# BACnet® Unplugged

## ZigBee® and BACnet Connect

By Jerald P. Martocci

BACnet forms the facility's information spinal cord in many buildings. Until now, BACnet was a predominantly wired communication technology. The challenge is to take the past innovation of wired BACnet systems and apply them to an increasingly wireless world. Recognizing that wireless yields cost savings and other benefits for many facilities, ZigBee Alliance is working with the BACnet Standing Standards Project Committee on an addendum to the BACnet standard, which would tunnel BACnet over ZigBee wireless networks.

ZigBee is an open technology and communications standard designed to promote interoperability between wireless devices. Applications span commercial, residential, and industrial markets. They include climate and lighting control, home health care, energy management and efficiency, as well as telephony.

The ZigBee Alliance formed to develop low-cost, low-power, self-forming, self-healing and reliable wireless sensor/controller networks. It is an association of companies working to develop and promote ZigBee, which is a global communications protocol and global standard for digital radio frequency technology.

The integration between BACnet and ZigBee began in January 2006, when the ZigBee Alliance invited the BACnet Committee into discussions. Two months later, the two organizations held a joint planning meeting, followed by the establishment of reciprocal working groups in April. ZigBee ratified its changes in June 2007. In January 2008, the BACnet Committee approved Addendum *q* for public review. The review period concluded May 2008.

### How ZigBee Works

Most BACnet sensors, actuators and controllers can be made wireless. Wireless gives installers greater flexibility in the placement of sensors and controls. The question is, how do installers tie wireless and wired devices together on a common infrastructure?

ZigBee nodes reside on a mesh network. The mesh resembles a street grid, with wireless "streets" connecting at various intersections. Each intersection is a node on the network. Nodes serve two functions. They can transmit, receive,

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and interpret information. They can also function as repeaters, allowing information to hop from one node to the next en route to its destination.

Signals do not necessarily take a linear path. When a drawbridge is raised over a river, drivers can take an alternate route over another bridge. The mesh works the same way. If one node fails, another repeater can reroute the signal through the mesh to the appropriate receiver. This ability to self-heal is one of the primary benefits of a ZigBee wireless infrastructure.

ZigBee networks are self-configuring. The sending node only needs to know the address of the receiving node. The data's exact route through the mesh meanders from node to node until it completes its journey. This type of network is simple to install.

ZigBee devices offer flexibility and can use ac or battery power. Onboard processors regulate energy use, extending battery life. ZigBee devices can idle in sleep mode during periods of inactivity. This increases their energy efficiency dramatically.

| | BACnet | ZigBee |
|---|---|---|
| Governance | ASHRAE | ZigBee Alliance |
| Standard Established | 1995 | 2004 |
| Markets | Commercial Buildings | Commercial and Residential Buildings |
| Object Model | Well-Defined | Work-in-Progress |
| Network | Various Wired Media<br>No Wireless | 900 mHz and<br>2.4 gHz Wireless |
| Power | Line Powered Devices | Line Powered<br>Battery Powered |
| Availability | Devices Always On | Devices Always On<br>or Sleeping |
| Data Rates | 9.6 – 76.8 kbps (MS/TP)<br>9.6 – 56 kbps (PTP)<br>78.8 kbps (LonTalk)<br>156 kbps (Arcnet)<br>10 – 100+ mbps (BACnet IP) | 250 kbps |
| Network Technology | Multiple | Mesh |
| Compatibility Testing | Established | Established |

*Table 1: Comparison between BACnet and ZigBee protocols.*

Security and IT departments worried about data security when digital radio frequency devices first emerged. They feared enterprising hackers could steal data or take control of building systems. ZigBee devices support encryption strong enough to reassure most cynics. A skilled systems integrator can network devices in a way that benign data, such as lighting controls, have basic security while more sensitive data, such as access controls, gets rigorous encryption. The BACnet network security feature, which recently completed public review, is functionally equivalent but an alternate implementation.

Critics also once worried about bandwidth. Today's ZigBee devices transmit information at comparable speeds to wired sensor, actuator, and controller devices using MS/TP communication. Because they are digital, they are just as accurate.

### Connecting a ZigBee Device to a ZigBee Network

A networked mesh of ZigBee nodes is called a personal area network (PAN). Each PAN operates independently of all others. Nodes within the PAN serve two purposes. The stack layer routes messages from an originating node to a receiving node. It is what allows nodes to function as repeaters, relaying data through the mesh. The application layer fulfills a function on the network. For example, a temperature sensor's function is to transmit temperature information to the building management system.

Before it can function, each node must be associated with a PAN. This is accomplished through a multistage commissioning process.

Each node has a unique IEEE 802 MAC address. Some are preprogrammed at the factory or by their installers to "know" the PAN to which they are intended to belong. If not, the newly installed node's first action is to search the mesh for a commissioning tool. The commissioning tool, often a ZigBee-enabled laptop, identifies the node by its unique address, establishes a connection and programs it to belong to a given PAN. A second tool, residing on the same laptop, uploads application data.

Once programmed, the node must find its PAN on the mesh. It issues a series of calls designed to locate a node designated as the coordinator. Only one coordinator exists on each PAN. Once the new node and coordinator find and recognize one another, a connection is established.

ZigBee is capable of transmitting encrypted data for added security. Security-enabled PANs have an additional node designated as the trust center. When the new node joins the PAN, the trust center determines whether it has permission to send and receive encrypted messages. If so, it programs the node with security policies such as whether the encryption key will be fixed or dynamic.

### Connecting the ZigBee to BACnet

Once a ZigBee node finds and connects to its PAN, it must find the subset of nodes that form its BACnet network. It does this in three ways: with a broadcast, multicast, or unicast call.

A broadcast call goes out to the entire PAN. Each node within the PAN receives the message, interprets the message, and replies with whether or not it belongs to the appropriate BACnet network. Although broadcast calls are programmatically simple to make, they place undue stress on the ZigBee network, consuming bandwidth and forcing every node on the PAN to read and interpret the message.

A multicast call is preferable in most cases. Here, a group of nodes is predefined as belonging to the BACnet network. Nodes not belonging to this predefined set can quickly reject the call without receiving and interpreting much data. Because this process consumes less bandwidth, it is preferable for larger networks.

For a unicast to work, the new node must be programmed to connect with one predefined node on the BACnet network. The node pings every other node in the PAN until it finds the appropriate BACnet node. The process conserves bandwidth but takes longer.

Once all ZigBee nodes locate and associate themselves with their assigned BACnet networks, they establish a pipeline for data transmission. A series of calls is placed to determine how data will flow through the pipeline. The process refines rate, speed, and other parameters to ensure the most efficient flow of information.

The integrated BACnet and ZigBee network is fully configured after the commissioning process is complete. Data travels on the wireless network much the same as it would on a wired network.

Neither ZigBee nor BACnet restricts the size of messages. Both technologies can accommodate any size message by chopping it into packets. This ability is called segmentation in BACnet and fragmentation in ZigBee.

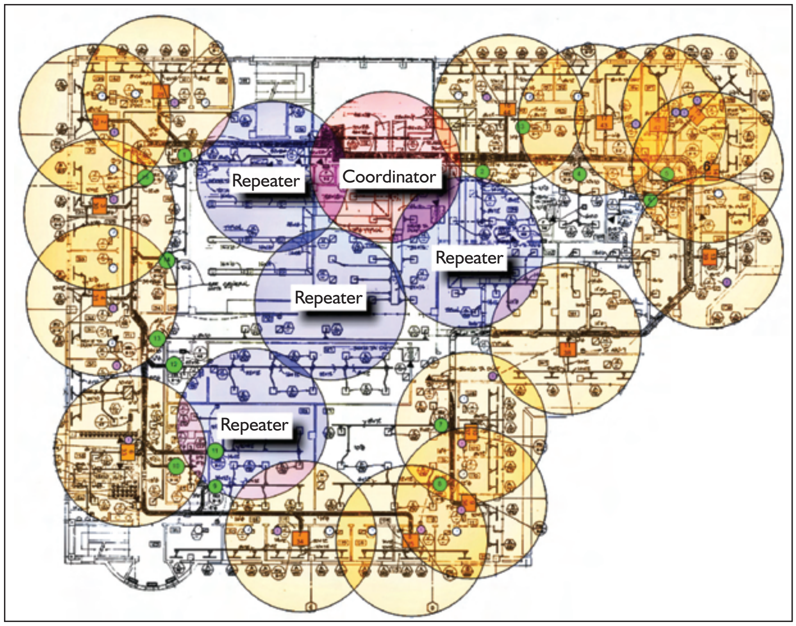


*Figure 1: A schematic of Georgia Tech's College of Computing shows the ZigBee network's coverage area, with repeaters providing redundant paths between all nodes.*

### Case Study

Georgia Tech University recently installed ZigBee functionality in its 40,000 $ft^2$ (12 192 $m^2$) College of Computing. Universities are ideal candidates for wireless infrastructure. Older buildings often have solid core walls, making wiring projects difficult and expensive. They also put a premium on space. Classrooms, laboratories, and faculty offices are in constant use. Scheduling installation involves working around class times and office hours.

The College of Computing had one thermostat for every three offices. To save energy, facility managers set the thermostats to allow ±9°F (±5°C) temperature variability at night and weekends. However, should a professor wish to work during off hours, he could push a button to give himself three hours of climate control.

The university wanted to upgrade the system to give faculty greater control and comfort. However, facility managers determined it would be prohibitively expensive to wire additional temperature sensors for each of the professors' offices. Georgia Tech brought on a controls company to design and install a wireless ZigBee solution instead. Using wireless technology, the company installed one temperature sensor in each office, as well as one occupancy button to provide after-hours comfort. The solution included 17 wireless controllers, 34 wireless sensors, and three additional repeaters for a total of 54 nodes. This implementation used a BACnet to ZigBee gateway installed on the MS/TP network extending the wired MS/TP network to the wireless ZigBee network. The ZigBee sensor and controller network then transmitted its wireless data back through this device onto the BACnet MS/TP network. This implementation was completely transparent to the preexisting wired BACnet devices.

Facility managers are impressed with the solution. The College of Computing is a harsh radio frequency environment full of competing wireless signals. The ZigBee network operates continuously even with ambient RF interference. It operates no differently, with no increase in downtime or error, than a completely wired system.

Facility managers are looking at wireless to solve spot problems around campus. For example, if a thermostat is above a piece of equipment that throws off a lot of heat, such as a copy machine, it can be inexpensively replaced with a wireless thermostat and situated elsewhere in the room. Wireless sensors and controllers are easier, faster, and less expensive to install or move. They also cause less disruption to workflows and avoid the need to alter or damage architecture.

## Conclusion

As new wireless applications and benefits emerge, longtime BACnet proponents are growing comfortable with the ZigBee and BACnet relationship. Vendors have come aboard as well. Many have recently announced and released ZigBee-based commercial products.

The relationship is still in its infancy. However, given its benefits, it's possible that the ZigBee and BACnet one-two punch may quickly become a dominant media for systems interoperability.●