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Open Networks for Energy Efficiency

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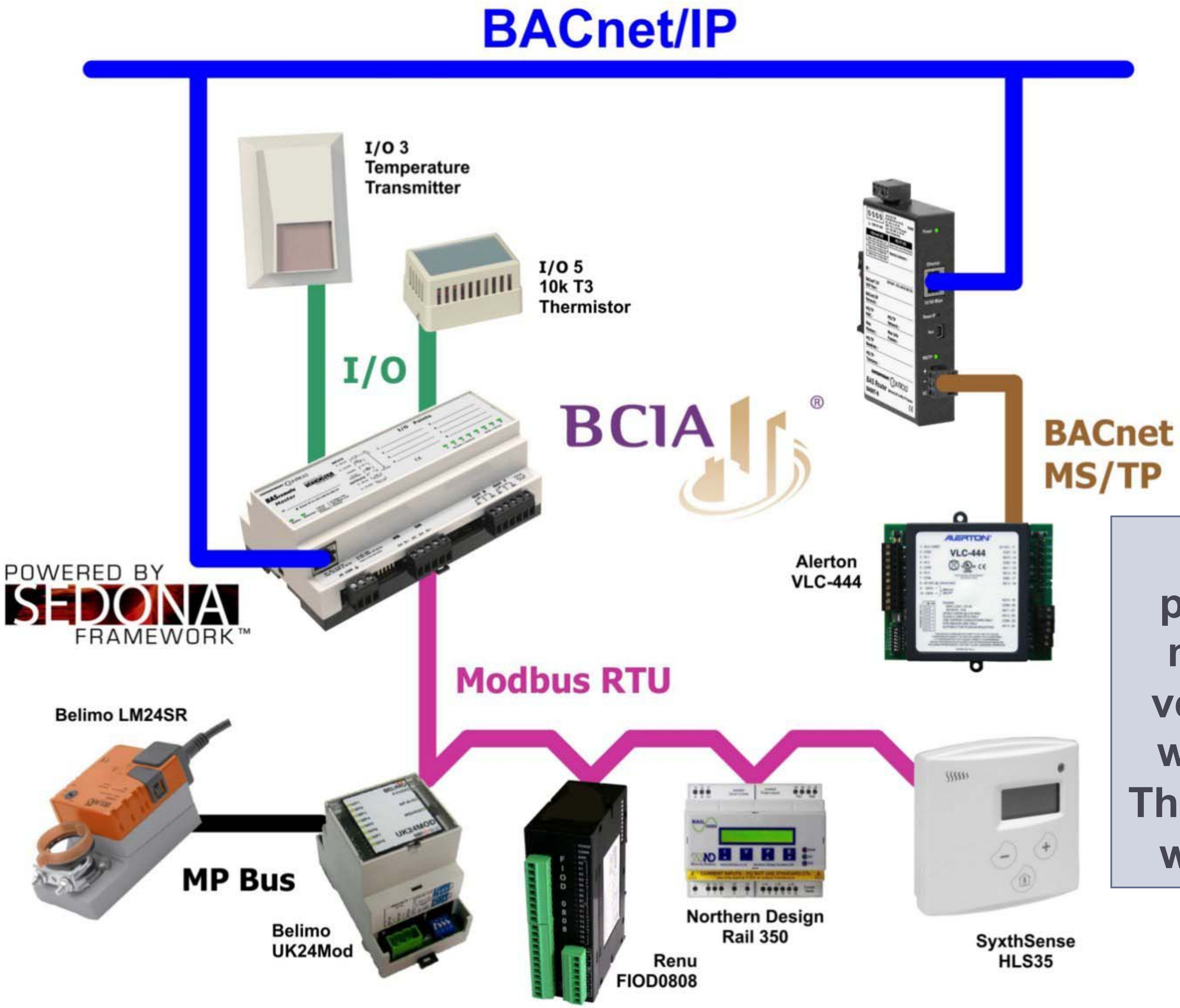
Everyone Wants to Save Energy

To save energy we need to measure it and the best way to measure energy is to use energy meters that support open network protocols like Google is doing with their PowerMeter and the most open of networks which is the Internet. They are helping consumers conserve.

Our Contribution to ConnectFest



Open network protocols allow the mixing of different vendor's equipment within one system. The same can be done with energy meters.

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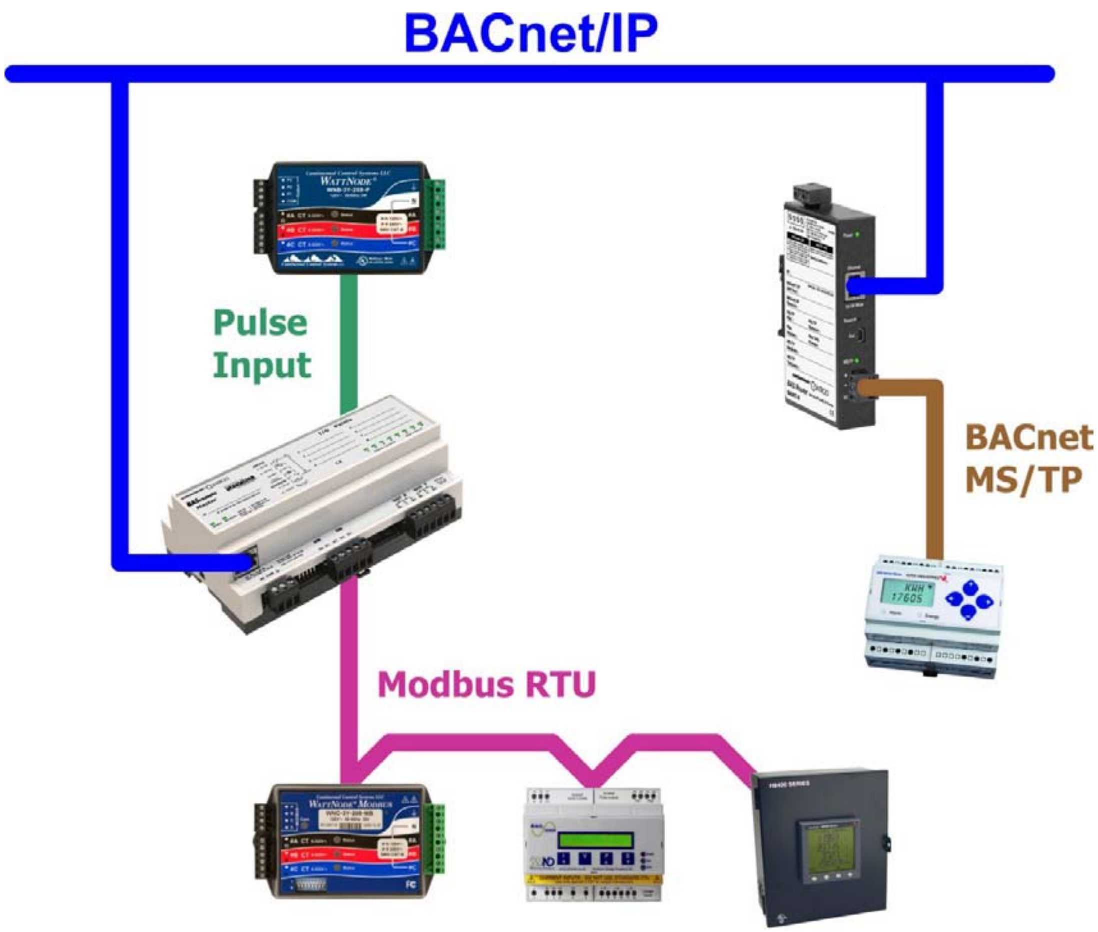
What Are Some Examples of Open Networks?

- BACnet – Building Automation and Control Network
  - BACnet/IP – typically over Ethernet
  - BACnet MS/TP – over EIA-485
- Modbus
  - Modbus TCP – over Ethernet
  - Modbus RTU or ASCII – over EIA-485
- Niagara Framework and Sedona Framework
- LON
- KNX

We will concentrate on two networks – BACnet and Modbus – and study the methods used to connect energy meters to these networks.

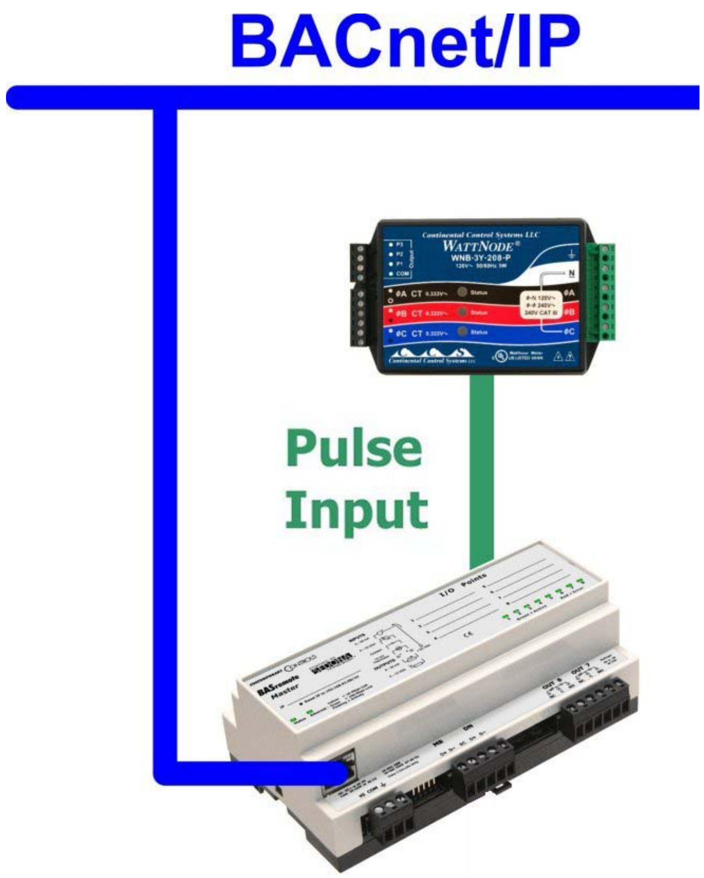
There are Several Ways to Interface Energy Meters



The type of meter dictates how it is to be interfaced. We recommend BACnet/IP at the top because it will operate over IP networks.

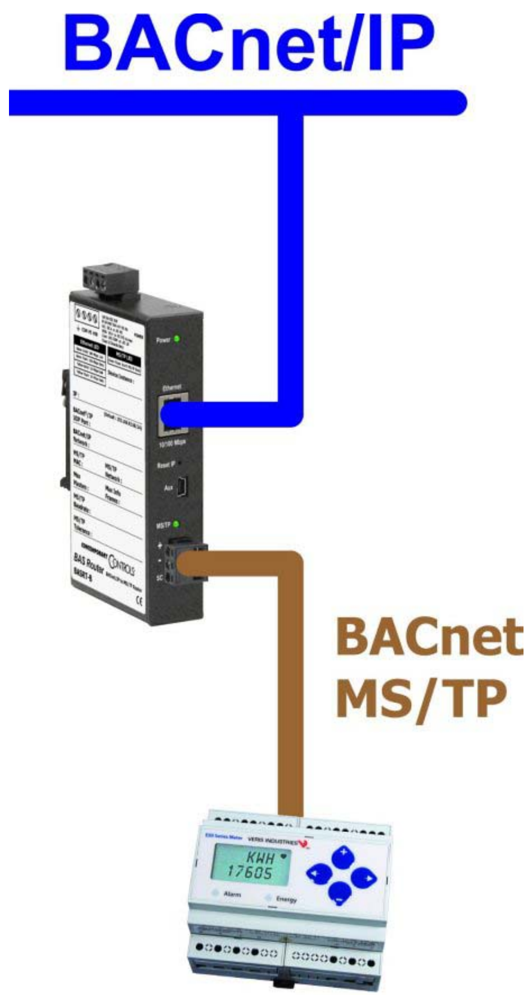
Pulse Style Energy Meters – Simple Interface

- Pulse style energy meters output a pulse for every unit of energy usage
- There is no network protocol conversion involved
- Requires a controller or interface to capture the pulses and scale the data into meaningful units
- Pulse meters commonly found in measuring electricity, liquid or gas
- Energy accumulation is stored in the interface and not in the energy meter so memory retention becomes an issue

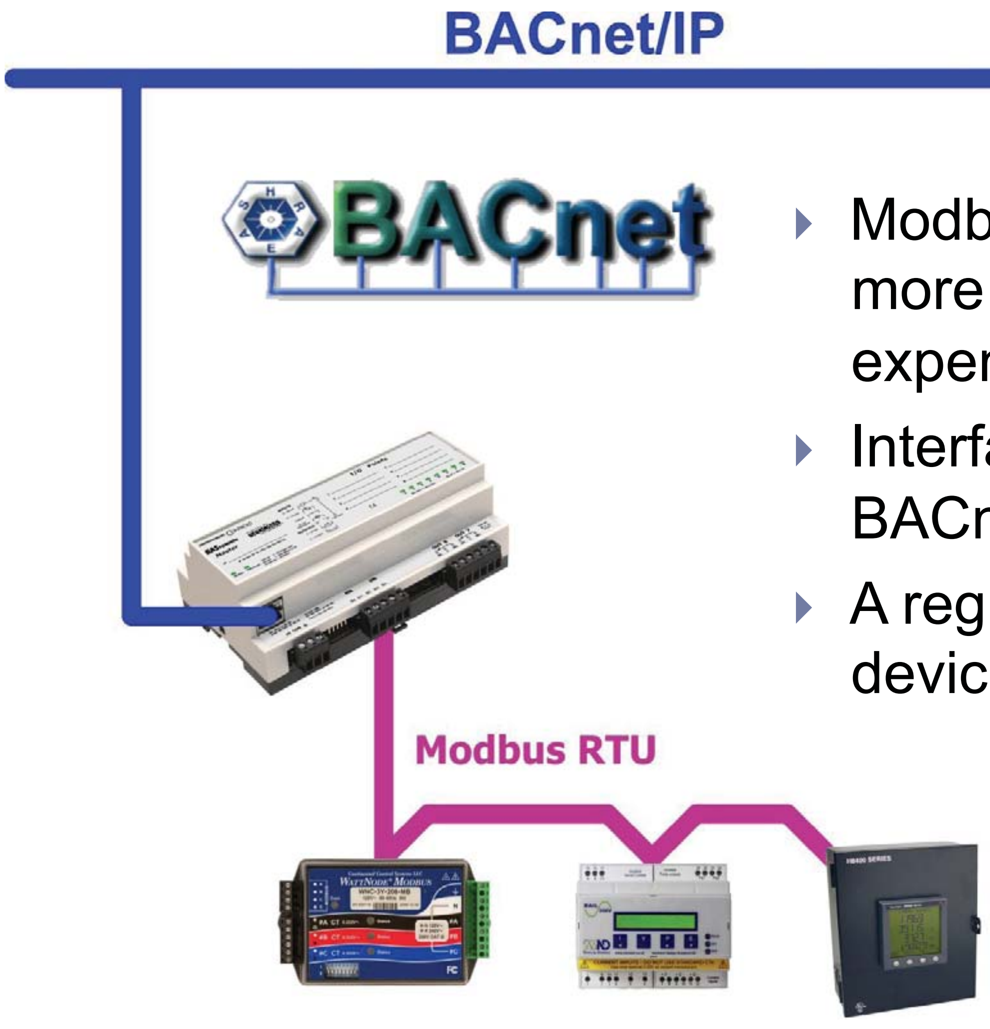


Protocol Style Energy Meters – BACnet MS/TP

- Protocol style meters provide much more functionality than pulse style meters
- BACnet MS/TP energy meters have the advantage that no gateway is required for interfacing – instead a BACnet router is needed
- The same energy meter may have either a Modbus RTU or BACnet MS/TP option as is the case for the meter shown
- It is possible to have a BACnet/IP energy meter in which case no interfacing is required – simply connect it directly onto Ethernet



Protocol Style Energy Meters – Modbus RTU



- Modbus energy meters are more common and less expensive than BACnet meters
- Interfacing a Modbus device to BACnet requires a gateway
- A register list defines the device's functionality

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Typical Modbus Energy Meter Register List

Complete Listing of Data Points

Address	Typical Offset	Units	Description	Integer: multiplier required	Float: upper 16 bits	Float: lower 16 bits
40001	0	KWH	Energy Consumption, LSW	X		
40002	1	KWH	Energy Consumption, MSW	X		
40003	2	KW	Real Power	X		
40004	3	VAR	Reactive Power	X		
40005	4	VA	Apparent Power	X		
40006	5	---	Power Factor	X		
40007	6	VOLTS	Voltage, line to line	X		
40008	7	VOLTS	Voltage, line to neutral	X		
40009	8	AMPS	Current	X		
40010	9	KW	Real Power, Phase A	X		
40011	10	KW	Real Power, Phase B	X		
40012	11	KW	Real Power, Phase C	X		
40013	12	---	Power Factor, phase A	X		
40014	13	---	Power Factor, phase B	X		
40015	14	---	Power Factor, phase C	X		
40016	15	VOLTS	Voltage, phase A-B	X		
40017	16	VOLTS	Voltage, phase B-C	X		
40018	17	VOLTS	Voltage, phase A-C	X		
40019	18	VOLTS	Voltage, phase A-N	X		
40020	19	VOLTS	Voltage, phase B-N	X		
40021	20	VOLTS	Voltage, phase C-N	X		
40022	21	AMPS	Current, phase A	X		
40023	22	AMPS	Current, phase B	X		
40024	23	AMPS	Current, phase C	X		
40025	24	KW	Average Real Power	X		
40026	25	KW	Minimum Real Power	X		
40027	26	KW	Maximum Real Power	X		
40257	---	KWH	Energy Consumption		X	
40258		KWH	Energy Consumption			X
40259	0	KWH	Energy Consumption (same 40257)		X	
40260		KWH	Energy Consumption (same 40258)			X
40261	2	KW	Real Power		X	
40262		KW	Real Power			X

The meter manufacturer provides a register listing that identifies where pertinent data can be found. This data can then be read by the building automation system.

The register list could be very long with information of little interest.

A Subset List of Registers is More Interesting

Quick Reference of the Most Common Data Points

Address	Typical Offset	Units	Description	Integer: multiplier required	Float: upper 16 bits	Float: lower 16 bits
40001	0	KWH	Energy Consumption, LSW	X		
40002	1	KWH	Energy Consumption, MSW	X		
40003	2	KW	Real Power	X		
40257	---	KWH	Energy Consumption		X	
40258		KWH	Energy Consumption			X
40259	0	KWH	Energy Consumption (same 40257)		X	
40260		KWH	Energy Consumption (same 40258)			X
40261	2	KW	Real Power		X	
40262		KW	Real Power			X

It is not necessary to read all locations – only the ones of interest. The register list identifies the register location along with the description of the data and how it is structured. This data structure is not compatible with BACnet so it must be converted. Modbus data is based upon registers while BACnet data is based upon objects.

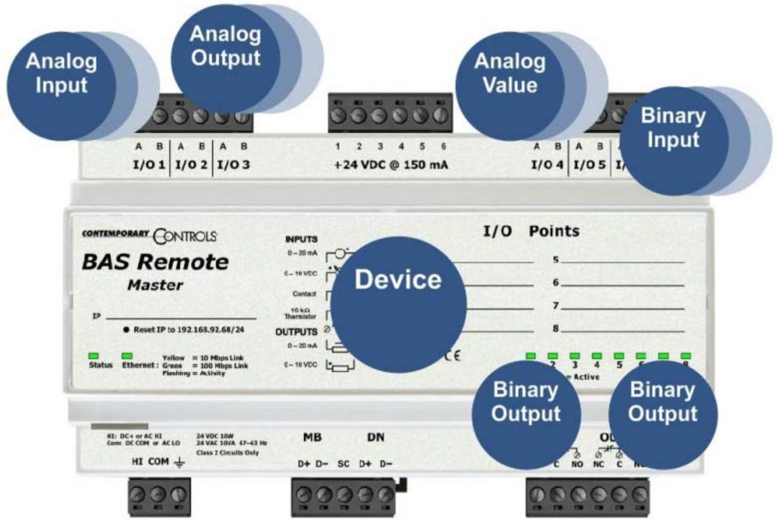
Modbus Data Locations and Structure

Memory Block	Bits	Access	Address Range
Coils	1	Read / Write	000001–065535
Discrete inputs	1	Read-Only	100001–165535
Input registers	16	Read-Only	300001–365535
Holding registers	16	Read / Write	400001–465535

- The Modbus address range is specific to inputs and outputs
  - Coils (discrete outputs) and discrete inputs require one-bit
  - Input and holding registers occupy 16-bits
  - Analog inputs/outputs and accumulators are represented by input and holding registers and it is not uncommon to see two 16-bit words representing one variable
- For energy meters, holding registers are the most common
- Input registers are seldom supported

BACnet Object Modeling

- A physical BACnet device has ONE Device object with a unique object instance
- Within the device there can be several object types such as analog inputs (AI) and binary outputs (BO) each with a unique object instance for the object type
- Each object has properties



Modeling Modbus Registers as BACnet Objects

Property	BI	BO	AI	AO
Object Identifier	R	R	R	R
Object Name	R	R	R	R
Object Type	R	R	R	R
Present Value	R	W	R	W
Status Flags	R	R	R	R
Event State	R	R	R	R
Out of Service	R	R	R	R
Polarity	R	R	NA	NA
Units	NA	NA	R	R
Priority Array	NA	R	NA	R
Relinquish Default	NA	R	NA	R
COV Increment	NA	NA	O	O

- Unlike Modbus, BACnet uses an object-based data structure with each object type having properties
- However, mapping Modbus registers to BACnet BIs, BOs, AIs and AOs is possible although compromises are made
- Modbus register addresses become BACnet object instances

BACnet Object to Modbus Register Mapping

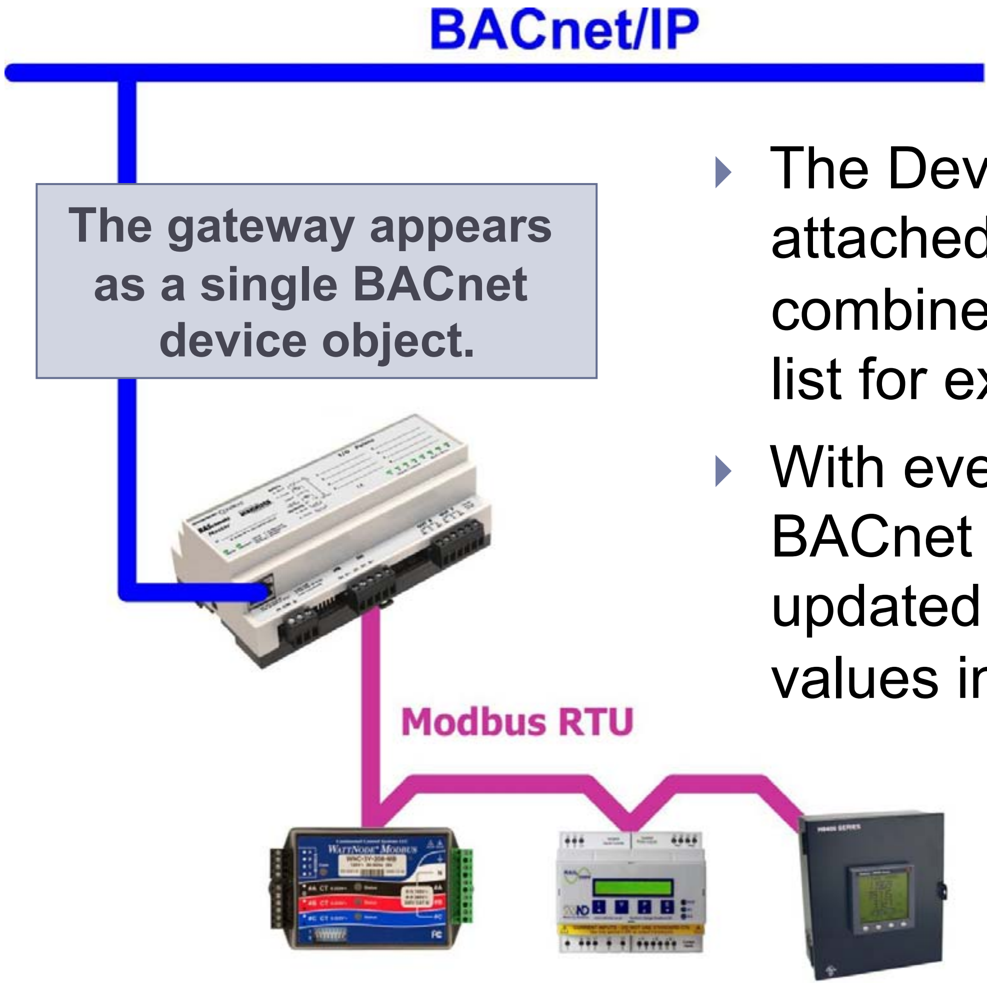
BACnet Object Type — BACnet Object Instance — Modbus Register

Print Preview | Print File | **BACnet Information** | Return to "Main" Sheet | **Modbus Information**

H8036-1 Energy Consumption	AI	1040259	KILOWATT_HOURS	10	Register	40259	Floating Point HI/LO	R_Only
H8036-1 Real Power	AI	1040261	KILOWATTS	10	Register	40261	Floating Point HI/LO	R_Only
H8036-1 Reactive Power	AI	1040263	KILOVOLT_AMPERES_REACT	10	Register	40263	Floating Point HI/LO	R_Only
H8036-1 Apparent Power	AI	1040265	KILOVOLT_AMPERES	10	Register	40265	Floating Point HI/LO	R_Only
H8036-1 Power Factor	AI	1040267	POWER_FACTOR	10	Register	40267	Floating Point HI/LO	R_Only
H8036-1 Voltage line to line	AI	1040269	VOLTS	10	Register	40269	Floating Point HI/LO	R_Only
H8036-1 Voltage line to neutral	AI	1040271	VOLTS	10	Register	40271	Floating Point HI/LO	R_Only
H8036-1 Current	AI	1040273	AMPERES	10	Register	40273	Floating Point HI/LO	R_Only
H8036-1 Demand (power) phase A	AI	1040275	KILOWATTS	10	Register	40275	Floating Point HI/LO	R_Only
H8036-1 Demand (power) phase B	AI	1040277	KILOWATTS	10	Register	40277	Floating Point HI/LO	R_Only
H8036-1 Demand (power) phase C	AI	1040279	KILOWATTS	10	Register	40279	Floating Point HI/LO	R_Only
H8036-1 Power Factor phase A	AI	1040281	POWER_FACTOR	10	Register	40281	Floating Point HI/LO	R_Only
H8036-1 Power Factor phase B	AI	1040283	POWER_FACTOR	10	Register	40283	Floating Point HI/LO	R_Only
H8036-1 Power Factor phase C	AI	1040285	POWER_FACTOR	10	Register	40285	Floating Point HI/LO	R_Only
H8036-1 Voltage phase A-B	AI	1040287	VOLTS	10	Register	40287	Floating Point HI/LO	R_Only
H8036-1 Voltage phase B-C	AI	1040289	VOLTS	10	Register	40289	Floating Point HI/LO	R_Only
H8036-1 Voltage phase A-C	AI	1040291	VOLTS	10	Register	40291	Floating Point HI/LO	R_Only
H8036-1 Voltage phase A-N	AI	1040293	VOLTS	10	Register	40293	Floating Point HI/LO	R_Only
H8036-1 Voltage phase B-N	AI	1040295	VOLTS	10	Register	40295	Floating Point HI/LO	R_Only
H8036-1 Voltage phase C-N	AI	1040297	VOLTS	10	Register	40297	Floating Point HI/LO	R_Only
H8036-1 Current phase A	AI	1040299	AMPERES	10	Register	40299	Floating Point HI/LO	R_Only
H8036-1 Current phase B	AI	1040301	AMPERES	10	Register	40301	Floating Point HI/LO	R_Only
H8036-1 Current phase C	AI	1040303	AMPERES	10	Register	40303	Floating Point HI/LO	R_Only
H8036-1 Average Real Power	AI	1040305	KILOWATTS	10	Register	40305	Floating Point HI/LO	R_Only
H8036-1 Average Real Power	AI	1040307	KILOWATTS	10	Register	40307	Floating Point HI/LO	R_Only
H8036-1 Maximum Real Power	AI	1040309	KILOWATTS	10	Register	40309	Floating Point HI/LO	R_Only

A one-to-one relationship between Modbus registers and BACnet objects is created using an off-line program. This Device Profile, which is unique to the manufacturer's energy meter, identifies what points to poll.

Executing a Scan List in the Gateway

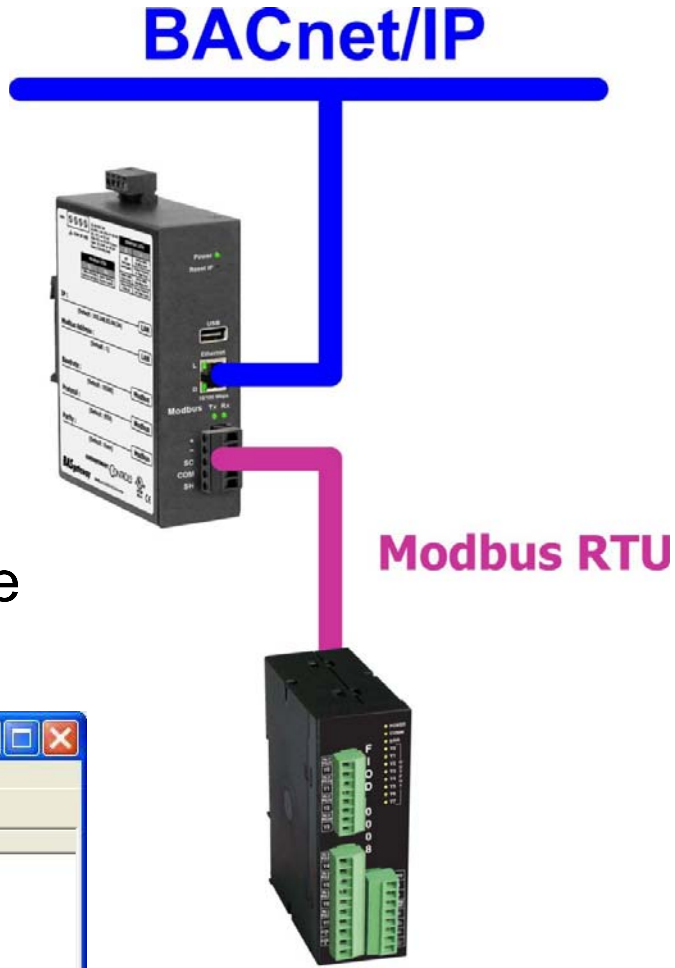


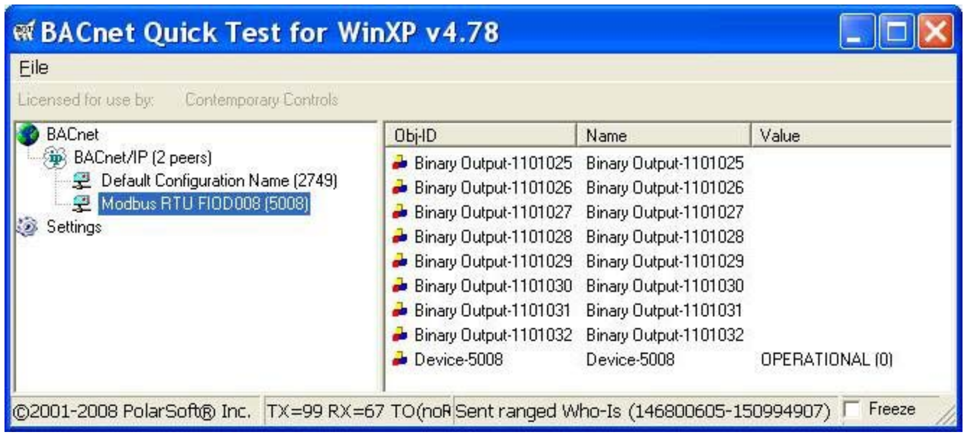
- The Device Profile for every attached energy meter is then combined to form a single scan list for execution in the gateway
- With every scan of the list, BACnet object values are updated accordingly from the values in the Modbus registers

The Modbus registers in all energy meters appear to be a collection of BACnet points within the gateway and not as separate physical meters.

The Virtual Routing Approach to Modbus Mapping

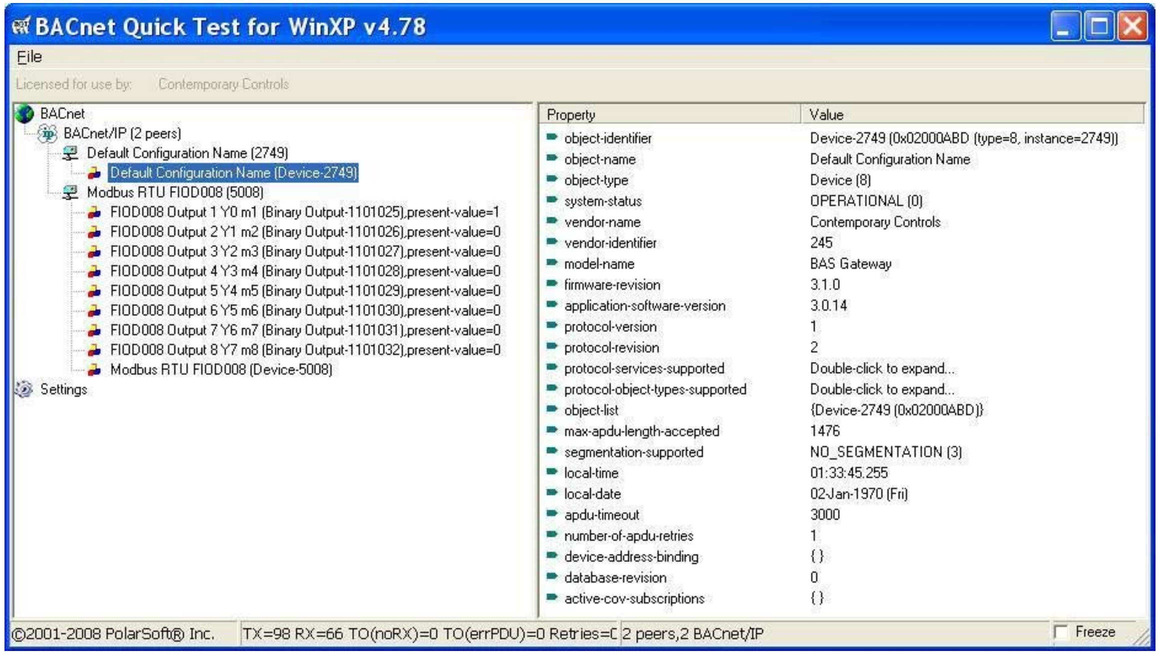
- Using the concept of virtual routing within the gateway, for every attached Modbus device a new BACnet device instance is created
- Notice that the Modbus device appears as its own device object with eight points of I/O as if it were a physical BACnet device





Virtual Routing – the Gateway Device Object

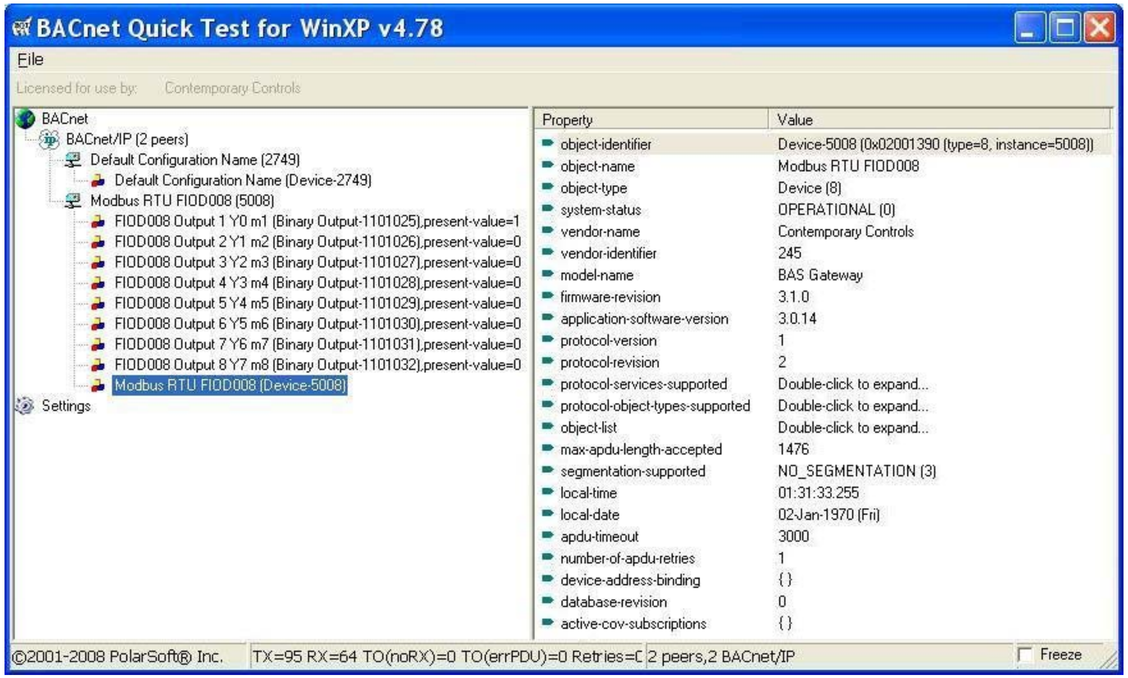
- As with any BACnet gateway, the gateway has a device instance but in the case of virtual routing has no I/O of its own
- With the conventional gateway approach, the BACnet gateway appears to have ALL the attached Modbus I/O as if the actual Modbus devices did not exist – this creates object instance conflict when multiple identical Modbus devices are attached



The gateway has only Device Object properties

Virtual Routing – the Modbus Device Object

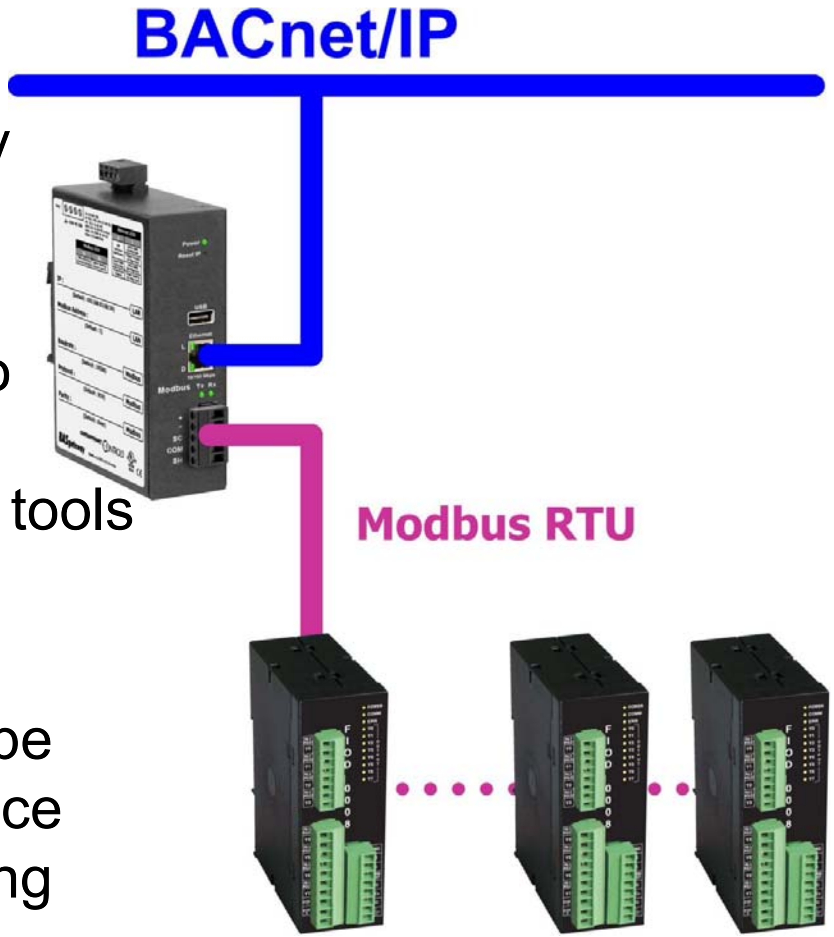
- With virtual routing, each attached Modbus device has its own device instance as if each were physical BACnet devices
- This allows for identical device profiles to be installed in each Modbus device without modification – a typical case when multiple energy meters of the same model are attached to the same gateway



The attached Modbus device also has Device Object properties

Virtual Routing – Adding More Modbus Devices

- Adding more Modbus devices to the same gateway creates additional BACnet device objects
- Conceptually, this is easier to envision and it makes troubleshooting with BACnet tools easier
- The big advantage is that identical energy meters can be represented by identical device profiles making commissioning much easier



Conclusions

- Energy meters are necessary to verify that energy saving methods are successful
- There are several energy meter styles on the market but energy meters that support open protocols provide the most functionality
- By choosing an energy meter with an open protocol, the purchaser has many options among the several energy meter manufacturers
- Modbus meters tend to be less expensive than BACnet meters but they still can be integrated into a BACnet system through the use of gateways
- By creating a scan list comprised of device profiles, a gateway can make Modbus energy meters appear as BACnet devices

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