



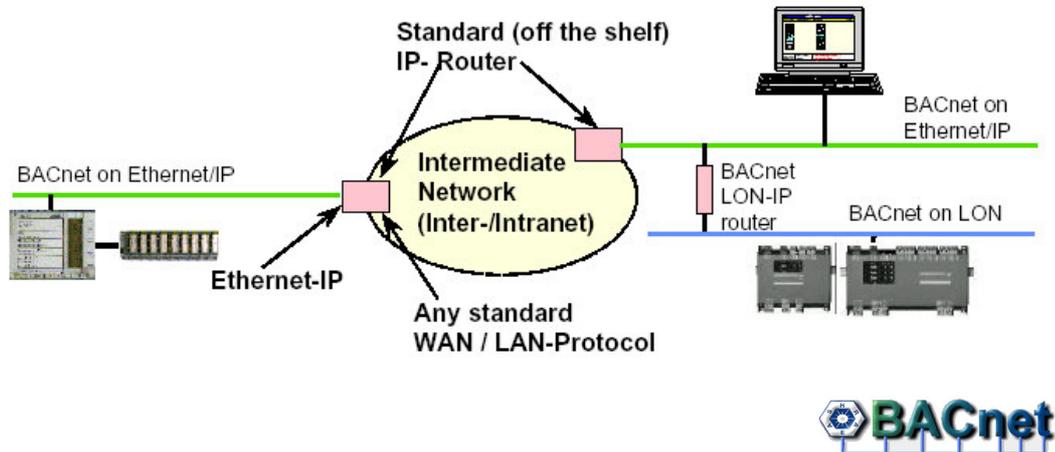
- Understand BACnet
- Study BACnet Protocol

Reference:

- <http://www.bacnet.org/Tutorial/HMN-Overview/sld001.htm>
- Networking and Integration of Facilities Automation Systems, Chapter 12



BACnet by ASHRAE



Control Network: BACnet

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- www.bacnet.org
- BACnet (**B**uilding **A**utomation and **C**ontrol **N**etwork) is a standardized data communication protocol which is used to connect all kinds of systems and infrastructure typically found in buildings, e.g. HVAC (Heating, Ventilation and Air Conditioning) control, access control systems, fire detection and alarm, vertical transport systems, elevator control, maintenance, waste management, lighting, etc.
- Developed by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- A key design criterion was that the protocol had to be applicable to all building automation needs. To accomplish this, BACnet specifies most all of the most common functions: analog and binary input, output, and values; control loops; schedules, etc., that clearly apply to almost any kind of monitoring or control application.



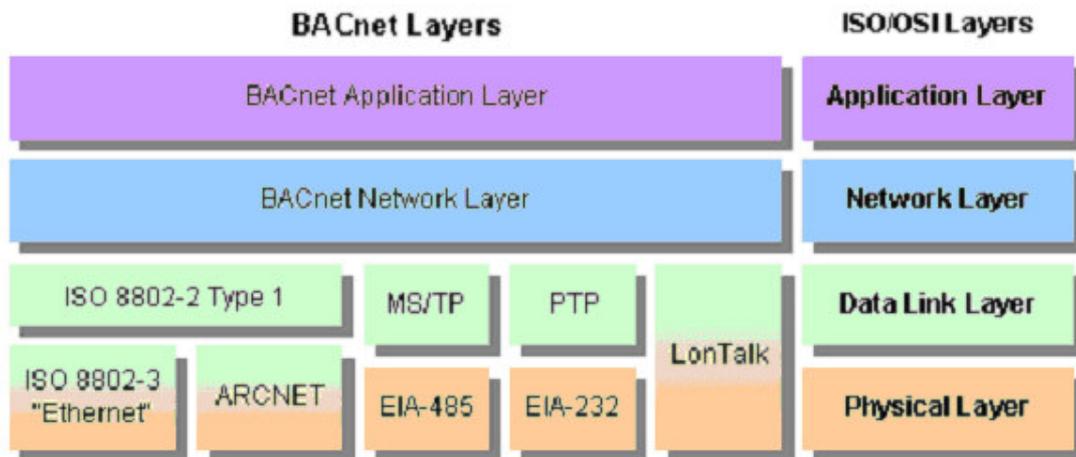
The Standards

- ANSI/ASHRAE 135
- ISO 16484-5
- ENV 1805-1

- 8.5 years in development
- Original standard published in 1995
- Updated standard published in 2001 that includes 5 addenda
- Approved as ISO standard in Jan-2003
- Available products include workstations, controllers, gateways, routers and diagnostic tools



BACnet Layers



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- The highest performance LAN option in terms of speed and data throughput is ISO 8802-3, better known as "Ethernet", which is very popular especially in the area of office networks. The second alternative is ARCNET (ATA/ANSI 878.1). In contrast to Ethernet, ARCNET uses a token-passing protocol to access the physical communication media and thus is deterministic, meaning that it is possible to place a bound on the maximum time that a device could have to wait before having a chance to transmit a message. This can be an important feature in real-time applications.

- The third networking possibility in BACnet, MS/TP (Master-Slave/Token-Passing), is not based on an existing standard (like Ethernet and ARCNET) but is a proprietary data link layer protocol which was designed from scratch. The MS/TP option was implemented to make it possible for manufacturers to build BACnet devices at lowest costs necessary for BACnet's success in competing with proprietary LANs. By virtue of its simple interface and its communication rates MS/TP can be implemented on many standard microcontrollers without the added cost of dedicated communications ICs. BACnet MS/TP uses EIA-485 as a physical layer.

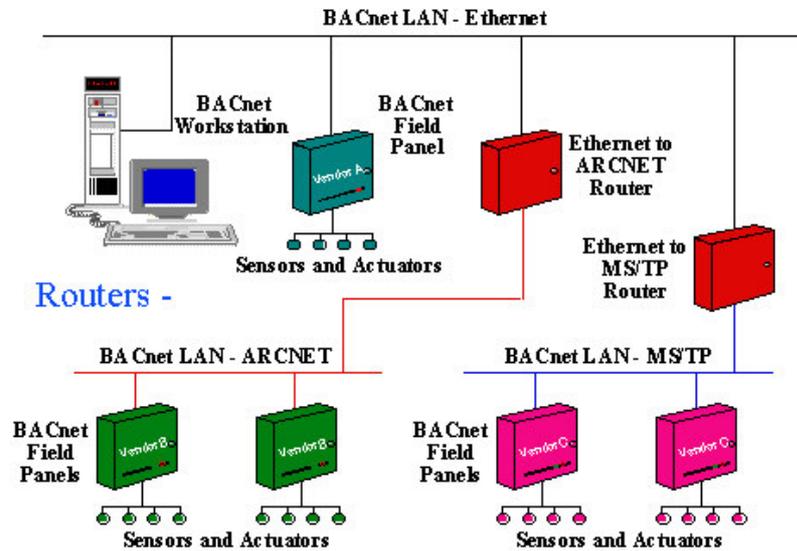
- The fourth option, LonTalk (ANSI/EIA 709), is the standardized language for the very popular building automation system LonWorks. BACnet only uses LonTalk as a data link layer protocol and does not make use of all the specific features defined in the LonTalk standard. LonTalk offers the greatest number of options in physical media including RF, infrared, twisted pair, coax and fibre-optic cables.

- The final data link and physical layer option in BACnet is the Point-To-Point (PTP) protocol. The PTP protocol accesses the communication medium through an EIA-232 full duplex interface. A typical application would be to connect to a modem for dial-up access to a remote building automation system.

- A single networking technology can be used in a system or multiple options can be combined to form a BACnet internetwork. In the latter case network segments using different LAN options are connected over router devices. It is frequently necessary to have multiple networks in a single installation. There may be too many devices to be connected to a single LAN, or the requirements of the installation might dictate the use of different types of LANs for different functions. In a typical scenario there is a number of controller devices based on MS/TP or LonTalk and a high-speed backbone based on Ethernet or ARCNET.



Network Layer



"re-package" BACnet messages and re-transmit them unchanged

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- The purpose of the BACnet network layer is to provide the means by which messages can be relayed from one BACnet network to another, regardless of the BACnet data link technology in use on that network.
- Some functions assigned to the network layer in the OSI model are not required in BACnet. One example is selecting a communications path between source and destination devices. BACnet imposes a requirement that, at most, one active path can exist between two devices.
- Another network layer function that BACnet does not support is message segmentation and reassembly. BACnet imposes a limitation on the length of the messages that pass through a router. The maximum length shall not exceed the capability of any data link technology encountered along the path from source to destination. Messages longer than this can still be conveyed, but they must be segmented and reassembled at the application layer. (Ethernet – 1497 bytes, ARCnet, MS/TP, PTP – 501 bytes, LonTalk – 228 bytes)



Network Layer PDU Structure

Version	1 byte
Control	1 byte
DNET	2 bytes
DLEN	1 byte
DADR	N bytes
SNET	2 bytes
Slen	1 byte
SADR	N bytes
Hop Count	1 byte
Message Type	1 byte
Vendor ID	2 bytes
APDU	N bytes

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- Control byte indicates the presence or absence of other network layer information. If the destination for the message is a device on the same network, no additional network layer information is needed. If the destination is on a remote network, the client device must include the destination network number and MAC address of the destination device. The router on the local network will insert addressing information about the local network so that a response can be returned. Thus, a device does not need to know its own network number.
- DNET – destination network number
- DLEN – length of ultimate destination MAC layer address (a value of 0 indicates a broadcast on the destination network)
- DADR – ultimate destination MAC layer address
- S... - source ...



Broadcast Messages

- Three forms:
 - Local
 - Remote
 - Global



•A local broadcast makes use of the broadcast MAC address appropriate to the local network's LAN technology, i.e., 0xFFFFFFFF for Ethernet, 0x00 for ARCnet, 0xFF for MS/TP, 0x00 in the DstSubnet field of Address Format 0 in LonTalk

•A remote broadcast is made on behalf of the source device on a specific distant network by a router directly connected to that network. In this case DNET shall specify the network number of the remote network and DLEN shall be set to zero

•A global broadcast, indicated by a DNET of 0xFFFF, is sent to all networks through all routers.



Application Layer

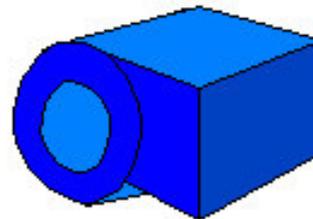
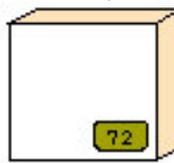
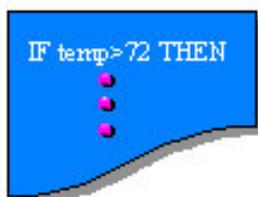
- The key to understand the BACnet Application Layer:
 - A model of the information contained in a building automation device
 - A group of functions or “services” used to exchange that information

- The internal design and configuration of a BACnet device is proprietary in nature and different for each vendor.
- BACnet overcomes this obstacle by defining a collection of abstract data structures called “objects”, the properties of which represent the various aspects of the hardware, software, and operation of the device.
- BACnet objects provide a means of identifying and accessing information without requiring knowledge of the details of a device’s internal design.
- The communications software in the device can interpret requests for information about these abstract objects and translate those requests to obtain the information from the real data structures inside the device.
- These objects provide a “network visible” representation of the BACnet device



Objects

Object_Name	SPACE TEMP
Object_Type	ANALOG INPUT
Present_Value	72.3
Status_Flags	Normal, Out-of-Service
High_Limit	78.0
Low_Limit	68.0



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- An object is simply a collection of information related to a particular function that can be uniquely identified and accessed over a network in a standardized way.
- All information in a BACnet system is represented by such data structures. The object concept allows us to talk about and organize information relating to physical inputs and outputs, as well as non-physical concepts like software, or calculations.
- Objects may represent single physical point, or logical groupings of points that perform a specific function. Objects meet the design requirement of providing each device with a common "network view," i.e., all objects, regardless of the machine in which they reside, look alike!
- All BACnet objects provide a set of properties which are used to get information from the object, or give information and commands to an object. You can think of an object's properties as a table with two columns. On the left is the name or identifier for the property, and on the right is the property's value. Some properties are read only meaning that you can look at the property value, but not change it. Some properties can be changed (written).
- The slide above shows an example of a temperature sensor, which might be represented as a BACnet Analog Input object. The example shows a few of the properties which might be available with this object, although in practice there would be many more properties than those shown.
- The object has a name property (SPACE TEMP) and an object type (ANALOG INPUT). The Present_Value property tells us what the temperature sensor is reading at this moment (72.3 degrees). Other properties show us other information about the sensor object, such as whether it appears to be functioning normally, or High and Low Limits for alarming purposes



Standard Object Types

 Binary Input	 Multi-state Input	 File
 Binary Output	 Multi-state Output	 Program
 Binary Value	 Multi-state Value	 Schedule
 Analog Input	 Loop	 Trend Log
 Analog Output	 Calendar	 Group
 Analog Value	 Notification Class	 Event Enrollment
 Averaging	 Command	 Device
 LifeSafetyZone	 LifeSafetyPoint	

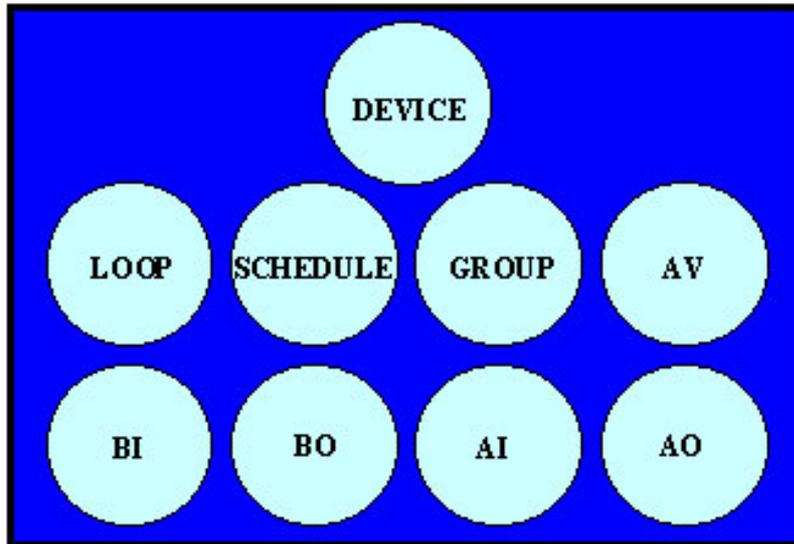
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- Although there are thousands of potentially useful object types which might be found in building automation, BACnet defines 23 standard object types in some detail. A BACnet standard object is one whose behavior, in terms of which properties it provides and what they do, is defined in the BACnet standard.
- This set of standard objects represents much of the functionality found in typical building automation and controls systems today. BACnet devices are only required to implement the Device object. Other objects are included as appropriate to the device's functions.



BACnet Device



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- A "BACnet Device" is simply a collection of objects that represents the functions actually present in a given real device. While the slide above shows only one instance of each kind of object in the example device, a more typical BACnet device might have 16 BI and BO objects, 2 or 3 Schedule objects, and so on.



BACnet Application Services

Alarm and Event services	Object Access services	Remote Device Management services	Virtual Terminal services	File Access services	Security services
<i>AcknowledgeAlarm</i>	<i>AddListElement</i>	<i>DeviceCommunicationControl</i>	VT-Open	<i>AtomicReadFile</i>	<i>Authenticate</i>
<i>ConfirmedCOVNotification</i>	<i>RemoveListElement</i>	<i>ConfirmedPrivateTransfer</i>	VT-Close	<i>AtomicWriteFile</i>	<i>RequestKey</i>
<i>ConfirmedEventNotification</i>	<i>CreateObject</i>	<i>UnconfirmedPrivateTransfer</i>	VT-Data		
<i>GetAlarmSummary</i>	<i>DeleteObject</i>	<i>ReinitializeDevice</i>			
<i>GetEnrollmentSummary</i>	<i>ReadProperty</i>	<i>ConfirmedTextMessage</i>			
<i>SubscribeCOV</i>	<i>ReadPropertyConditional</i>	<i>UnconfirmedTextMessage</i>			
<i>UnconfirmedCOVNotification</i>	<i>ReadPropertyMultiple</i>	<i>TimeSynchronization</i>			
<i>UnconfirmedEventNotification</i>	<i>WriteProperty</i>	Who-Has			
	<i>WritePropertyMultiple</i>	I-Have			
		Who-Is			
		I-Am			

- The second part of the development challenge was to agree on what kinds of messages building automation and control devices might want to send to each other. Because BACnet is based on a "Client-Server" communication model, these messages are called "services" which are carried out by the server on behalf of the client.
- Here are the services related to accessing the properties of the objects previously described. Their names pretty much describe what the services do. The ReadProperty service, for example, is a message that contains the object and property identifiers that uniquely identify which object's property is to be read and sent back. The message is always sent to a specific recipient and returns, hopefully, the requested property value in a standard form.



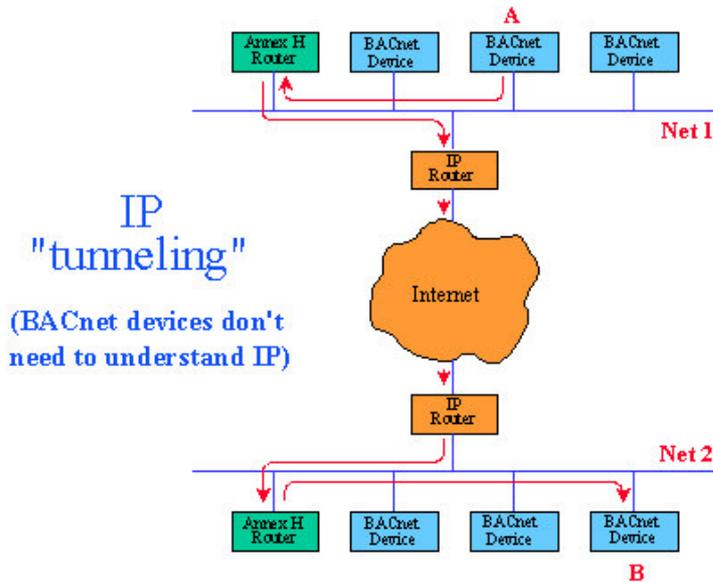
Internet Message

- Two ways to provide internet message:
 - IP Message Tunnelling
 - BACnet/IP

- Beside using the LANs referred to previously, BACnet messages can travel over networks that use the Internet Protocol (IP) as their networking protocol.
- The major distinction between the two ways that BACnet can work over an IP internet can be summarized as follows:
 - In IP message tunneling, the BACnet devices don't know, or need to know, anything at all about IP.
 - In BACnet/IP, each BACnet device is actually a full-fledged IP node, complete with its own IP address and IP protocol stack.



IP Tunnelling



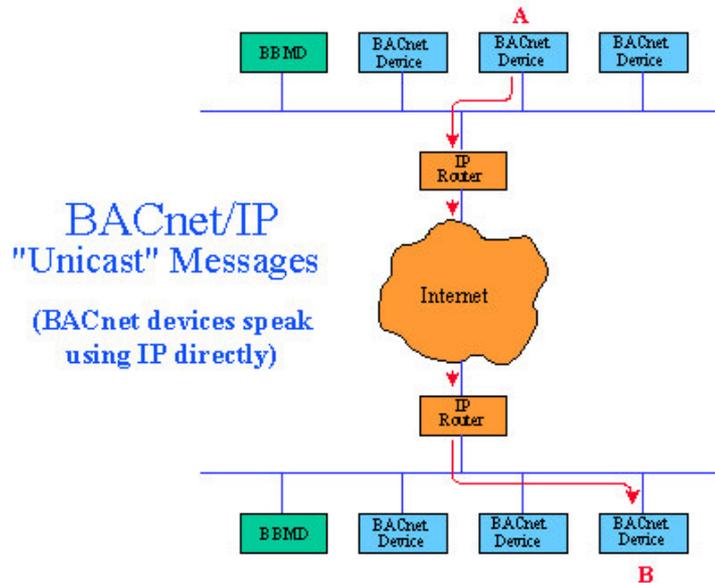
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- In IP tunneling, Device A on Network 1 addresses a message to Device B on Network 2 using the BACnet network layer protocol. It sends the message to the Annex H router on its local network. (The router is called an "Annex H" router because Annex H is the place in the standard where this process is defined.) The Annex H router knows how to send IP messages over the Internet (or an "Intranet" based on IP) to its peer device on Network 2. It encapsulates the BACnet message (in a User Datagram Protocol frame) and sends it via IP to the Annex H router on Network 2. Note that both networks are connected via a standard IP router to the Internet at large.
- When the Annex H router on Network 2 receives the IP message from its peer, it removes the encapsulated BACnet message and sends it on to its final destination, Device B.
- The only downside to this is that each message shows up twice on each network - once as a pure BACnet message and once as an IP message.



BACnet/IP



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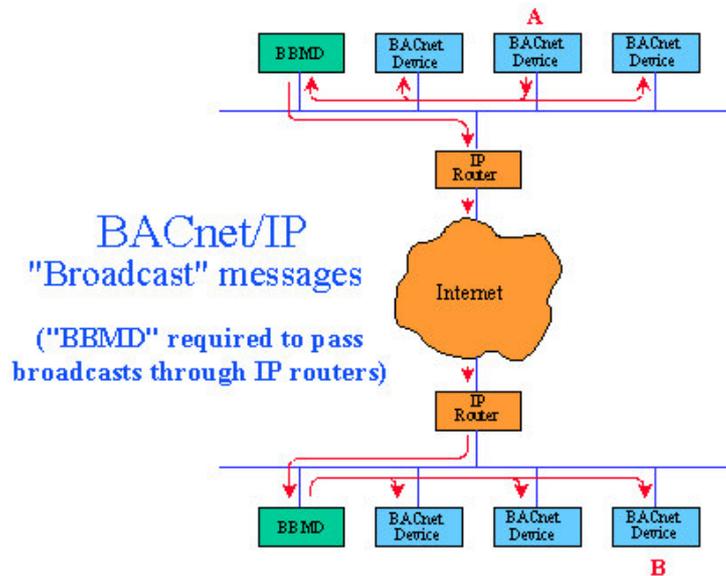
- BACnet/IP is a different beast entirely. BACnet/IP devices view the IP internet as if it were a local area network. A device's IP address (a 4-octet number like 128.253.245.74) serves the same purpose as a device's MAC or physical LAN address in other BACnet networks (and in the BACnet network layer protocol control information).

- The "BACnet Virtual Link Layer" or BVLL provides a set of messages that are used to deal, among other things, with specific idiosyncrasies of IP networks, such as the way broadcasts are handled. In addition, BVLL concept provides the following benefit:

- the BVLL control information can be easily extended to encompass virtually any kind of new network technology or other "microprotocol" that might come along. (A microprotocol is a set of rules that provide a "value-added" function like data encryption or data compression on packets that are otherwise ready for transport.) This means that with a minimum of fuss a specification could be developed to run BACnet directly over Asynchronous Transfer Mode (ATM) networks, Synchronous Optical Networks (SONET), Frame Relay networks, Integrated Services Digital Networks (ISDN), etc., and to provide for enhanced security and efficiency measures, all without touching BACnet's existing application and network layer protocols.



BACnet/IP Broadcast



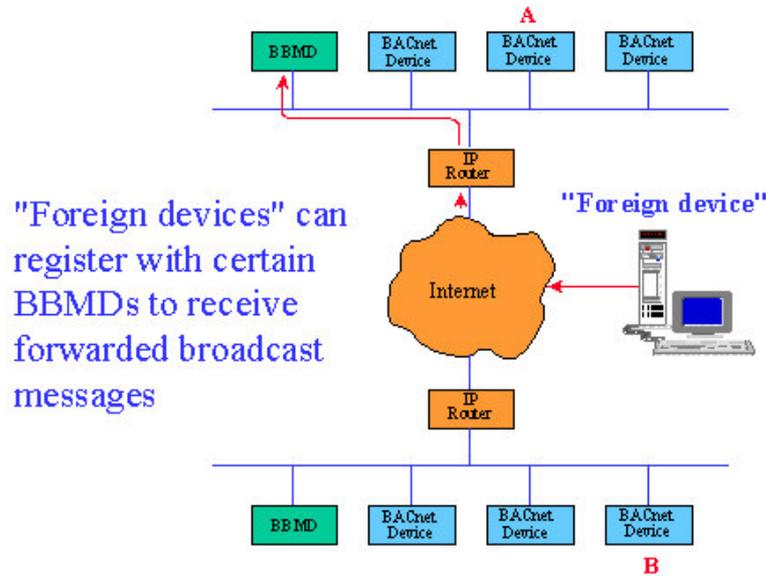
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- BACnet/IP devices don't need Annex H routers and can talk with each other directly over the Internet. The only hitch is that IP routers don't normally pass along "broadcast" messages, i.e., messages intended for all devices on a BACnet internetwork. Enter the "BACnet Broadcast Management Device" (BBMD).
- BBMDs act similarly to the Annex H routers previously described except that they only handle the forwarding of broadcasted IP messages. Since broadcasts are generally used very infrequently in BACnet, their propagation should not cause any problems.



Foreign Devices registration



- BACnet/IP also allows “foreign devices” to join the BACnet network from any subnet via SLIP or PPP, e.g., through an Internet Service Provider (ISP)
- By registering with a BBMD, the foreign workstation becomes a member of the BACnet/IP network and will receive forwarded broadcast messages from the BBMD when they are available and can request that messages be broadcast by the BBMD on its behalf. The foreign device can, of course, talk with any BACnet device directly without registration but will only receive broadcasts if the registration procedure is followed.



Why Should BACnet Succeed?

- User demand
- No fixed architecture
- Object model is easily extended
- Doesn't depend on current technology
- Broad participation in its development
- Many vendors are committed to it
- Global interest

•Benefits of BACnet:

- No charge for its use – anyone may develop implementations without cost
- Maintained by an ASHRAE committee representing all sectors of the industry
- Designed specifically for building control
- Can be implemented in devices of any size
- Can be readily enhanced and improved
- Not tied to present technology