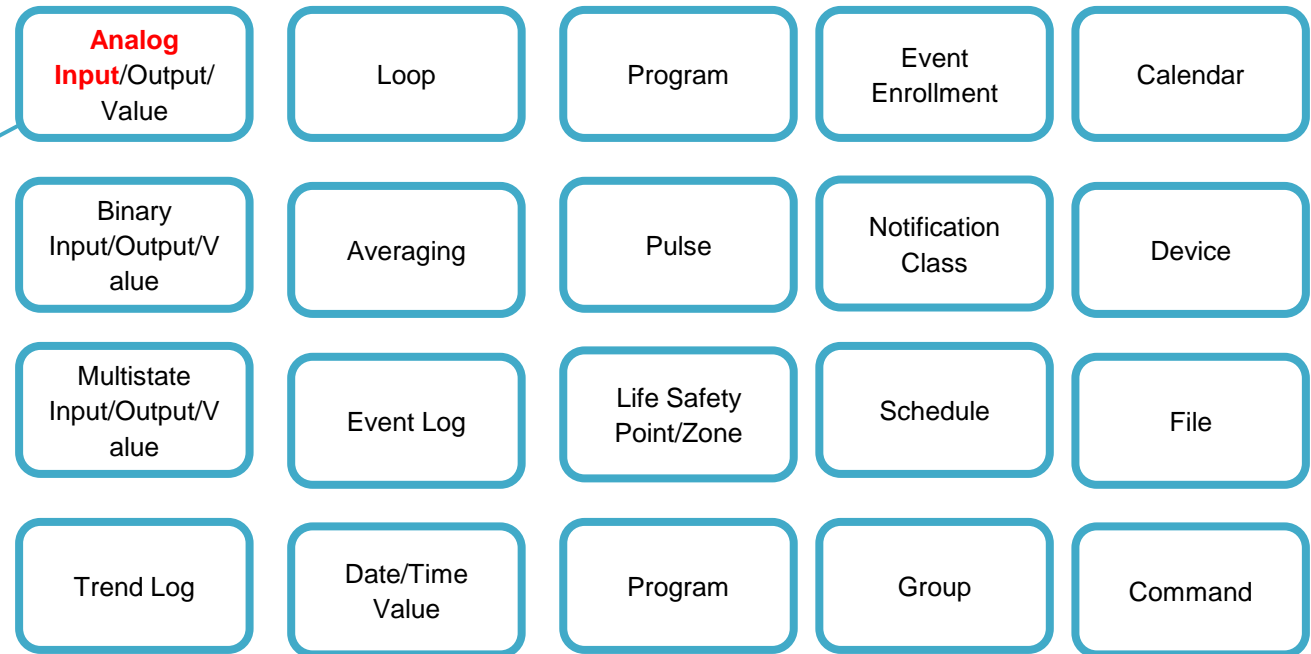
# Network Communication - BACnet

Objects: Represent information  
 Services: Requests and interoperation  
 Network Types: Transport systems

Analog Input Properties

Required	Object_Identifier	43
	Object_Name	SpaceTemp
	Object_Type	Analog-input
	Present_Value	72.3
	Status_Flags	Normal, InService
Optional	High_Limit	78.0
	Low Limit	62.0

## BACnet Standard Objects Sampling (60 total – 2016)



# BACnet Transport Protocols – Data Link/Physical Layers

Most Frequent Among BACnet Vendors

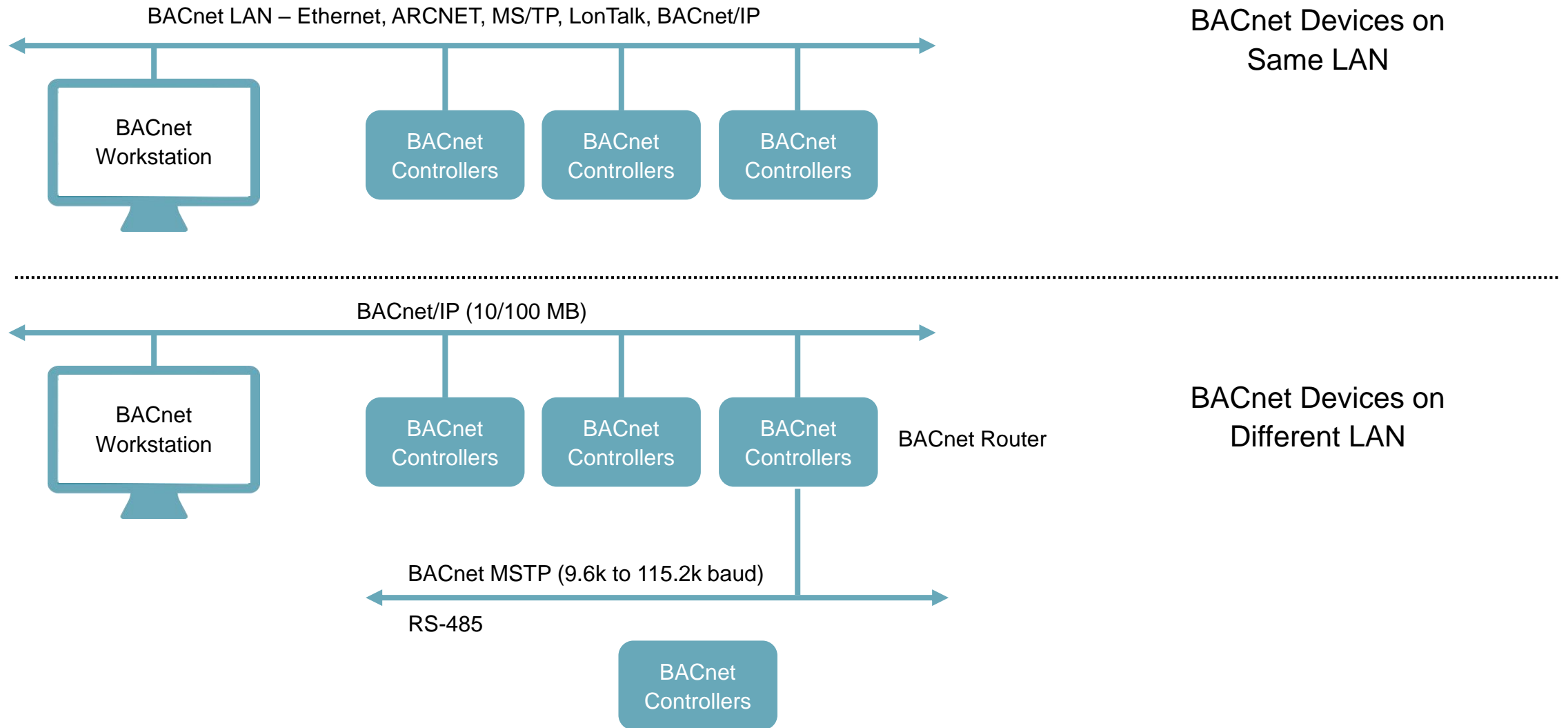
- BACnet Ethernet
- BACnet/IP
- MS/TP
- PTP
- LonTalk
- ARCnet

\*Zigbee

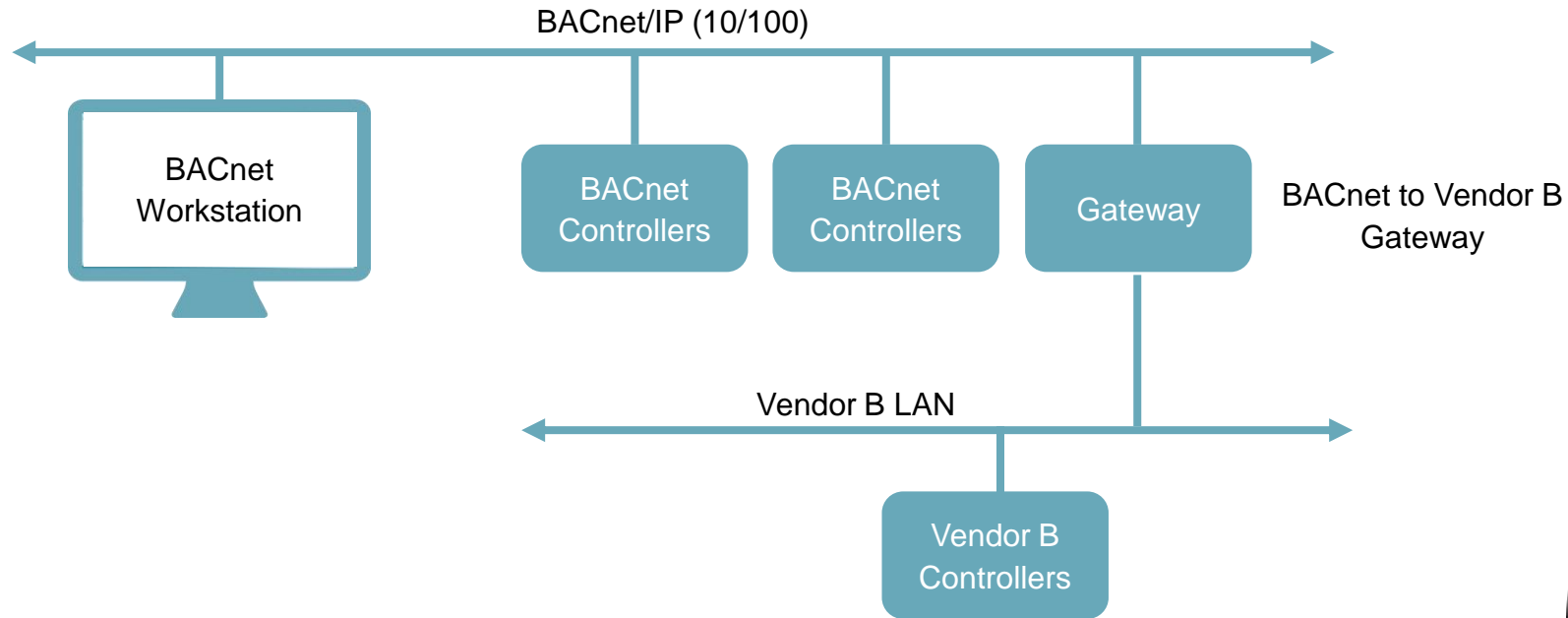
\***BACnet Secure Connect - New**

Protocol	Pros	Cons
Ethernet	<ul style="list-style-type: none"> <li>• Very Fast</li> <li>• Existing IP network</li> <li>• IT Familiarity</li> </ul>	<ul style="list-style-type: none"> <li>• IP routers block</li> </ul>
BACnet/IP	<ul style="list-style-type: none"> <li>• Very Fast</li> <li>• Existing IP network</li> <li>• Preferred for BACnet</li> </ul>	<ul style="list-style-type: none"> <li>• Broadcast messaging setup</li> </ul>
MS/TP	<ul style="list-style-type: none"> <li>• Low cost</li> <li>• Easy/familiar installation</li> <li>• Popular on lower tier</li> </ul>	<ul style="list-style-type: none"> <li>• Slower speed</li> </ul>

# Basic BACnet Networking



# Basic BACnet Networking



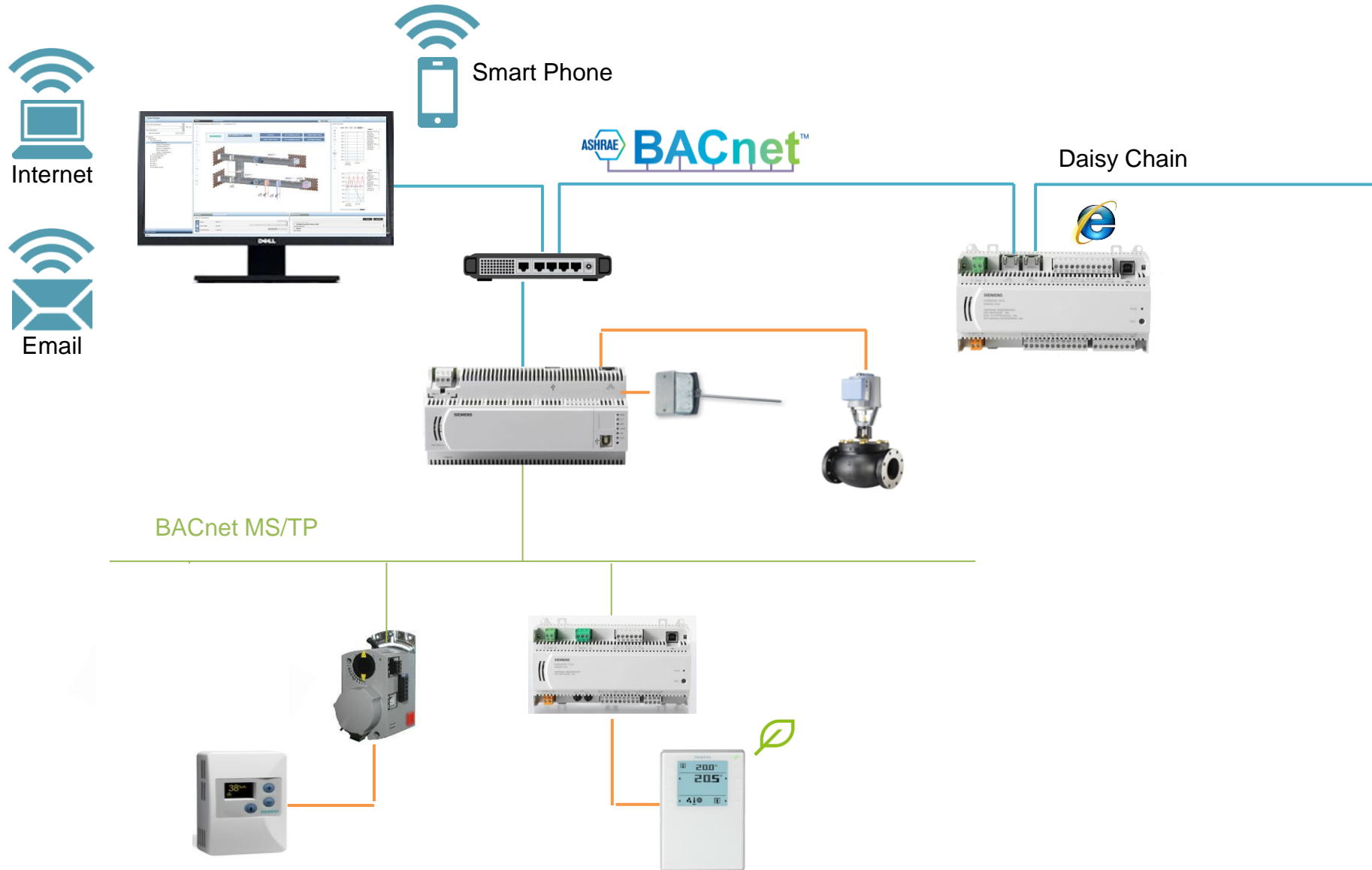
BACnet to Non-BACnet Devices  
(e.g. Modbus, BAS Legacy)



BTL Listing ensures products have been successful tested by the BTL

*\*ASHRAE does not test for compliance*

# Other Communication Protocols



The image features a perspective view of a tunnel formed by concentric rings of binary code (0s and 1s) that recede into the distance. At the center of the tunnel is a bright, glowing white sphere. Overlaid on the right side of the image is a solid teal circle with a thin white border. Inside this circle, the word "Trends" is written in a clean, white, sans-serif font.

Trends

# Key Trends Affecting Building Systems Next Evolution

## Smart Buildings and Internet of Things (IoT)

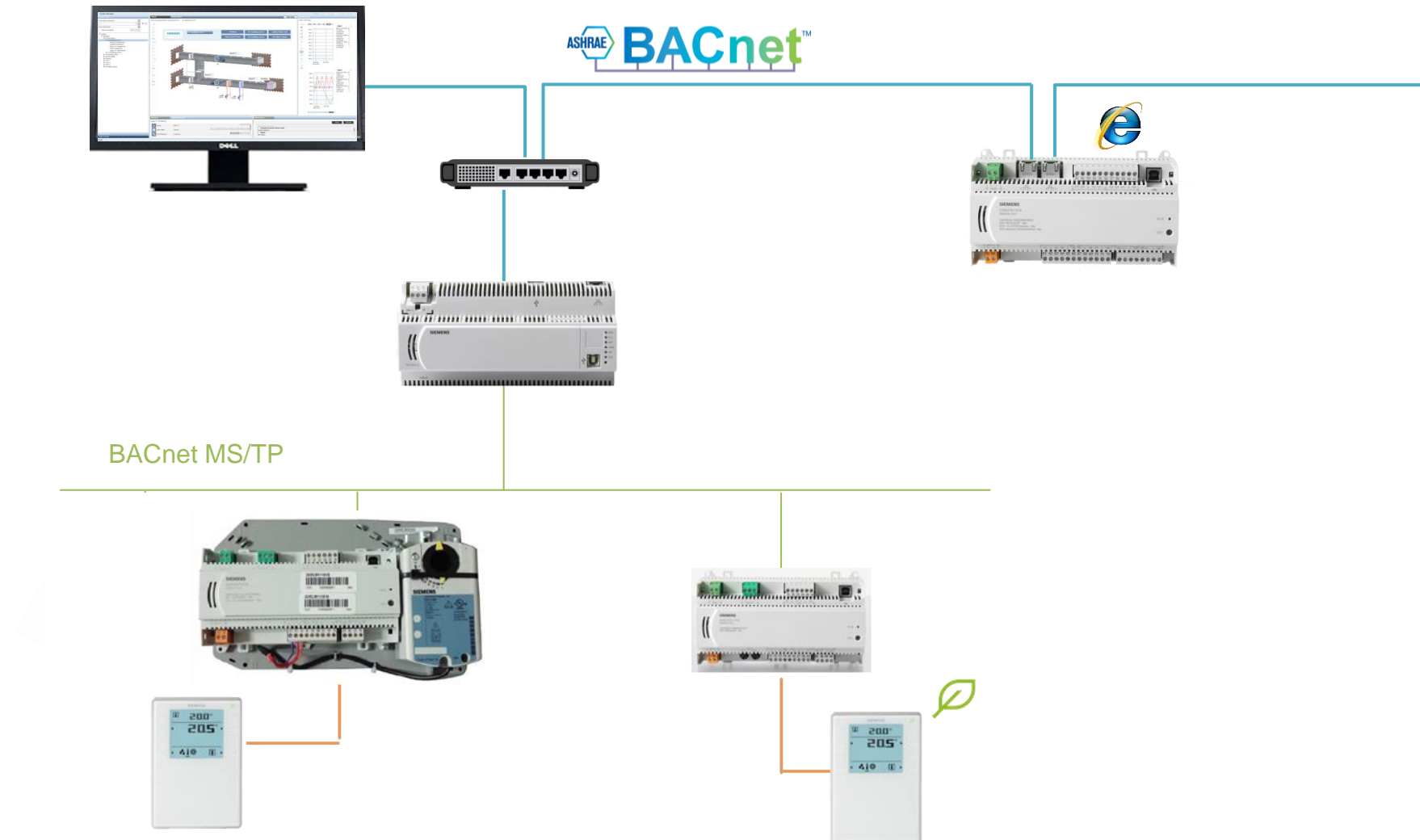
- The global smart building market is expected to grow from \$72.6B (2021) to \$121.6B by 2026\*
- The internet and emerging tech are enabling this growth
- Increasing use of Division 25 specifications – more holistic view of integrated systems from conceptual phase through the final build.
- HVAC, lighting, security, life safety, and almost any conceivable building system have tapped into IoT and API integrations to the BAS
- Improve building life cycle performance, lower life cycle costs, deliver higher occupant satisfaction

## Big Data and Cloud Computing

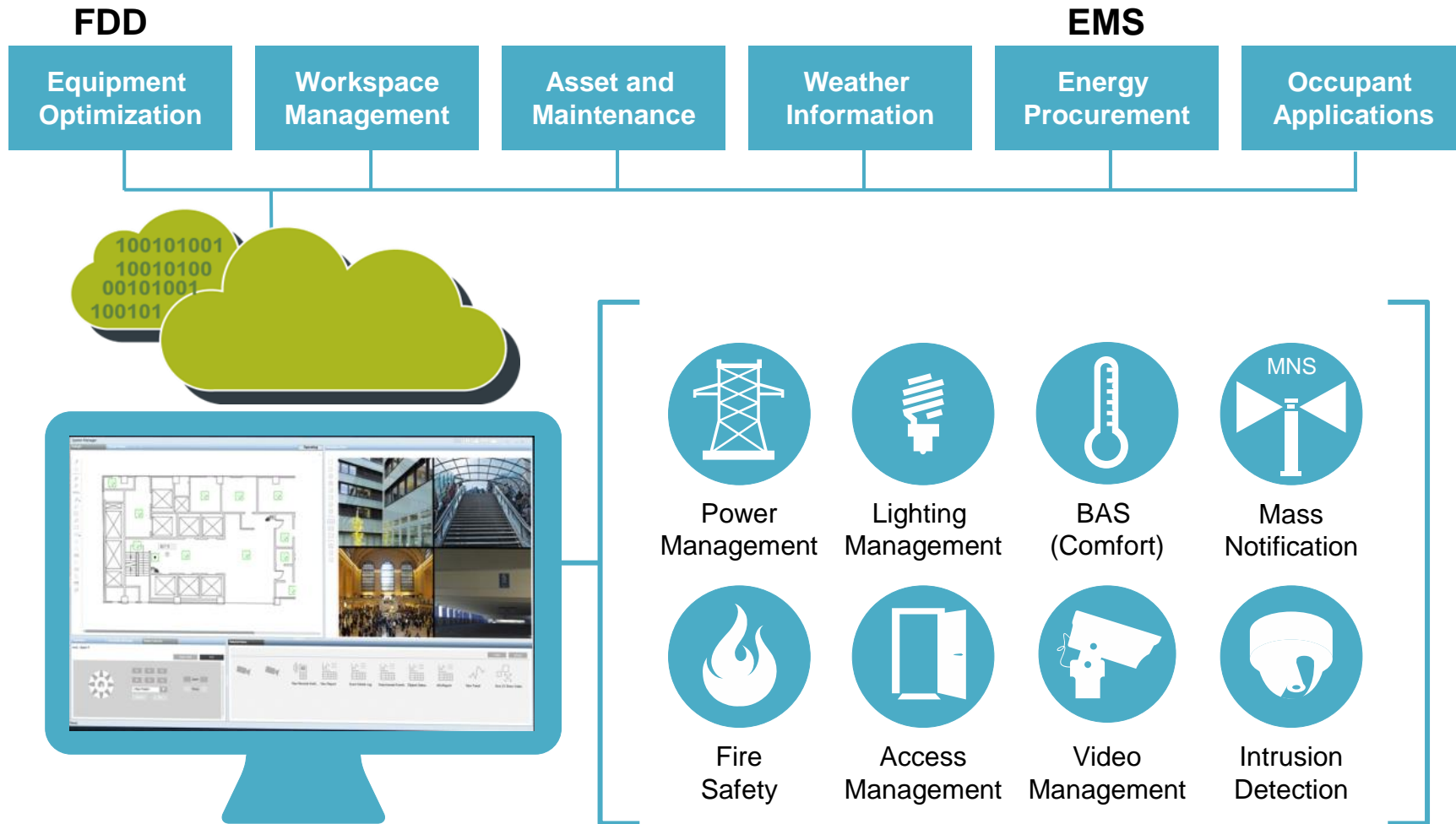
- Unprecedented volume and detail of data – collect, transmit and analyze
- Data collection – intelligent field devices and systems
- Data transmission – frequently cloud based services
- Data analytics - a true analytic platform that can analyze data and monitor system performance

*\*MarketandMarkets global research and consulting firm*

# Architecture

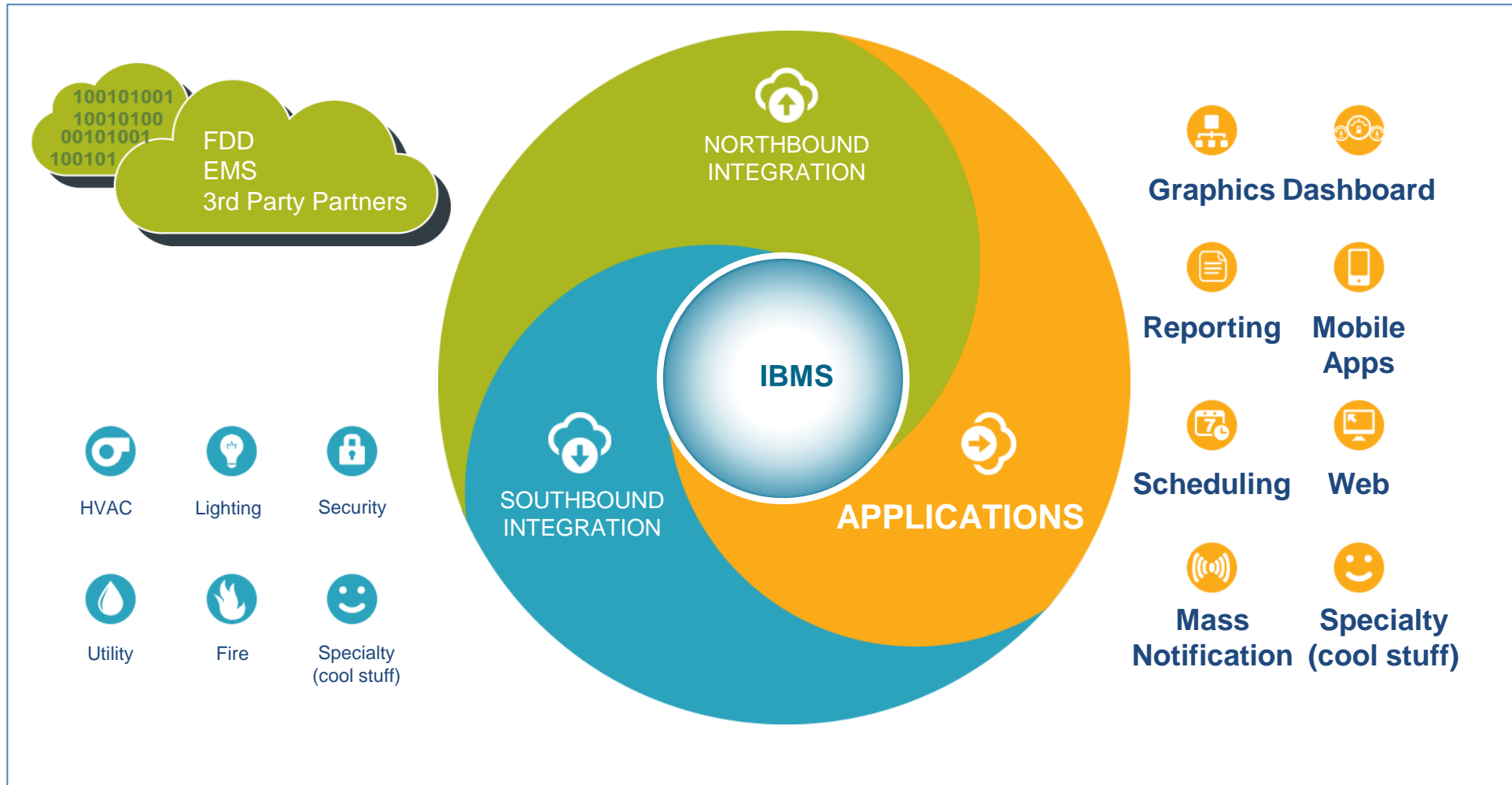


# Enterprise Level



Integrated Building Management System (IBMS)

# Integrated Building Management System – IBMS



The image features a perspective view of a tunnel formed by rows of binary code (0s and 1s) that recede into the distance, creating a sense of depth. The code is rendered in a light blue/teal color against a darker background. In the center of the image, there is a large, solid teal circle with a thin white border. Inside this circle, the text "Wrap-up" is written in a clean, white, sans-serif font.

**Wrap-up**

## BAS Basics – Key Take-Aways

- Building Use, Technology and Occupants drive BAS Technology
- Devices become BAS points
- Control loop = Input + Processor + Output
- BACnet is the communication link ... ***BACnet Secure Connect (BACnet/SC)***

## Trends Summary

- Customers demanding more data for more users – Network Speed/Third party Apps
- Staffing issues driving FDD (Fault Detection Diagnostics)
- Smart Buildings driving Room and Level System Integration
- Cloud based services – Enterprise Level Applications

# BAS Basics

## Resources:

- ASHRAE Handbook:
  - Fundamentals
    - Chapter 7: Fundamentals of Control
  - HVAC Applications
    - Chapter 40: Computer Applications (BAS architecture, Networking, communications)
    - Chapter 42: Supervisory Control Strategies and Optimization (CPOP)
    - Chapter 47: Design and Application of Controls
- ASHRAE Guideline 13-2015: Specifying Direct Digital Control Systems
- Frank Shadpour, P.E. – The Fundamentals of HVAC Direct Digital Control (Practical Applications and Design)
- [www.DDC-Online.org](http://www.DDC-Online.org)

# Questions

# Thank you for attending!



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