white paper Wireless

Wireless Controller Networks for Building Automation

Benefits and opportunities for facility owners

t.a.c by Schneider Electric

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I. Executive Summary

Wireless technology has transformed communications in many areas, such as cell phones and PC networks. Now, with recent advances in technology and cost, as well as the emergence of standards, wireless solutions are ready to be deployed in building automation networks.

The cost of wiring alone is incentive enough for many building owners to look at wireless control systems, since wireless installations can be done anywhere, at any time, saving from 20% to 80% of the installation cost of controls. Wireless networks that are based on the IEEE mesh standard of networking are self-configuring, so they can be installed with minimal expertise and system administration.

Benefits extend well beyond installation savings. Wireless mesh control networks are highly reliable, self-healing, reduce life-cycle maintenance costs, and can be integrated gradually and seamlessly with existing standards-based wired networks.

Wireless also brings new flexibility to building control. Instead of placing controls where wiring permits, building owners are free to place controls where needed to improve building performance. This could have a major impact on energy efficiency, reducing wasted lighting and heating expenditure by 50 percent in many cases.

TAC has made its entire family of field controllers wireless-enabled, based on the leading standards, enabling organizations to take advantage of wireless building control networks for both new and existing facilities. Previously hard-to-wire or challenging structures - such as hotels, museums, large retail spaces and constantly changing office layouts - can be networked into a control system with little or no disruption.

As wireless technology continues to advance, new applications will emerge, expanding the ability of building owners to manage and control their buildings for performance and savings.

II. Promises and challenges of wireless networks

As the world moves to wireless, it is only a matter of time before controller networks in buildings are wireless too.

The potential of wireless networks is enormous. Consider, for example, that installation alone can account for *20% to 80% of the cost* of a HVAC system.[1] Imagine if those costs could be dramatically reduced in some areas.

The business drivers go well beyond immediate cost savings too. A report by Frost & Sullivan cites these additional potential benefits of wireless networks:[2]

- **Interoperability** – they have the ability to interface with the existing wired systems which are present in 90 to 95 percent of the buildings
- **Flexibility** – wireless devices can be easily detached and setup at another place in case the office is relocated or redesigned
- **Retrofitting** - only the installation cost is incurred. Just imagine the potential of low-cost wireless devices in the mammoth retrofit building market
- **Challenging environments** - they can be deployed in hard-to-reach and hard-to-wire applications typically found in older buildings

[1] Michael Kintner-Meyer, Pacific Northwest National Laboratory, “Opportunities of Wireless Sensors and Controls for Building Operation”, 2004.
[2] Frost & Sullivan, "Wireless Communication - The Opportunity is Knocking”, 13 Apr 2005

These are many of the same benefits that have driven the wireless revolution in other markets, from cell phones to home networks.

Furthermore, facility managers face a growing mountain of challenges, making the appeal of wireless simplicity even greater. Among the problems faced, Frost & Sullivan cite "reduced operating and capital budgets, staff shortages, information overload, increased regulations from safety monitoring organizations and government bodies, [and] pressure to reduce downtime."[3]

All of these challenges can be alleviated, to one degree or another, with wireless networks.

WHAT HAS BEEN HOLDING IT BACK?

The expected explosion in wireless networks has been waiting for several key issues to be solved.

To put it simply, a dropped cell phone call is one thing, but building control systems must meet a higher standard, and there is no room for controllers that are constantly going offline as network connections fade or break down.

Among the concerns to be overcome have been:

- **Multipath interference** – Radio frequencies, used by wireless controller networks, are subject to interference from each other, and from other technologies that may be present in a facility
- **Data security and reliability** – As with all networks, security and reliability are critical
- **Cost** – The first wireless devices were too expensive to attract the interest of building owners
- **Transmission collisions** – When two nodes attempt to send data at the same time, their messages sometimes collide thus disrupt network traffic.
- **Physical obstructions** – Wireless communication can be obstructed by walls, beams, columns, floors and ceilings.
- **Health concerns** – There has been some concern that the radio frequency (RF) signals of a wireless network can be damaging to health.

Over the last few years, these concerns have been addressed through various advances in technology, design and manufacturing.

A key advance in wireless has been the reduction in cost. Wireless technology has reached the price point where devices can be distributed liberally throughout a building and still realize savings. This is a critical factor, because the easiest and most reliable solution to interference, obstructions and other problems is to place wireless devices where needed to sustain reliable connections.

Data encryption is now available on low cost chips that can be easily added to wireless devices, not only keeping prices low, but also protecting data through encryption.

Multi-path interference and transmission collisions cannot be avoided. However, depending on the wireless technology, these occurrences of collisions and multi-paths may be reduced or handled in a non-disruptive manner. Simply by designating a specific channel for a wireless network can help isolate that network.

Physical obstructions can be overcome by choosing the proper site locations that will maximize network communications while minimizing interference. In addition, wireless mesh networks are designed to include path redundancy. If a one path is obstructed, the transmission messages simply travel through another route.

[3] Frost & Sullivan, Technical Insights, “Smart Sensors and Sensor Networks: Opportunities for Networked Intelligent Wireless Sensors”.

Whereas there are no definitive studies linking RF radiation to harmful effects on humans, the power levels of wireless controller networks are over 200 times less than what is allowed for cell phones and Wi-Fi networks.

STANDARDS — THE FINAL PIECE OF THE PUZZLE

The last issue holding back wireless adoption has been a lack of standards, but that too is changing rapidly with the advent ZigBee, an emerging wireless standard.

According to Frost & Sullivan, Bluetooth did not catch on as a standard because it was suited for continuous streaming data. Wi-Fi also did not take hold because of energy consumption issues. But according to most analysts, ZigBee, which is based on IEEE 802.15.4, is arising as a de facto standard. Analyst Michael Poole writes:

> *"What really seems to hold enormous potential for the BAS industry is ZigBee. Designed for low bandwidth, occasional data and the ability to be used in mesh networks is what make this technology the most suitable for the building automation markets."*[4]

The momentum for ZigBee as a standard is clearly growing. In early 2006, ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) formed a working group to investigate making ZigBee part of BACnet (a major protocol for wired building networks).[5]

In a recent press release, the ZigBee Alliance (an association of companies committed to the ZigBee standard) and the ASHRAE BACnet Committee announced they will work together to establish interoperability between the two technologies. Meetings to plan and implement the interoperability are already underway.[6]

ZigBee describes how the BACnet messages are delivered wirelessly. The BACnet message is the same whether used in wired or wireless networks ensuring interoperability with existing BACnet devices.

Since BACnet is a major communications standard for wired building automation, the coordination of efforts with ZigBee is a major step in creating the interoperability that building owners need.

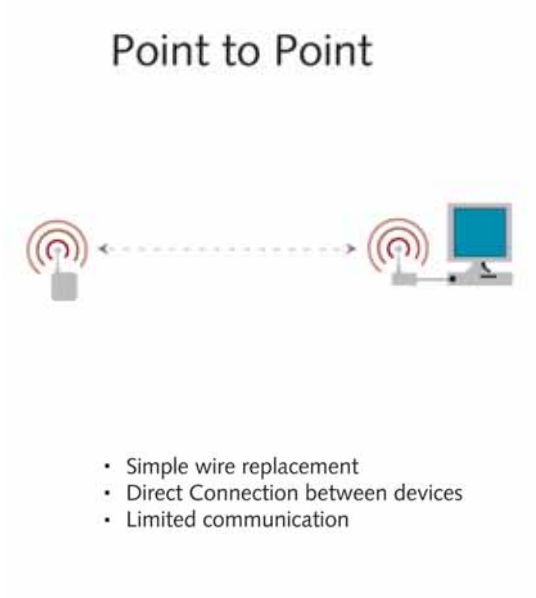
WIRELESS IS READY

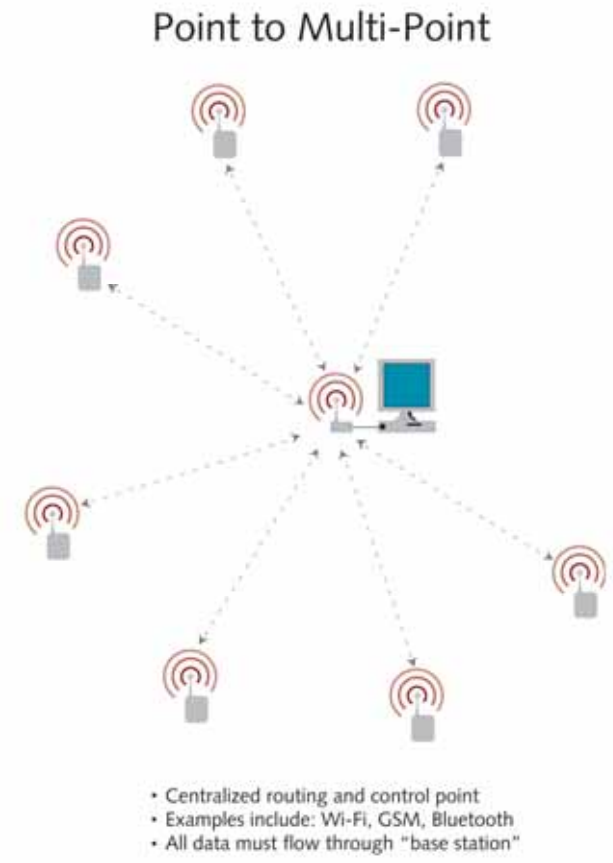
With the emergence of standards, it appears that wireless controller networks are ready to take their place in the tool box of building owners and facility managers.

Wireless networking is a technology whose time has come. The benefits are simply too great to pass up for facility managers who are pressed by budget constraints and maintenance woes.
The next section describes how wireless networks operate and takes a closer look at the significant benefits they make possible.

[4] Frost & Sullivan, "Wireless Communication - The Opportunity is Knocking, 13 Apr 2005
[5] "Where's the Wire?", CSE Magazine, May 2006
[6] "ZigBee AND BACNET Link up," ZigBee Alliance press release, May 17, 2006

III. Overview of wireless building automation networks





HOW THEY WORK

Wireless technology for building automation is, in principle, no different than other wireless technology we are all accustomed to, such as home wireless PC networks. However, they must be more reliable, use less power and be more cost-effective.

Wireless controllers broadcast and receive high-quality radio frequency (RF) signals to establish and maintain network connections with other controllers, forming a network that works, functionally, as if the system were wired (except with far greater flexibility).

Since the power levels of wireless networks are limited by regulatory agencies, their range is typically a few hundred feet or less, depending on obstructions. Thus, wireless network nodes must be close enough to send and receive signals to each other.

Wireless networks can have different topologies, or organizations, depending on their purpose or limitations in the environment. In the early days of wireless, most networks were structured in one of two ways:

Point to Point. A point to point link is a direct connection from one device to another. In practice, point-to-point links have limited use. One controller might have a point to point wireless link to a nearby hub, where it joins the rest of the network. Or point to point can be used to send a wireless signal over a long distance, from one device to the next.

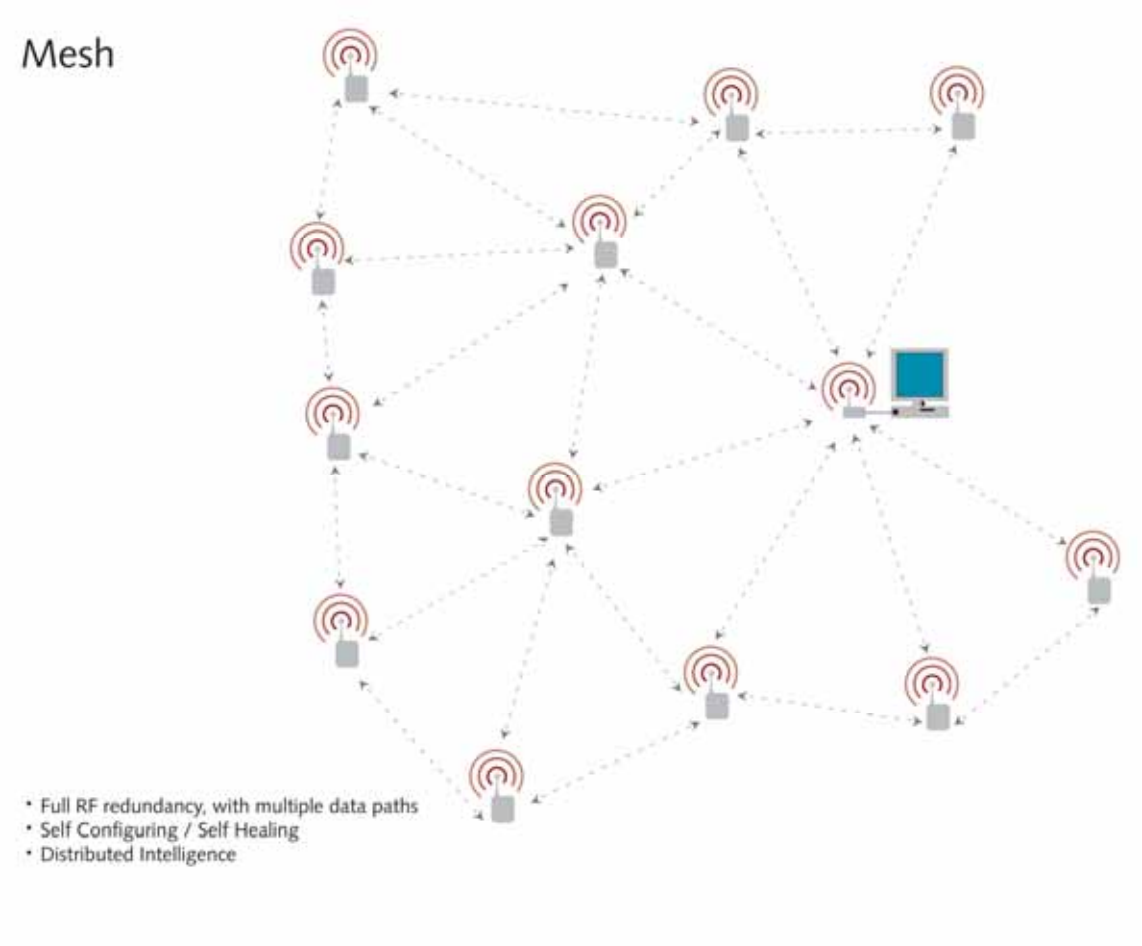
Point to Multi-point. Point to multi-point networks are a hub-and-spoke arrangement, with a central point that controls communication with all of the other wireless nodes in the network. This type of network, which is commonly used in home PC wireless networks, is simple to implement and manage, but has limitations. Since every node must interact directly with the hub, the area of the network is restricted to the strength of the RF signal. Also, if there is any interference between the hub and an end node, the devices are out of touch with each other until the interference is fixed.

THE EMERGENCE OF MESH NETWORKING

A key development in recent years has been the mesh network, made possible by advances in microelectronics and miniaturization, allowing more computing power to be embedded in inexpensive devices.

Mesh. Mesh networks use distributed intelligence to communicate with all other devices within range. Not only can all nodes send and receive messages, but they also function as routers and can relay messages for their neighbors. Through this relaying process, a packet of wireless data finds its way to its ultimate destination, passing through whatever intermediate nodes are available.

The result is, literally, a "mesh" of intersecting communication lines.



Obviously, in order to realize the full benefit of a mesh, each node must be within signal range of two or more other nodes. An inexpensive way to accomplish this — in case controllers are too far apart — is to use low-cost repeaters, whose only function is to fill in the mesh and provide more connections for the network. It's interesting to note that while mesh networks enable effective wireless communications, the reverse is also true — mesh networks are only practical thanks to wireless technology.

Mesh is supported by ZigBee, the emerging standard for wireless building controls. And while it is simple in concept, mesh networking has profound implications for building owners.

A CLOSER LOOK AT THE BENEFITS

Self-configuring. Mesh networks are self-configuring, because each device in the network contains a micro controlled router. This means that changing the network or adding a new wireless controller is as simple as attaching it to an inconspicuous wall or behind a door. The network discovers the newly "installed" device and incorporates it into the network, without the need for a system administrator.

Self-healing. Just as importantly, mesh networks are self-healing. If a device loses contact with one neighbor, it simply finds another one to "talk" to. This makes mesh networks extremely reliable. The more nodes that are in range of each other, the "denser" the network is, and the more reliable it becomes.

Simplified maintenance. Wireless networks, whether mesh or another topology, are easier to maintain. Maintenance personnel can use a laptop or handheld diagnostic device to communicate and perform diagnostics, without running wires. This is a significant advantage in cases where controllers are inside storage tanks, on top of towers, or in other hard-to-reach locations.

Reduced life-cycle costs. Installation cost savings are usually enough to justify wireless controllers. Additionally, wireless networks continue to generate savings throughout their life-cycle because they are so easy to maintain, move, or replace.

Seamless upgrades, transitions. With the ZigBee Alliance and the ASHRAE BACnet Committee now coordinating their efforts and industry leaders delivering open products, the transition to wireless is not an all-or-nothing proposition. Wireless control networks can be phased in easily - one room, area, floor, or building at a time. A building undergoing floor plan or other changes is an ideal opportunity to install wireless controls.

Flexibility. Free from wiring and all the associated problems and costs, building owners can place wireless controllers virtually anywhere. Instead of hiring wiring architects and teams of technicians, then phasing installation over a period of weeks or months, one person can walk around the building, placing controllers wherever needed.

This is a paradigm shift in how facility environments can be managed. Instead of placing controllers where they are easy to wire, controllers can be placed *where they are actually needed* to optimize building performance and environment, and keep up with floor plan changes.

"Instead of placing controllers where they are easy to wire, controllers can be placed where they are actually needed to optimize building performance."

THE IMPACT ON ENERGY EFFICIENCY

One of the greatest benefits of wireless networks in building automation may well be energy-efficiency, made possible by the easy, low-cost deployment of sensors and controls wherever needed.

As of 2003, only 5.4% of the existing U.S. commercial buildings (23.5% of the U.S. commercial floor area) were equipped with an energy management and control system (EMCS).[7] While European buildings are further along in that regard, most facilities suffer from the limitations for wiring.

[7] Pacific Northwest National Laboratory, “Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways”, April 2005

The typical commercial building uses thermostats to control air temperature in the building zones with little special resolution for heating, cooling, or ventilation requirements. Often sensors and controllers are sparsely used, in order to limit the capital cost of the control system. As a result, climate conditions are often too hot or too cold, insufficiently ventilated, and probably very energy inefficient.

Since energy-efficient control systems typically produce double-digit savings, the ability to go wireless for low installation costs is a powerful incentive for many organizations. By installing a wireless mesh control network over a wide area, many organizations can reduce wasted lighting and heating expenditure by 50 percent.[8]

A Frost & Sullivan report gives this example:

> Wireless sensing devices...can detect the presence of a person inside the facility or the specific cubicle and turn on power devices selectively. It would not be necessary to turn on the entire HVAC system for just one person who decides to work on the weekend. This could result effect in massive cost savings.[9]

The next section explains TAC's wireless controller solution and how it takes advantage of open standards, wireless capabilities, and a broad range of controllers to give building owners a new level of control over their facilities and their budgets.

IV. TAC Andover Continuum Wireless Solution

OVERVIEW

TAC, a leading provider of open, standards-based control systems for building automation, has developed a complete line of wireless-enabled controllers.

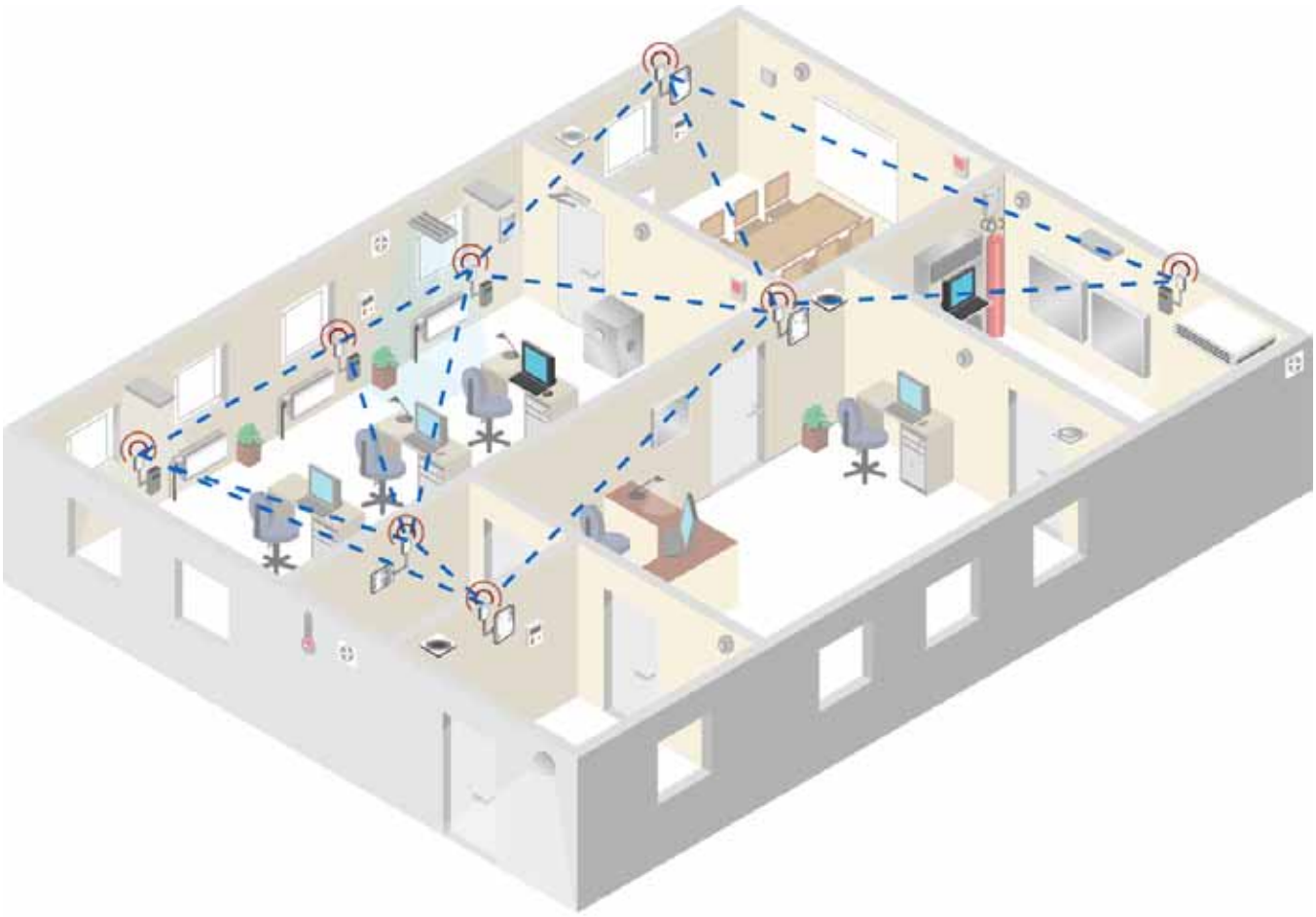
The solution is based on the TAC Andover Continuum family of controllers, which is used in more than 40,000 buildings around the world to control the largest to the smallest applications — from chillers, cooling towers, boilers, and air handling units to packaged HVAC units, heat pumps, and fan coils units, to security applications (e.g. access control, motion detection, glass break detection, intrusion detection).

The TAC wireless solution is the first to support a full range of BACnet B-AAC controllers that are ZigBee ready. The TAC solution also provides a smooth transition to wireless for TAC customers as well as users of other standards-based solutions.

In addition, TAC provides a powerful and graphical management tool that allows system administrators to see and manage the entire wireless network — based on real-time information from the wireless-enabled controllers.

TAC's combination of wireless flexibility, standards-based technology, and a comprehensive range of controllers gives building owners the opportunity to take advantage of all the wireless benefits described in the previous section of this paper.

[8] Frost &Sullivan, "Wireless Communication - The Opportunity is Knocking, 13 Apr 2005
[9] Frost & Sullivan, Technical Insights, “Smart Sensors and Sensor Networks: Opportunities for Networked Intelligent Wireless Sensors”.



A typical control network using TAC's wireless solution. Each building controller or router can support up to 32 nodes of wireless field controllers. These router/controllers provide the function of linking the wireless controllers to the building's Ethernet network.

A COMPREHENSIVE SOLUTION

TAC's wireless solution provides a full set of capabilities for implementing a wireless network solution, including:

- A full line of wireless-enabled Andover Continuum Infinet and BACnet field controllers, providing control solutions for every aspect of building management.
- Wireless devices (adapters and repeaters) that allow users to create a wireless mesh network segment that connects Andover Continuum Infinet or BACnet controllers within a network.
- A Wireless Maintenance Tool with a powerful and graphical dashboard to help building owners view, manage, tune and maintain a stable and robust wireless mesh network.
- CyberStation software as the front-end interface for both wired and wireless controllers enabling users to view graphics and trends, run reports, modify schedules, change setpoints, manage alarms, and more. The Building Management System is accessible from multiple interfaces such as fixed workstations, service tools, wall displays and through the Internet.

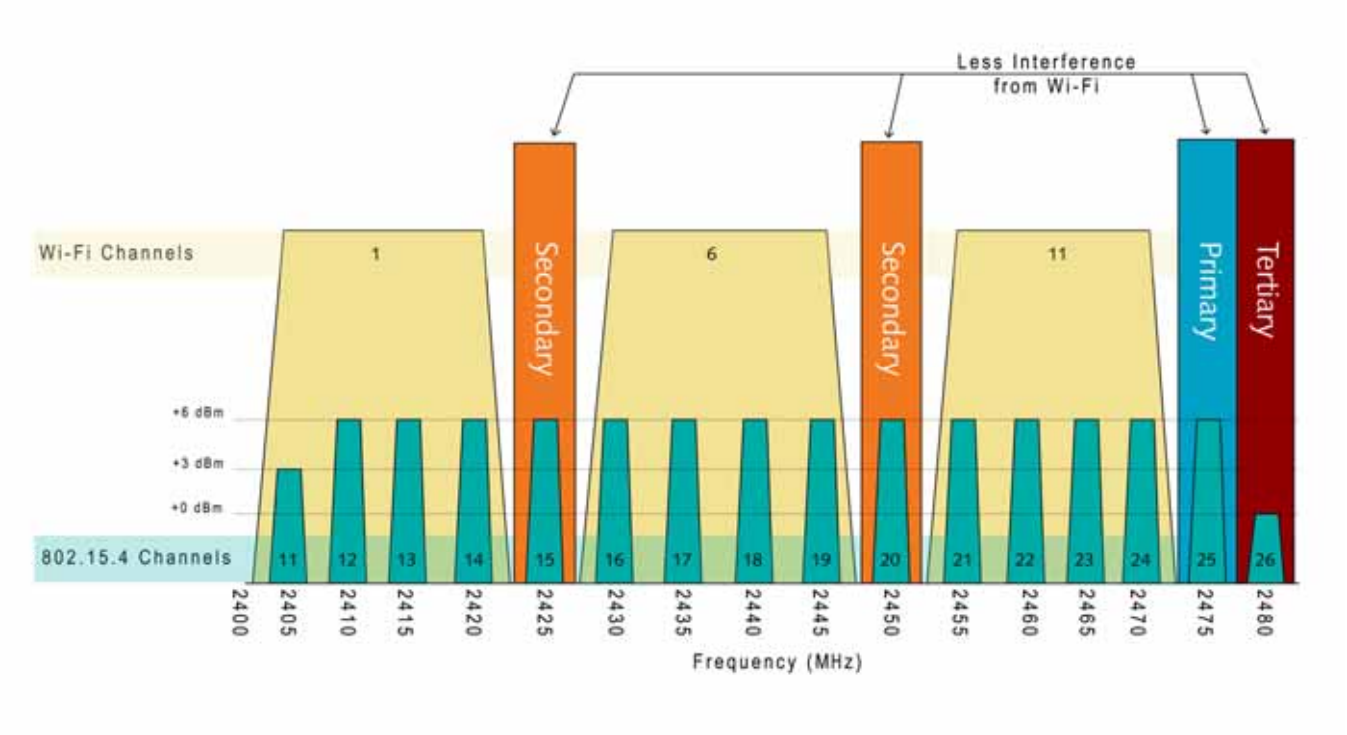
OPEN AND STANDARDS-BASED

TAC's solution is based on the leading industry standards, in order to provide interoperability and backward compatibility for existing TAC customers. Thus, new wireless controllers can be installed as needed, and companies can upgrade over time, as they choose.

BACnet. Andover Continuum's full family of BACnet controllers conforms to the ASHRAE standard 135-2004. Any one of these devices can become part of a wireless network, keeping your system BACnet compliant while maintaining the convenience of wireless.

ZigBee. TAC's solution is based on the same IEEE 802.15.4 standard that the ZigBee Alliance is using in their evolving standard. ZigBee mesh topology allows for low-cost installation, high network reliability, and flexibility to place environmental controls where they're needed — not just where maintenance staff can reach or where wires are easy to install. When the ZigBee standard is finalized, TAC's solution can easily be upgraded for ZigBee compliance.

2.4 GHz frequency range. TAC's wireless solution uses the 2.4 GHz frequency range, the most globally compatible frequency range for wireless communications. According to Frost & Sullivan: "Radio communication takes place in the unlicensed spectrum. In North America, it is the 916 MHz and 2.4 GHz bands, and in EU it is the 868 MHz and the 2.4 GHz bands.... 2.4 GHz is an unlicensed frequency worldwide."[10]



The graph shows the frequency ranges commonly used by Wi-Fi channels and designated IEEE 802.15.4 channels. By specifying the wireless controller network channel, the system can avoid interference from other wireless networks.

[10] Frost & Sullivan, Technical Insights, "Smart Sensors and Sensor Networks: Opportunities for Networked Intelligent Wireless Sensors".

SUPERIOR WIRELESS NETWORK PERFORMANCE

TAC's wireless solution uses "proactive discovery," providing increased network reliability. Proactive discovery means the network configures and reconfigures itself constantly. The network assumes that links will fail and performance will change, so it continually searches for and 'remembers' optimal linkages.

In addition, TAC utilizes dynamic routing, where messages are broadcast to all neighbors, which further enhances network performance and communications reliability.

Although 'decisions' on traffic are made locally by the wireless devices, the network can be managed globally with the Wireless Maintenance Tool.

CENTRAL NETWORK MANAGEMENT

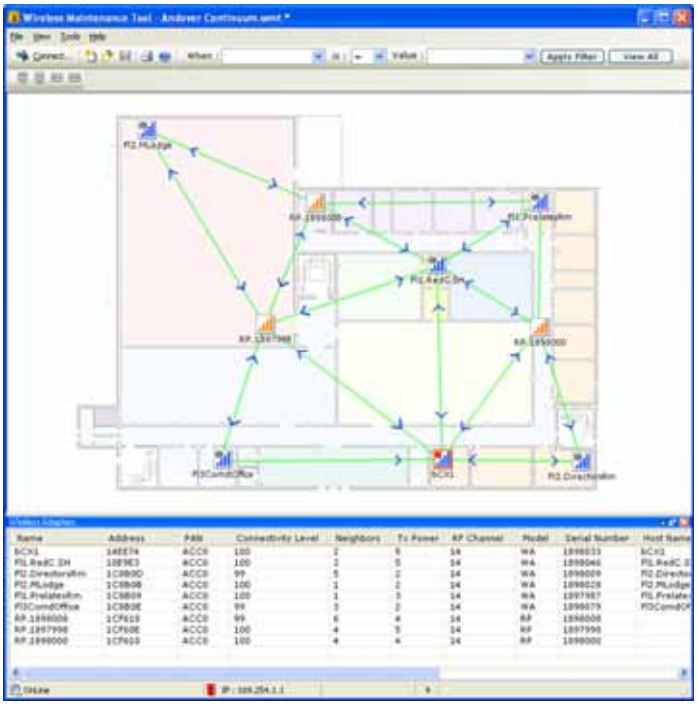
A powerful, graphical Wireless Maintenance Tool lets network administrators monitor and control all of the nodes on the network. Unlike many solutions, which let you see the node but still require you to adjust its settings physically at the controller, TAC provides the ability to actually make adjustments and exercise true building control from your desktop.

From the network control station, you can access every wireless node, choose from 16 channel selections, and set the power level, so you can adjust the wireless settings for any device on the network, at any time. This makes it a simple matter to adjust power settings when needed to suit the environment — for example, in hospitals where there are restrictions on RF power.

Graphic display and control. Network display screens graphically present the mesh network, all the devices in it, and their connectivity levels. Right click on any host or adapter icon and you can filter the display or check the properties for that adapter. The network can be mapped onto actual floor plans, to accurately reflect the location of each wireless node.

Using TAC's Wireless Maintenance Tool, administrators can:

- Check and adjust link quality of each node
- Identify number of 'neighbors' for each node
- Measure signal strength
- View power settings, PAN ID and channel numbers
- Ping test
- Trace test



Users can view the entire wireless network at any time, with connections and signal strengths clearly displayed.

Through the wireless control station, users can see the settings of each node and make adjustments remotely.

Tabular Reports. Using the Wireless Adapter Details Table, you can see even more information. This table lists online/offline status, filter status, number of neighbor connections, and so on. Tabular reports can be customized easily to provide a simple overview for management and troubleshooting. Runtime data from all nodes on the wireless network is updated every second, so the information is always accurate.

Tabular reports make it easy to drill down into various network segments and devices for management and troubleshooting.

V. Wireless at work: Application examples

With TAC's combination of wireless capabilities, open standards, and a broad range of controllers, building owners can gain a new level of control over their facilities and their budgets. Areas that previously could not be wired - due to physical challenges or budgetary reasons - can now be monitored and controlled cost-effectively with wireless technology.

Following are some of the applications where wireless networks offer immediate advantages and opportunities for building owners.

Retrofits and upgrades. Since over 90% of existing buildings are wired, the immediate potential for using wireless controller networks in these buildings is in phased upgrades, expansions, or layering new capabilities onto the existing wired network. For example, building owners can use wireless to enhance environmental controls and achieve dramatic gains in energy efficiency.

Commercial offices. Office environments and layouts change often in response to the changing business needs of tenants or companies. In a life-cycle perspective, wireless solutions offer significant savings and less disruption of tenants or occupants.

Retail. Previously hard-to-wire, large retail spaces can take advantage of wireless controller networks. Also, the constantly changing building layout due to new tenants makes wireless an attractive solution. The potential energy savings are especially attractive to retailers too, because they typically operate on extremely thin profit margins.

New construction. Increasingly, new buildings are expected to take advantage of wireless technology to reduce initial costs and offer tenants greater flexibility and ongoing savings.

Hotels/hospitality industry. Wireless solutions allow changes or retrofits with a minimum of occupant disruption, thus preventing customer dissatisfaction or loss of income.

Museums and historical buildings. Glass, marble, high ceilings or sealed wall construction are often found in museums and older buildings. Wireless technology offers a unique solution to implement controls without destroying the historical integrity.

Fast track projects. Deadlines that would be impossible to meet with wiring solutions are quite possible, and even easy, using wireless networks.

High-cost installation areas. In some applications, the savings from wireless can be large, such as when union electricians perform installations, when electrical codes require conduits, or when trenches between buildings are required.

Small remote structures. Areas that previously were not worth the cost and trouble can now be monitored and controlled, such as parking gates, pumping stations, warehouses and storage facilities.

Dangerous installations. Many walls in older buildings cannot be penetrated without exposing workers to asbestos or creating other health or safety issues. Wireless networks avoid these problems.

The Masonic Temple historic building

The Challenge

St. John's Masonic Temple in Newburyport, Massachusetts, was originally built in 1880 and was converted to a Masonic lodge in the 1920s. Because of the structure's age and its designation as a historic landmark, the Masons faced several challenges when they began looking for a way to reduce their energy costs.

The three-story building relied on an aging control system to provide heat for 10 zones. However, the zones were unable to communicate with each other, and only two were able to command the boiler to start operating. Further complicating things, the building usage did not follow "regular" hours. When an evening event required heat, the building manager had to start the boiler several hours ahead of time. Then someone would have to turn off the system manually or it would run all night.

As a non-profit organization, the Masons were not in a position to fund the high-cost installation of a new building control solution. Moreover, thick walls would have made it time-consuming and costly to add traditional controls in difficult-to-wire locations.

The Solution

TAC integrated a wireless controller network with the Masonic Temple's existing thermostat-controlled, heat system to provide enhanced climate control throughout the facility. A phased installation ensured a non-disruptive conversion to the new solution.

Wireless capabilities lowered installation costs by eliminating the need to contend with hard-to-wire locations. It also enabled the Masons to leverage new technology without disturbing the integrity of this historic building.

TAC was able to reuse the existing system's valves. However, TAC replaced the old hardwired thermostats with wireless controllers and digital "Smart Sensors". Then TAC networked the building's 10 climate control zones: four on the first floor, four on the second floor, and two on the third floor. Each zone now communicates with a master controller in the basement—and any zone can call for heat.

The building manager uses a single workstation to schedule requests for heat in advance. Turning on/off the fans, valves and boilers is now handled automatically — not manually. Controlling the Masonic Temple's indoor climate is now transparent to those who use the building.

The Bottom Line

After TAC had enabled just three of the 10 zones with wireless technology, the Masonic Temple reported that it had reduced fuel oil consumption by 1,000 gallons in a 3-month period. The organization expects even greater fuel savings now that the entire control system has been updated.

The building owners were able to update their environmental controls systems and achieve significant energy savings, as well as many other benefits - without violating any wiring restrictions placed on historic buildings.

VI. Future applications and opportunities

With the problems of wireless networks resolved, and the emergence of standards now well underway, analysts expect new applications to be developed that take advantage of the unique capabilities of wireless technology.

Areas that were impossible to wire — and therefore not even considered — are now not only possible, but practical and cost-effective.

For example, one analyst states that the structural health of buildings will be monitored in new ways: "Advancements in nanotechnology are enabling production of tiny sensors which can be placed at various joints, reinforcements, and other places during construction of a structure. These sensors constantly monitor the structural health and provide accurate data regarding cracks, excessive loads, or any other critical situation."[11]

Meanwhile, wireless technology itself is expected to continue advancing. On the horizon are frequency-hopping technology to improve network connectivity, advanced security algorithms, and continued reductions in size, cost, and capabilities. In addition, the emergence of standards in wireless networking, such as ZigBee and BACnet, will help accelerate adoption by providing interoperability and a smooth transition path for building owners.

VII. Conclusion

Just as wireless technology has transformed other communications, from cell phones to home PC networks, wireless is ready to take its place as a cost-effective, flexible solution for building automation and control.

Not only does wireless networking dramatically reduce installation costs, it continues to produce savings through simplified maintenance, flexibility, and the opportunity to improve building performance for significantly reduced energy costs.

For both new structures and old, wireless networking is expected to grow by leaps and bounds, improving existing applications and opening up new ones as the technology advances and matures.

VII. About TAC

TAC is a leading provider of building automation solutions and services for indoor climate, security and energy use, delivered with advanced technology to end users and property owners throughout the world. With over 80 years of experience in the HVAC, building automation and security arenas, TAC has over 3,700 employees worldwide with partners and branches in 75 countries.

TAC's parent company, Schneider Electric, is the world's power and control specialist for the residential, building, industry, energy and infrastructure markets. Its world-class brands include Merlin Gerin, Square D and Telemecanique. With 92,000 employees and operations in 130 countries, Schneider Electric generated sales of €11.7 billion in 2005 through 13,000 distributor outlets.

[11] Frost & Sullivan, Technical Insights, "Wireless Sensors in Building Automation," Feb. 2005

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