

# Benefit of IP in Commercial Buildings

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## **Benefits of the use of the Internet Protocol in Commercial Buildings Automation**

The motivation for using the Internet Protocol (IP) in buildings relates to general convergence trends in both the information technology and building sectors. In this white paper, we focus on the technical implementation of building automation systems, and illustrate the benefits of the widespread use of IP, enabling interoperability between diverse building automation systems. We will illustrate in which areas IP will simplify creation of building automation systems and where additional effort is required for these systems to become reality.

### **1. The architecture of current building automation systems**

Building Automation Systems (BAS) are traditionally composed of one or more vertical subsystems, with each subsystem often divided into horizontal, functional layers. Traditional building subsystems include heating, ventilation and air conditioning (HVAC) control; lighting applications; security monitoring; and fire detection & annunciation. These subsystems are designed to operate independently or collaboratively. As an example, the HVAC subsystem typically controls air flow within a building to maintain comfort while minimizing cost. However, if the fire subsystem detects smoke or fire, the HVAC system will alter its primary function in order to exhaust smoke from the fire's location.

Contemporary BAS systems typically interface to IT networks, data centers, video surveillance, elevator control, and shade control. As more entities such as lighting control and energy management within the facility are automated, monitoring and controlling these entities will be integrated into the BAS.

Each vertical subsystem is comprised of functional layers composed of sensors, actuators, local controllers, enterprise controllers, and user portals. Driven by technology and economics, BAS functionality has evolved from centralized to distributed designs. System performance and reliability has increased as specific control functions can be implemented as closely as possible to the device itself. As an example, room temperature control was the province of a centralized mini-computer in the 1980s. Today, room controllers are installed in the room itself, directly monitoring and controlling room temperature. Communication to the higher system layers is by exception only (e.g., if data or events need to be reported to a business system for organization-wide analytics). Table 1 provides a representative sampling of these device applications, while Table 2 provides communication parameter requirements for each of the layers.

An HVAC system is designed to maintain prescribed comfort and safety policies at minimal cost, and will automatically adjust intake and exhaust air to reach comfort levels while abiding by regulatory air exchange requirements. Chillers, boilers, and air handling equipment are monitored and controlled, and building startup and shutdown are all controlled by the HVAC system.

Lighting systems address all lighting applications within the facility, and often utilize HVAC schedules to optimize energy by scheduling lights appropriately. Modern lighting systems also have variety of user interfaces, including the ability to access room scheduling databases to further optimize lighting.

Security systems monitor and control various building aspects such as door access for building personnel and tampering of window and door entry points. The advent of cost-effective video cameras allows centralized monitoring of the building interior and perimeter in real-time.

The fire system is integrated with all other building systems, to assure that the fire system can override all necessary normal operating conditions in case of emergency.

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Device Type	HVAC	Lighting	Security	Fire
<b>Sensors</b>	Room Temperature Outdoor Air Temp Humidity CO <sub>2</sub> Room Occupancy	Light Switch Sun Load Ambient Light Level Room Occupancy	Movement Window Tamper Door Ajar Sensor	Smoke Detector CO Detector
<b>Actuators</b>	Dampers Air Intake/Exhaust	Lights Dimmers	Door Actuation	Sirens Strobe Lights Pull Stations
<b>Local Controller</b>	Room Controllers Fume Hood Controllers Clean Room Controllers Fire Alarm Detection	Light Scheduling Fire Alarm Detection Shade Control	Personnel Admittance	Fire Panel
<b>Enterprise Controller</b>	Energy Management Subsystem Integration Smoke Control Alarm Management Temporary Overrides 3 <sup>rd</sup> Party integration User Access Redundancy	Lighting Schedules Event Overrides User Access	Video Surveillance Parking Lot Monitoring Watchtour Terrorist Lockdown Alarm Management User Access	Smoke Control Evacuation Manual Override Automatic Override Fireman Auto-call Elevator Override User Access Fireman Access Redundancy

Table 1 – BAS Distributed Application Examples

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Device Type	Media Type	Communication Rate	Application Protocols Supported	Typical Number of Devices Supported on bus
<b>Sensors</b>	EIA-485 EIA-709.3 802.15.4	9.6–76.8 kb/s	BACnet MS/TP LON	1- 16
<b>Actuators</b>	EIA-485 EIA-709.3	9.6–76.8 kb/s	BACnet MS/TP LON	1- 16
<b>Local Controllers</b>	EIA-485 802.15.4	38.4–76.8 kb/s	BACnet MS/TP LON	1 - 100
<b>Enterprise Controllers</b>	Cat-5e	10/100 mb/s	BACnet IP (IPv4) Web Services SNMP	100+

Table 2 – BAS communication Requirement Examples

Additionally, building systems typically support a configuration mode to allow initial setup. These systems can then be programmed for automatic control based on normal operating conditions, as well as for fail-safe operation in case portions of the overall system are inoperable. Mission-critical systems often have either hot or passive redundancy based on the control requirements. All systems also have user interfaces with the ability to override automatic control with manual, temporary overrides.

## 2. Vision of Future Building Automation Systems

The traditional topology of BAS systems will continue to evolve as technology, cost points and standards change. Sensors will likely be designed using wireless interfaces supplanting wired ones. Due to regulatory requirements in the fire and security markets, wireless interfaces will be less prevalent for these applications. However, the HVAC and lighting sectors have already begun transitioning to wireless sensors. These devices incur significant installation cost savings and are more adaptable to building remodeling than their wired counterparts. Thanks to technology advances, particularly in mesh networking, wireless communication reliability has improved considerably, and is now nearly as reliable as wired communication. The use of energy scavenging, battery-less sensing devices has reached a cost and technology threshold where such sensors are now commercially available.

Room controllers typically accept inputs from sensors, but then control the environment through actuation, which requires power levels not achievable via energy scavenging or battery power. Actuators will likely be line-powered devices, which support a higher cost point and contain available processing power and memory. As a result, these devices will likely support IP sooner than will sensors.

Enterprise controllers already support IP (mostly IPv4), SNMP, and web services. They traditionally fulfill the task of gateway devices by translating proprietary protocols into a common object model. As the industry develops and deploys more application standards, this gateway function will decrease, thereby rendering the device less useful. Additionally, area and room controllers will directly support IP and web services in the future, overtaking tasks of and eventually eliminating enterprise controllers.

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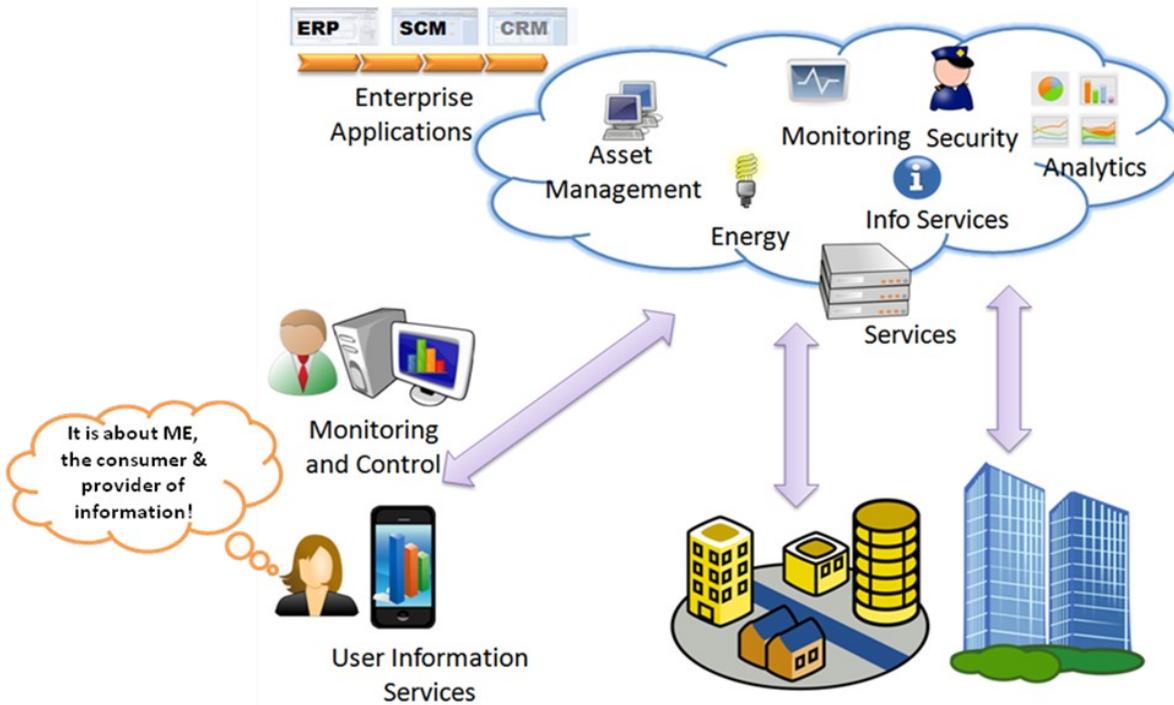


Figure 2 – Converged System with Enterprise Integration and Facility Management

### 3. Technological Benefits

Just as individual elements in building automation systems (sensors, room controllers, enterprise controllers) are evolving, so too will the way these elements interconnect change significantly. This change will lead to additional benefits in terms of development and maintenance cost, feature richness, and customer satisfaction.

**System convergence:** Employing the same general-purpose technology, infrastructure, and often even the same wiring for different applications can deliver significant cost savings. A single technology is typically easier to manage, secure, and troubleshoot than multiple incompatible, application-specific communication infrastructures. Convergence will allow standardized interaction between different components of automation systems. In addition, the common communication substrate enables more rapid innovation, where new applications do not need new communication networks, and where different applications can more freely communicate with each other. For instance, movement sensors can be useful not only in intrusion detection, but also in temperature and light control systems. These qualities are vital in today's dynamic business environment.

**IP-based:** One fundamental difference between current and future systems will be the adoption of IP as a core communication protocol. A high level motivation for this change will be system convergence and the synergies it will create. From the technical point of view, IP-based communication will allow the adoption of well-proven Internet technologies and enable interoperable interaction among heterogeneous systems directly without the use of custom-built gateways, effectively increasing the business value of the infrastructure itself. Due to its vast adoption and maturity, the creation of large IP-based networks is well-understood, and supported by a large variety of products. Using IP-enabled approaches for building automation therefore allows access to this well-established toolbox and eliminates the need to develop dedicated or home-grown networking solutions for building automation, also minimizing vendor lock-in and isolated infrastructures that may not match contemporary requirements for security, trust, privacy, and business performance. Adoption of IP end-to-end thus lessens both current and future costs. Furthermore, the ubiquity of IP will help to further simplify the

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systems and focus on the offered functionality, rather than on proprietary implementations, enabling a new generation of cooperative and dynamic services to emerge in the building domain.

Finally, introducing IP to building systems will also foster adoption of a layered communication architecture. Using IP as a communication protocol demands a clear separation between physical and logical communication. Therefore, participants in the system need not be aware which physical technology is used to communicate to a specific participant, enabling focus on services provided in the automation domain, rather than maintaining low-level interactions over proprietary protocols. This layering will greatly simplify interaction, as less knowledge about the physical system is needed to exchange information. Such an approach will accelerate a new generation of automation services with a much richer and faster development lifecycle than today's segmented and isolated systems, eventually keeping up with the rapid progress in the information technology domain.

**Structured Cabling:** Structured cabling is a standardized method for cable installation and management. The advantage of this type of installation procedure is to provide for an application-tested and approved method for usage, installation, documentation and reuse of networking cable. Cable installation, labeling, documentation, terminations, and patching are all provided for in structured cabling guidelines. The maximum length of any cable is documented on a per application basis. Cable lifetime can be extended with this type of approach procedure as the installation location, termination, usage, and distances are all recorded in a standard fashion. Reuse potential of the cable is greatly increased during retrofit and remodeling, as the function and ownership of each cable is recorded in a standard fashion. Similarly, applications are tested and documented to ensure interference is not coupled to end devices or existing wires. One example would be an all IP-based architecture, which would treat an IP sensor as an ordinary end device, and therefore would be managed the same as all other CAT5 or CAT6 end points or hosts. Another benefit is the noise rejection and isolation of each individual wire pair for an IP based installation, compared to other cable installation types.

**End-to-end:** One of the key paradigms of the Internet architecture is the end-to-end principle, which suggests that many functions can be correctly implemented only in the end nodes, and that the network in between should implement only the essential functions. All devices and management components should be able to interact directly with each other via a common IP infrastructure, whose task is to deliver data packets from sender to receiver over the network. The network infrastructure (e.g., switches, routers) will forward the packets based on network-related information (such as IP address or QoS class) and will not use any information from the application that is carried in the packet's data payload.

Following this paradigm enables the creation of flexible and extensible systems. The alternative is a gateway-based system in which individual parts are interconnected via protocol translators; as noted earlier, protocol translation gateways have benefits and drawbacks, with flexibility and scalability being a particular challenge.

By contrast, flexibility and scalability are fundamental benefits of an end-to-end IP architecture, enabling the creation of larger systems by extending the network via routers while reducing the need for special physical communication interfaces with extensive range. For example, when a house with several floors is equipped with a wireless intrusion system, wireless networks may be set up on each floor and interconnected via Ethernet, power line or wireless, rather than necessitating the use of proprietary (and costly) extended range network transports.

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Furthermore, a large collection of tools already exists for managing IP-based networks. Many of these tools are freely available, further lowering cost. Some of the most common tools include the ping utility for checking reachability and latency; packet sniffers (such as Wireshark) that help troubleshoot network traffic; and Simple Network Management Protocol (SNMP) applications for remote management.. Advanced functionality such as dynamic discovery, universally addressable names, and network address translation (NAT) can also be used. Having these components readily available is a significant improvement compared to dedicated, non-IP enabled devices, for which all protocols and tools must be developed individually.

Another benefit that the end-to-end principle provides is additional flexibility for individual component placement. For instance, management functionality can be freely distributed in the system to accommodate requirements such as performance, reliability, and redundancy. Consider a large shopping mall, which must always provide a pleasant climate. In such a scenario, reliability is vital, so management functions are likely to run on redundant servers. In a simpler scenario where cost is more important, one could install the management software on an off-the-shelf PC with no further redundancy mechanisms. Finally, one could even put the HVAC control onto devices themselves, as in the case of a thermostat mounted inside a room, so that no IT equipment is needed for such a system. When the end-to-end principle is respected, the management components and the devices can be placed wherever it is logistically best for the particular system, as long as they are connected to a common network.

**Based on IT systems:** Ultimately, all parts of the automation system, including sensors and actuators, will be intelligent and networked via IP, with the difference between classic IT systems and building automation systems disappearing. Thus, the building automation domain can employ the powerful solutions developed in the IT world. Currently, the creation of building automation features (e.g., security) is the dedicated and extensive task of comparatively small communities like BACnet, LON or KNX. In the future, solutions like IPSec, VPN, or SSL that have been developed, used, and that are constantly improved by larger Internet communities will be integrated into building automation. Also, typical building system functionalities like discovery and description of devices or alarm notifications are already supported by web protocols like DPWS, Bonjour, and UPnP. Thus, building systems can and will benefit from the advanced solutions of the larger IT world.

Due to their wide adoption, web technologies are accompanied by a collection of sophisticated free and commercial tools for design, development, and testing, which promises to support cost-effective development of future automation systems by enabling faster development cycles and providing a choice of a larger portfolio of hardware platforms.

## 4. The Missing Pieces

While the vision and benefits of future building automation systems are clear, the step-wise migration path to this new IP-based architecture is not yet fully in place, as technical and business challenges must first be addressed.

One major challenge is to provide these new, IP-enabled building automation systems at a reasonable initial cost. These new systems rely on more intelligent devices, cross-layer system interaction, and more advanced communication technologies, which may lead to increased up-front system cost, even if the elimination of additional wiring and infrastructure helps offset the cost for the initial implementations.

For example, the key enabler for the future building automation systems will be the support of IP on each device, necessitating integration of IP-capable transceivers. These transceivers must provide comparatively high

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performance communication in order to support IP, while addressing cost and energy constraints. Fortunately, a set of existing solutions like 802.15.4, Wi-Fi, and powerline already fulfill these requirements for certain scenarios in the building automation domain. In the future, this portfolio must still be augmented with other wireless and wired solutions so that IP communication will be possible in all application areas. Over time, general-purpose technology will be manufactured in substantially larger quantities, which helps drive down future costs. The bill of materials (BOM) for a device itself is not the only factor that influences system cost. Energy consumption is a major concern, particularly for battery-powered wireless devices. Normally, these devices are powered by standard, cost-effective energy sources like AA batteries; despite this fact, battery replacement is a system maintenance effort that often requires specialized staff. Therefore, it is crucial that battery replacement is not required before the regular system maintenance intervals.

A cost-effective wireless solution therefore must combine IP communication, low chip cost, and long battery lifetime. Currently, proprietary solutions can achieve the required battery lifetime—but only at the cost of sacrificing IP compliance. However, 802.15.4 and low power WiFi-based solutions have the potential to cope with all of these requirements. Power over the communication line (e.g., power over Ethernet) and emerging energy scavenging (self-powered) systems are being slowly integrated into commercial products, and may provide more cost- and maintenance-effective solutions.

While challenges to achieving the required cost effectiveness exist, future building automation systems also provide tremendous opportunities for substantial cost savings compared to contemporary systems. Cost saving will come from using standard IT equipment in the form of IP routers, switches, cabling, and existing tools and mechanisms to manage these system components. In addition, convergence with IT systems will create new business opportunities by enabling more flexible business models, and via the creation of advanced functionalities and services (e.g. optimization of energy cost). The migration to IP-based building automation systems will take place once these benefits outweigh the BOM and maintenance costs. Additionally, building systems will evolve as do individual components, thanks to the introduction of new technologies which will lead to better lifecycle management of the building infrastructure.

The other major challenge to migrate to these envisioned systems will be the definition of common services and interaction contexts. While the Internet Protocol allows for data exchange with each device in the building, additional protocols must still exchange meaningful information. This requirement can best be explained by looking at the analogy of making a phone call. A person's phone, together with the telephone provider's infrastructure, makes it possible to call virtually anyone on the planet. However, even if a person is able to call anyone, he is only able to communicate with people who speak the same language. The opportunity to call someone is independent of the ability to actually communicate with that person. Similarly, IP and the IP network make devices accessible, but only a common set of upper layer protocols or services combined with device profiles will allow for meaningful communication with the devices to achieve the desired value of control. The web technologies in the Internet are an excellent example of this heterogeneity and how it can be mastered.

Switching to IP is therefore only the first step when creating future building automation systems. Common protocols and data formats must be agreed upon to enable devices from different vendors and even different domains (e.g., building, health care, IT) to interoperate with each other. Such protocols must be flexible enough to accommodate disparate functional requirements coming from different domains and applications, and must also support future business models built on continuously evolving Internet-based services.

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One could argue that a number of well-established building automation standards which could fill this gap already exist. The only migration effort required is to transmit the same data packets, as defined today, via the Internet Protocol. However, this approach would be an oversimplification of the fundamental changes that occur when migrating to IP. We can again use the telephony example to illustrate the effect of switching from a closed, specialized system to an open, IP-based system. In recent years, most carriers have migrated from an analog solution to digital emulation of analog voice called Voice over IP (VoIP) based systems. Apart from the task of communicating audio via IP, these systems also must support connection establishment between two parties. In traditional analog systems, the caller types in the recipient's phone number, which generates a sequence of pulses or tones that are processed by the carrier's infrastructure and finally lead to the recipient's phone ringing.

A straightforward translation of the previous dialing mechanism would be to simply send the telephone number of the recipient in an IP packet to a server at the telephone company which then forwards the packet to the recipient. However, modern VoIP systems do not use this basic translation. Instead, they usually employ the Session Initiation Protocol (SIP). While SIP is able to provide similar functionality to the end user, like the traditional dialing process (i.e. establish a connection between a caller and a recipient), it differs in many aspects. For example, SIP includes a mechanism for session establishment in which media type, codec, or sampling rate for the individual call are negotiated. This property of SIP is not directly motivated by the task to establish a phone connection between two participants, but rather reflects the inherent difference of IP-based telephony systems from the classical system. In a VoIP system, the phones become virtual elements for which there is no particular requirement on how they are connected to the network (e.g., Ethernet, Wi-Fi, LTE), how they are implemented (e.g., hard phones, VoIP software on a PC, notebook, smartphone), nor where they are physically located. Additionally, the quality of the IP network between two participants may vary based on the current network load. Thus, in order to reflect the participant's and network's capability, negotiation of the connection properties is crucial to VoIP systems—but was not required in traditional telephony systems.

While session establishment is not a focus topic for building automation systems, it showcases the effect of switching from a closed, specialized system, to an open, IP-based system. For building automation, solutions must be developed to uniquely address devices and each information item in the context of an IP network, where a device may be a physical device as well as virtual device software implementation, and which may be executed multiple times on a single server representing multiple devices. Also, the discovery of devices (real or virtual) in small- and large-scale networks must be supported, allowing for quick identification of devices of interest in a potentially large population. Furthermore, the description of a device's capability is needed that is powerful enough to be used for diverse devices in diverse domains so that the cross-domain integration is supported. Protocols must also be in place for the transmission of event or alarm notifications. Traditionally, this kind of information is communicated with a broadcast, which is an efficient solution when devices are connected to a local, exclusive medium (like a bus), but is inappropriate in shared, large-scale IP networks. Thus, a suitable event notification mechanism must be deployed. Finally, a security solution is required that provides suitable protection for IP-based automation systems while introducing acceptable configuration and management overhead.

Numerous different activities exist which may help to address the aforementioned challenges, and may lead to the required protocol suite for future building automation systems. One activity in this area is the BACnet IT working group, which is investigating how to use proven IT solutions for the issues of security, authentication, and network management in a next generation BACnet. The OASIS standard suite WS-DD, mostly known for the DPWS, provides a protocol suite for IP-based device communication based on the W3C web services. WS-DD includes an extensive set of protocols for discovery, description and event notification for devices with

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a high amount of flexibility, which makes it easy to be adapted in different domains. The Internet Engineering Task Force (IETF) CORE Working Group is developing a set of communication protocols that also addresses IP based device communication. These protocols are particularly well-suited for wireless devices due to the small protocol overhead and their support for traffic reduction via caching of device information.

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## 5. Summary

In this paper, we gave an overview of the evolution of building automation systems from a technical implementation point of view. Although this vision is motivated against the background of commercial building automation, we can see that the vision of converged, IP-based systems is not limited to this domain. For example, for home automation and home entertainment systems, this convergence has already taken place using technologies like UPnP and DLNA, which are integrated in many of today's TVs, set-top boxes, and mobile phones. Additionally, current developments in the area of the Smart Grid bring forth promising solutions like the ZigBee Smart Energy Profile 2.0, which offers IP-based control for advanced metering infrastructure (AMI) and home area networks (HAN). This approach is in line with the vision of future, converged building automation systems discussed in this paper. Therefore, we are confident that it will only be a matter of time until the vision described in this paper will become reality.

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## Document History

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