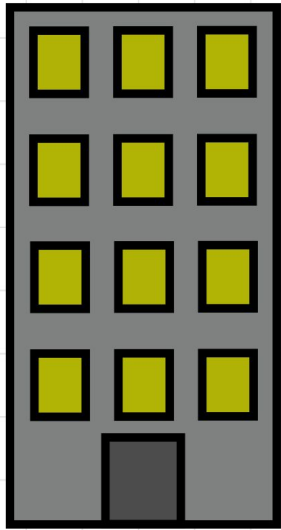# BACnet & Lighting in 2023

Challenges in 1998 when developing a native BACnet networked lighting control system:

- Blink Warn
- Fade or Step to Level
- Group or Zone Actions
- Automatic Timeouts (CA - Title 24)
- Scenes and Preset Levels
- Dawn / Dusk Schedules

The Lighting Applications working group was formed in 2001 to improve BACnet's use as a native network lighting control protocol.

Since then, new BACnet objects, services, properties, and other standard values have been added to the BACnet standard to support lighting control.

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Object Reliability Property

New standard values were added to Reliability property of objects:
- TRIPPED
  - The end device, such as an actuator, is not responding to commands, prevented by a tripped condition or by being mechanically held open.
- LAMP_FAILURE
  - Indicates that the lamp has failed in a physical lighting device.
- COMMUNICATION_FAILURE
  - Proper operation of the object is dependent on communication with a remote sensor or device and communication with the remote sensor or device has been lost.

BACnet™

Output Object Interface_Value Property

HOA (Hand Off Auto) switches are common in control equipment, and permit a local override of output values. Assuming the HOA control cannot be "trumped" by the controller, there is nothing the controller can do to change the value of the output. There is no other process that can change the value of its output. However, the actual output value is of interest (especially to workstations), but are not reportable via a standard mechanism in BACnet, assuming the value of the HOA switch is known by the controller.

- Interface_Value
  - This read-only property indicates the value, in engineering units, of the physical output. If the BACnet device is not capable of knowing the value of the physical output, then the value of this property shall be NULL.

BACnet™

Lighting Output Object

- Present_Value in Percent of Normalized Range
  - 0.0%=Off
  - 1.0-100% =On
  - -1.0 = Warn
  - -2.0 = Warn Relinquish
  - -3.0 = Warn Off
  - -4.0 = Restore On
  - -5.0 = Default On
  - -6.0 = Toggle Restore
  - -7.0 = Toggle Default
- Lighting_Command for dimming control
  - operation, target level, ramp rate, fade time, step, priority
  - Operations include:
    - fade-to, ramp-to, stop
    - step-up, step-down, step-off
    - warn, warn-relinquish, warn-off
    - restore-on, default-on
    - toggle, toggle-restore, toggle-default
- Internal dimming engine drives Tracking_Value
- Internal Egress_Time timer for automatic relinquish
- Low and High trim to clamp the Present_Value
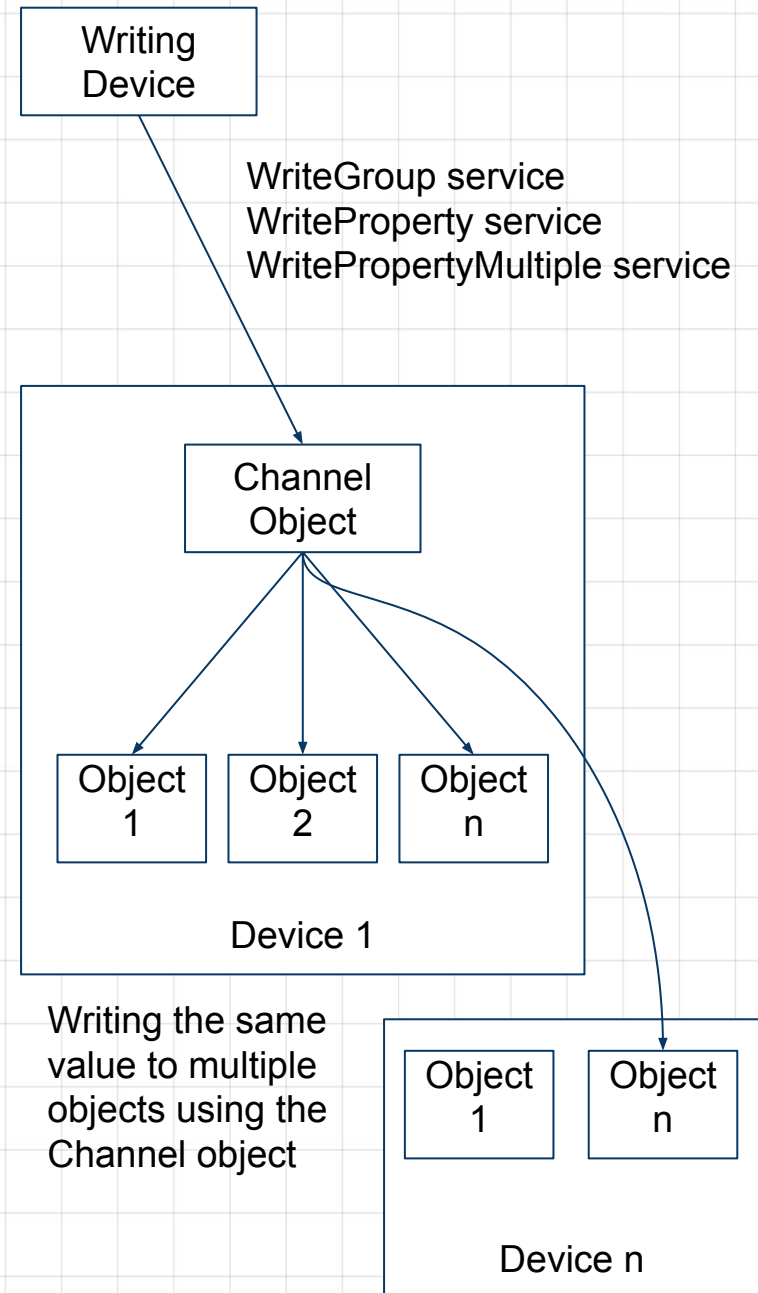
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Binary Lighting Output Object

- Present_Value is Enumerated for lighting control
  - Off
  - On
  - Warn
  - Warn-relinquish
  - Warn-off
  - Stop
  - + vendor specific if needed
- Internal Egress_Time timer for automatic relinquish
- Strike and Hour counting properties
- Power property
- Optional event notification parameters

BACnet™

Channel Object

- Present_Value is Channel Value (pseudo Commandable)
  - similar to Any - primitives
  - includes Lighting Command
- Propagated value to List of Object Property References
  - Object Property Reference can be another device
  - Execution Delay + Inhibit
  - Channel Number
  - Group membership
- Defined data coercion

Writing Device

WriteGroup service
WriteProperty service
WritePropertyMultiple service

Channel Object

Object 1

Object 2

Object n

Device 1

Writing the same value to multiple objects using the Channel object

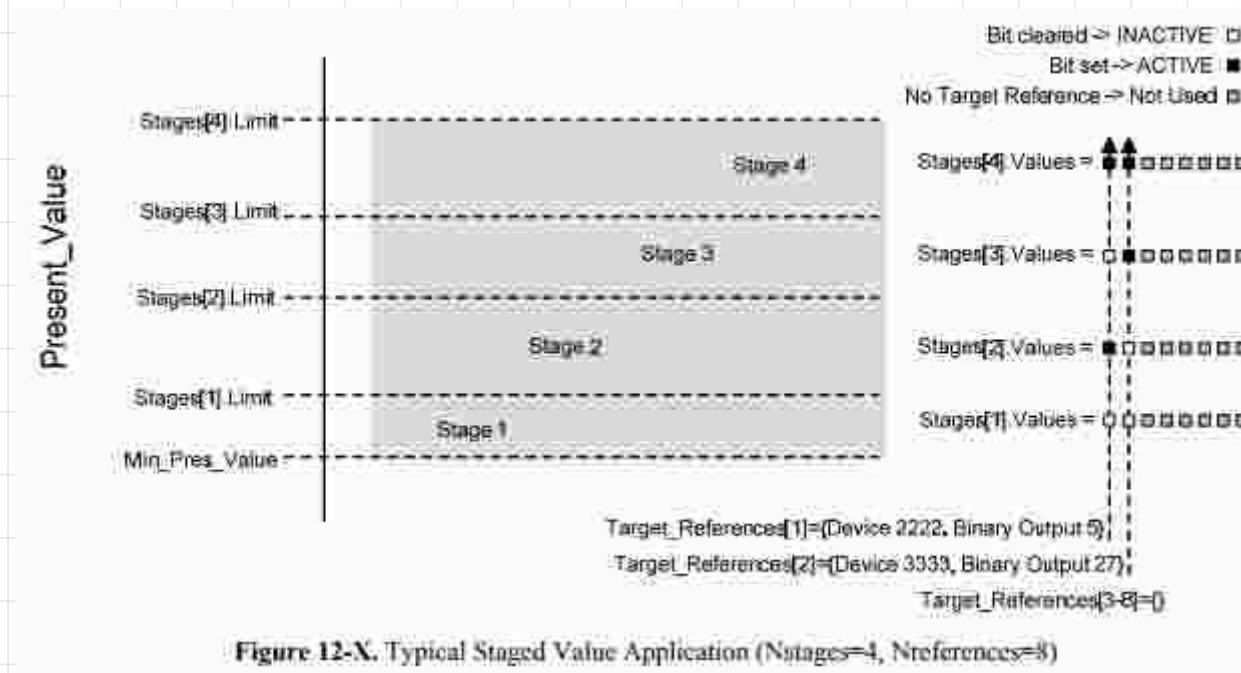Object 1

Object n

Device n

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WriteGroup Service

- Broadcast Write to Channel Objects in a Single Group
- Group number is designed to limit
  - 0=reserved
  - 1=min
  - 4,294,967,295=max
- Priority - used if not specified
- Change List - Tuples
  - Channel Number = property of Channel object 1-65535
  - Overriding Priority - specific priority if needed
  - Value - may be coerced if not exact datatype
- Inhibit Delay - if allowed by Channel object
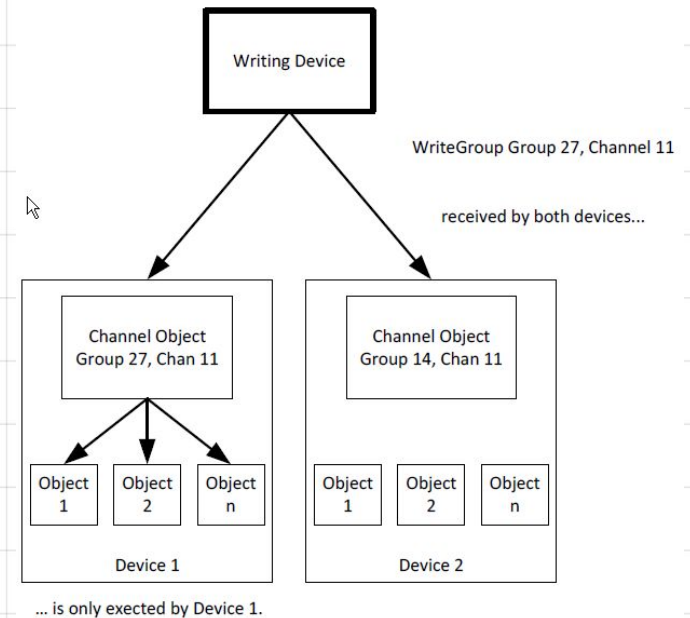
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Staging object

The Staging object type provides a way for BACnet devices to map analog values onto multiple Binary Value, Binary Output, or Binary Lighting Output objects. The Staging object can be used by 0-100% lighting commands that turn on individual fixtures to achieve step-lighting.

Figure 12-X. Typical Staged Value Application (Nstages=4, Nreferences=3)

Timer object

Many building automation applications have timer functionality, which should be made network visible for interoperable control, monitoring, and visualization.
A new object type Timer is added to allow timer functionality to be network visible. A new event algorithm CHANGE_OF_TIMER is added to accommodate the event detection characteristics and notification needs of the Timer object.
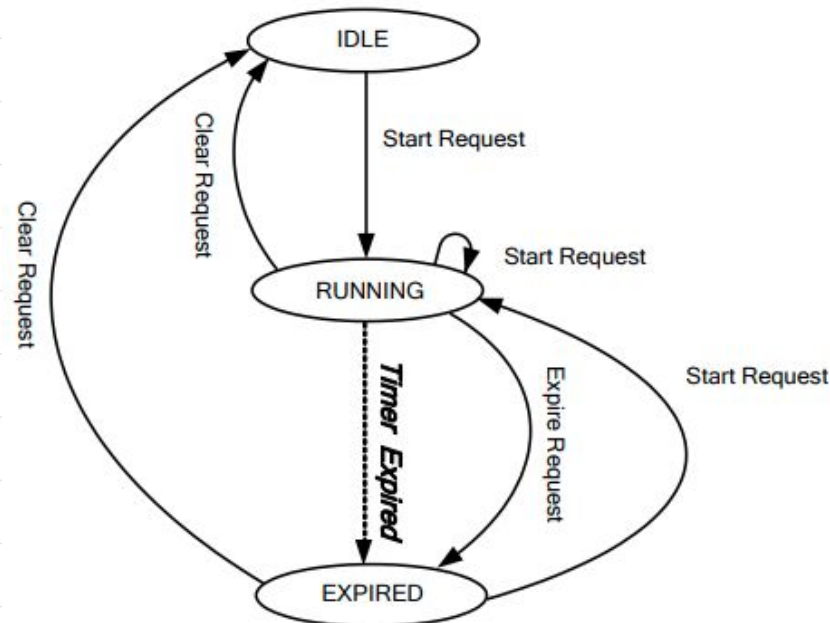
BACnet™

Color object

The Color object type provides a way for BACnet devices to interact with X,Y color, directly or with control commands:

- None
- Fade To
- Stop
- Override
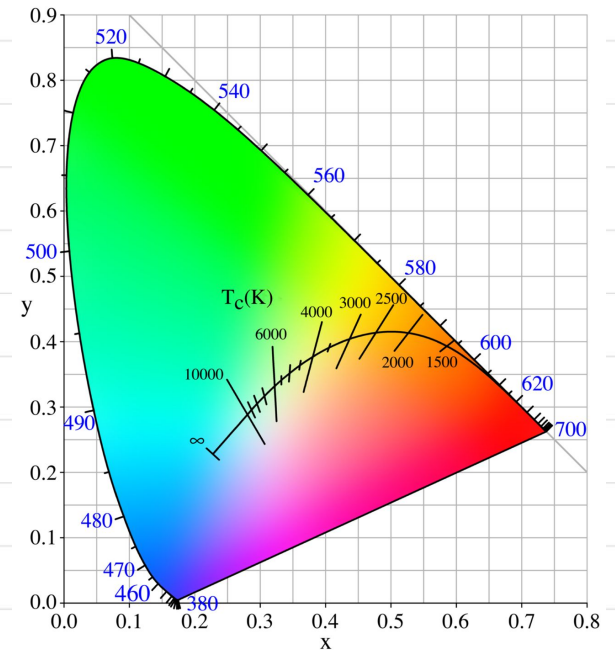
The Color object is coupled with a Lighting Output object which provides the brightness value.
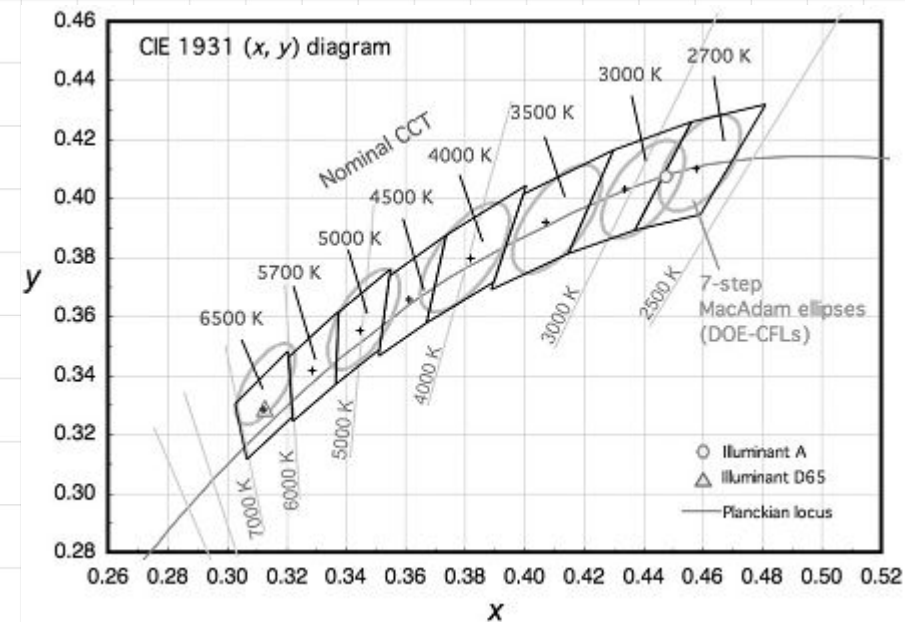
Color Temperature object

The Color Temperature object type provides a way for BACnet devices to interact with closest coordinated color temperature (CCT), directly or with control commands:

- None
- Fade To
- Stop
- Override

The Color Temperature object is coupled with a Lighting Output object which provides the brightness value.

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BACnet - BIBBs - Building Blocks

- Annex K describes the BACnet Interoperability Building Blocks (BIBBs)
- BIBBs used in PICS, standard Profiles
- Example:
  - K.1.2 BIBB
  - Data Sharing-ReadProperty-B (DS-RP-B): The B device is a provider of data to device A.
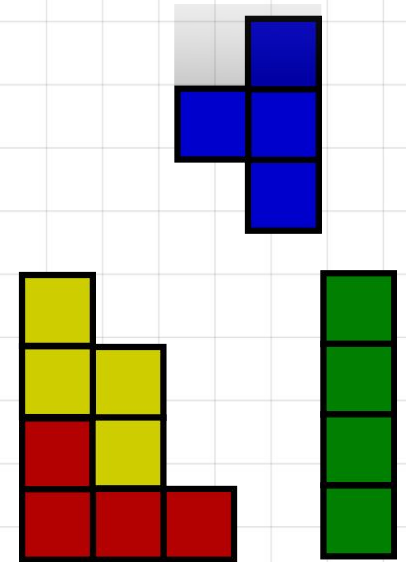
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Lighting BIBBs

With the addition of the Lighting object types and new services, lighting specific BACnet Interoperability Building Blocks (BIBBs) and device profiles were defined.

- Lighting Operator Devices and workstations.
  - This family is composed of B-XAWS, B-ALWS, and B-LOD.
- Lighting Control Stations.
  - This family is composed of B-ALCS and B-LCS.
- Lighting Supervisor (button/switch/sensor) and Lighting Device (lamp/ballast).
  - This family is composed of B-LS and B-LD.

Data Sharing

B-ALCS	B-LCS
DS-RP-A,B	DS-RP-A,B
DS-RPM-A	
DS-WP-A	DS-WP-A
DS-WPM-A	
DS-WG-A	
DS-ALO-A	DS-LO-A

Scheduling

B-ALCS	B-LCS
SCHED-E-B	

Device & Network Management

B-ALCS	B-LCS
DM-DDB-A,B	DM-DDB-A,B
DM-DOB-B	DM-DOB-B
DM-DCC-B	DM-DCC-B

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BACnet - Key Features

- Multiple datalink to choose from (Ethernet, WiFi, IPv4, IPv6, IPv6/6LoPAN/802.15.4, EIA-485, etc).
- Optional IT friendly interfaces (RESTful API, JSON responses, object tags) and Security (TLS/websocket)
- Robust objects and services supporting Schedules, Events, Alarms, Audit Logs, Trending, Access Control, Life Safety, Elevators, and Files in addition to many value objects.
- BACnet core interoperability between components is based on an object-oriented model. In this scheme, individual automation system devices can perform any type of function from data sharing to scheduling, from controlling light brightness and color fading to scenes, to integration between HVAC, security, fire and life safety, access control.
- Each device, whether it is a controller or an endpoint, can participate in the BACnet network, and has its own identity.

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BACnet Objects for Modeling a Device

accumulator	binary-output	file	multi-state-output	trend-log
analog-input	binary-value	group	multi-state-value	load-control
analog-output	calendar	life-safety-point	notification-class	structured-view
analog-value	command	life-safety-zone	program	trend-log-multiple
averaging	device	loop	pulse-converter	binary-input
credential-data-input	event-enrollment	multi-state-input	schedule	event-log
access-zone	access-rights	access-point	access-user	access-credential
characterstring-value	bitstring-value	access-door	global-group	characterstring-value
date-pattern-value	date-value	datetime-pattern-value	datetime-value	integer-value
large-analog-value	octetstring-value	positive-integer-value	time-pattern-value	time-value
channel	network-security	timer	lighting-output	binary-lighting-output
notification-forwarder	alert-enrollment	network-port	elevator-group	escalator
lift	staging	audit-log	audit-reporter	color
color-temperature				

BACnet™

BACnet Object Property Values

Table 12-2. Properties of the Analog Input Object Type

Property Identifier	Property Datatype	Conformance Code
Object_Identifier	BACnetObjectIdentifier	R
Object_Name	CharacterString	R
Object_Type	BACnetObjectType	R
Present_Value	REAL	R[1]
Description	CharacterString	O
Device_Type	CharacterString	O
Status_Flags	BACnetStatusFlags	R
Event_State	BACnetEventState	R
Reliability	BACnetReliability	O
Out_Of_Service	BOOLEAN	R
Update_Interval	Unsigned	O
Units	BACnetEngineeringUnits	R
Min_Pres_Value	REAL	O
Max_Pres_Value	REAL	O
Resolution	REAL	O
COV_Increment	REAL	O[2]
Time_Delay	Unsigned	O[3,5]
Notification_Class	Unsigned	O[3,5]
High_Limit	REAL	O[3,5]
Low_Limit	REAL	O[3,5]
Deadband	REAL	O[3,5]
Limit_Enable	BACnetLimitEnable	O[3,5]
Event_Enable	BACnetEventTransitionBits	O[3,5]
Acked_Transitions	BACnetEventTransitionBits	O[3,5]
Notify_Type	BACnetNotifyType	O[3,5]
Event_Time_Stamps	BACnetARRAY[3] of BACnetTimeStamp	O[3,5]
Event_Message_Texts	BACnetARRAY[3] of CharacterString	O[5]
Event_Message_Texts_Config	BACnetARRAY[3] of CharacterString	O[5]
Event_Detection_Enable	BOOLEAN	O[3,5]
Event_Algorithm_Inhibit_Ref	BACnetObjectPropertyReference	O[5]
Event_Algorithm_Inhibit	BOOLEAN	O[5,6]
Time_Delay_Normal	Unsigned	O[5]
Reliability_Evaluation_Inhibit	BOOLEAN	O[7]
Property_List	BACnetARRAY[N] of BACnetPropertyIdentifier	R
Interface_Value	BACnetOptionalREAL	O
Fault_High_Limit	REAL	O[8]
Fault_Low_Limit	REAL	O[8]
Audit_Level	BACnetAuditLevel	O[9]
Auditable_Operations	BACnetAuditOperationFlags	O[9]
Tags	BACnetARRAY[N] of BACnetNameValue	O
Profile_Location	CharacterString	O
Profile_Name	CharacterString	O

For 'value' objects, additional property values assist the building or application integration to understand other related information of the 'value', such as Units, Status or Name and provide a vendor a rich palette from which to model their device features.

BACnet™

BACnet Confirmed Services

- Confirmed == Unicast, Acknowledged

AcknowledgeAlarm	AtomicWriteFile	WritePropertyMultiple
COV-Notification	AddListElement	PrivateTransfer
EventNotification	RemoveListElement	TextMessage
GetAlarmSummary	CreateObject	ReinitializeDevice
GetEnrollmentSummary	DeleteObject	VTOpen
SubscribeCOV	ReadProperty	VTClose
SubscribeCOVProperty	ReadPropertyMultiple	VTData
LifeSafetyOperation	ReadRange	Authenticate
AtomicReadFile	WriteProperty	RequestKey
GetEventInformation		AuditLogQuery

ReadPropertyConditional	ConfirmedCOVNotificationMultiple
DeviceCommunicationControl	SubscribeCOVPropertyMultiple

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BACnet Confirmed Services

- Unconfirmed == Broadcast (usually)

I-Am	TextMessage
I-Have	TimeSynchronization
COV-Notification	WhoHas
EventNotification	WhoIs
PrivateTransfer	UTC-TimeSynchronization
WriteGroup	COV-NotificationMultiple
Who-Am-I	AuditNotification

You-Are
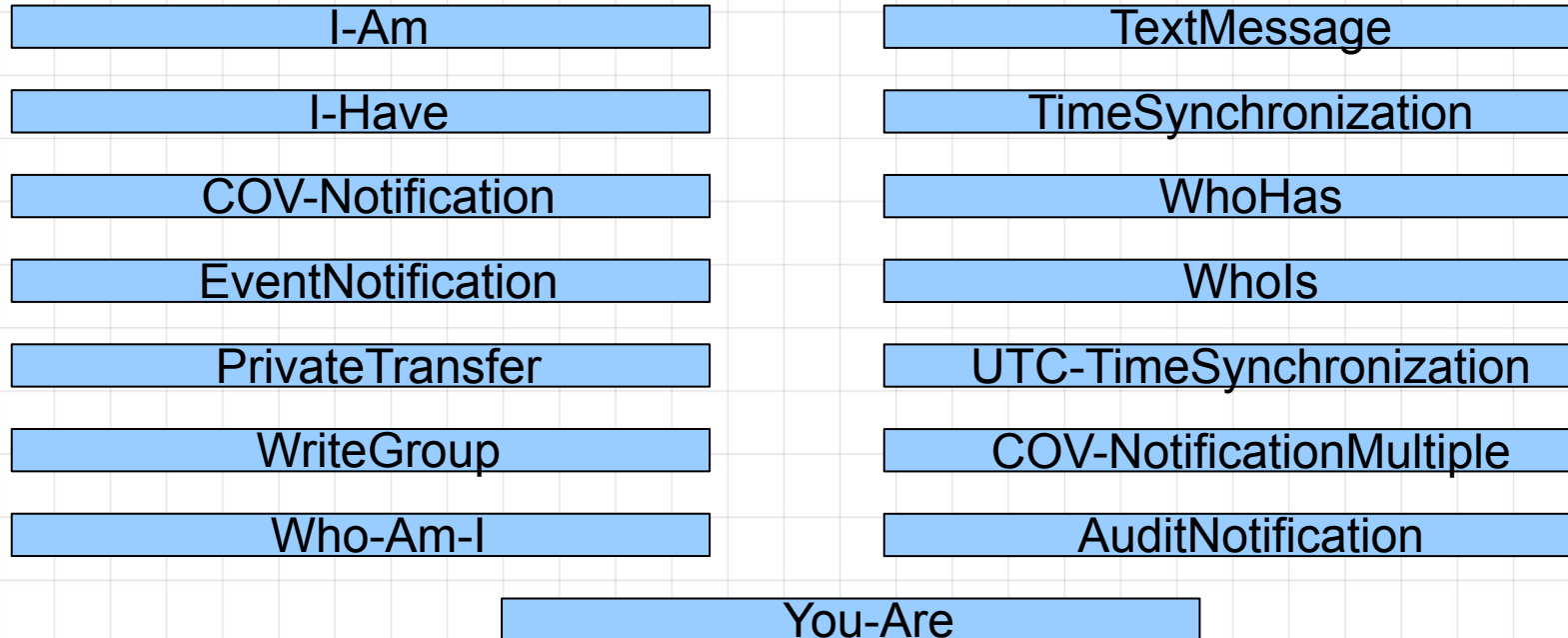
BACnet tm

BACnet Application Layer
Design: BACnet object modeling for Lighting Control

- Required
  - Device object
  - Network Port object
- Lighting Specific Outputs
  - Lighting Output object
  - Binary Lighting Output object
  - Staging object
  - Color object
  - Color Temperature object
- Shades & Blinds
  - Analog Output object
  - Binary Output object
  - Multi-state Output object
- Sensors (light, motion, touch)
  - Analog Input object
  - Binary Input object
  - Multi-state Input object

- Demand Response/Shed
  - Load Control object
  - Averaging object
- Grouping Lights
  - Channel object
- Daylight Harvesting
  - Loop object
- Area Timeout
  - Timer object
- Time of Day Scheduling
  - Schedule object
  - Calendar object
- Configuration Parameters
  - Analog Value object
  - Binary Value object
  - Multi-state Value object

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BACnet Application Layer
Design: BACnet Network Communication

- Object property services
  - ReadProperty
  - WriteProperty
  - ReadPropertyMultiple
  - WritePropertyMultiple
- Control services
  - WriteGroup
  - WriteProperty
- Device discovery and management services
  - ReinitializeDevice
  - DeviceCommunicationControl
  - Who-Am-I
  - You-Are
  - Who-Is
  - I-Am

- Other object services
  - AtomicReadFile
  - AtomicWriteFile
  - COVNotification
  - SubscribeCOV
- Other Device services
  - TimeSynchronization
  - UTCTimeSynchronization
- Peer to Peer control is possible with any device!
- Native BACnet vs Gateway
  - Gateway adds latency
  - Gateway restricts the BACnet service & object property model
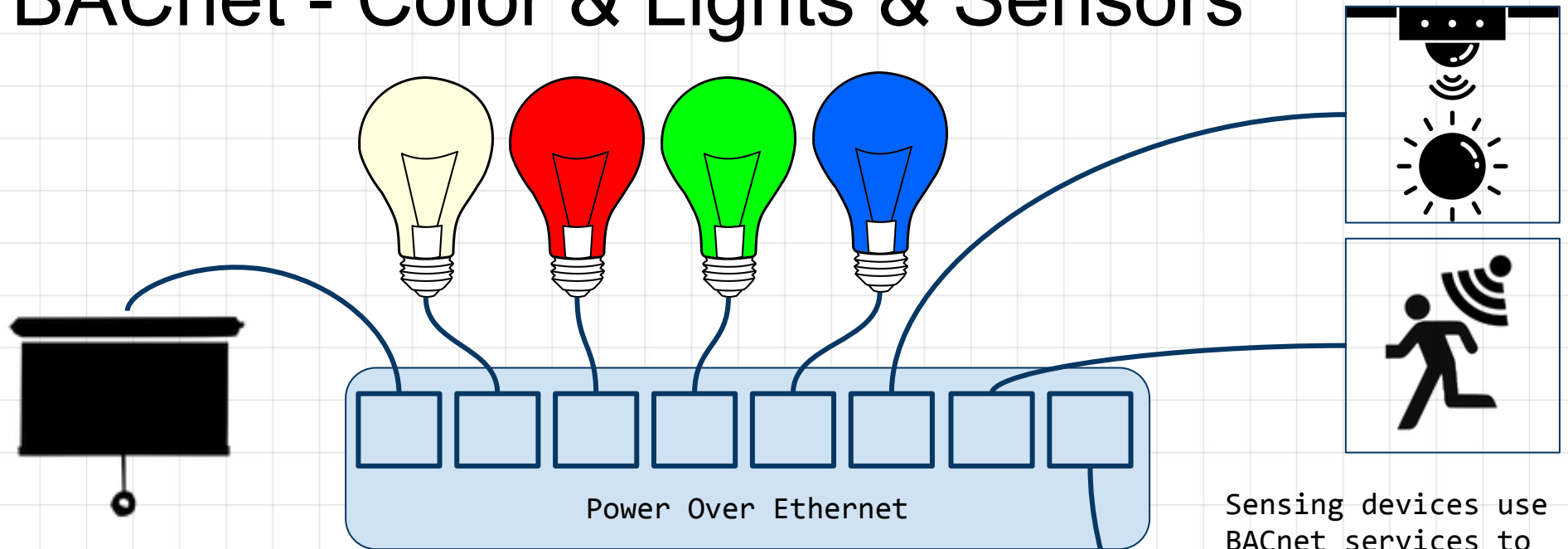 - Gateway requires a translation from the downstream protocol

BACnet ™

BACnet Application Layer
Design: Extensibility

- Vendors can create their own services using Confirmed or Unconfirmed Private Transfer for services that BACnet hasn't standardized:
  - Tunnel non-BACnet protocols
  - Send Non-BACnet notifications or events
  - Enable vendor specific features
- Vendors can create their own objects with their own set of properties for objects that BACnet hasn't standardized:
  - Only required to have object name, type, and instance properties
- Vendors can add their own properties to BACnet standard objects
- Many of the enumerations used in standard BACnet object property value and services are vendor extensible
- BACnet Vendor ID is free to any entity

BACnet - Color & Lights & Sensors

Power Over Ethernet

```
IEEE 802.3af-2003 PoE    15.4 W
IEEE 802.3at-2009 PoE+   25.5 W
IEEE 802.3bt-2018 PoE++  51   W
IEEE 802.3bt-2018 4PPoE  71.3 W
IEEE 802.3bu-2016 PoDL   50   W
```

Sensing devices use BACnet services to directly control other BACnet device objects, or to notify other BACnet building controllers

There are IP migration transmission systems called 'IP over any cable' technology on the market today that allow installers/end-users to take advantage of extended PoE power & Ethernet distances using legacy cable.
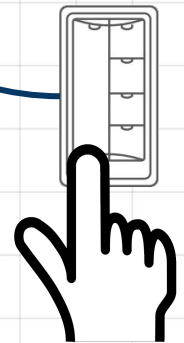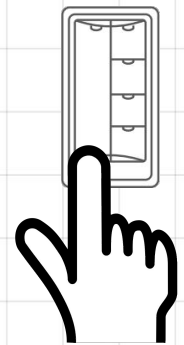
BACnet ™

BACnet Integration - Vivarium

Environmental controls

- Lighting - A lighting system simulates the requirements of the animal and plant species, such as day/night regulator
- Temperature - simulates conditions found in their natural habitat, including simulated day/night or seasonal periods
- Humidity - simulates conditions found in their natural habitat, including simulated day/night or seasonal periods
- Ventilation and openings - Access inside the vivarium is required for the purpose of maintenance, sometimes with the use of special lighting that won't disrupt experiments or the species inside

BACnet - Key Benefits

- Worldwide standardized data communication for building automation
- Independent of specific technologies and suppliers
- Comprehensive solution for building control and automation networks
- Compatibility with IT infrastructure and highly scalable solutions
- Validation at independent testing laboratories and product certification
- Continuously being maintained and upgraded while preserving current investments