White Paper
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IA for Commercial Automation

Architectural conversion and other innovative ideas for commercial automation applications

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Executive Summary

The use of Intel-based technologies and Intel® Architecture (IA) in the commercial automation segment such as Building Automation Systems (BAS) is virtually non-existent today. This raises possibilities for conversion of existing commercial automation products from PowerPC (PPC) and other architectures to IA to bring innovation to this segment through its application in terms of performance, functionality, scalability and stability. Technologies such as Intel® vPro™ technology can be used as a device management tool to manage BAS networks in the future.

The use of Intel-based technologies and IA in the commercial automation segment such as Building Automation Systems (BAS) is virtually non-existent today. This raises possibilities for conversion of existing commercial automation products from PPC and other architectures to IA.

This paper also looks into the possibility of applying WiMax or other wired/wireless communication technologies in the building automation industry. The innovation in the communication aspect of BAS networks is slow due to cost and technology limitations. Communication technologies such as WiMax could potentially serve as replacement to traditional wired networks in BAS networks and could potentially reduce costs for the end user since cost of wiring contributes to a large portion of the cost of a projects. Also, enhancing wireless communication could enable the installation of such systems in existing buildings, since wiring work would not be required. Thunderbolt technology could be used to replace traditional 2-wire copper cables such as the RS485 daisy chained networks.

The potential for IA in this segment could be limited by a few factors such as technical and commercial feasibility of setting up localized WiMax networks or limitations in range or stability. Also, this application may also require real-time OS capability and other requirements such as stability and availability for control of more critical systems linked to the BAS such as fire and smoke control.

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Background

Building Automation Systems (BAS) is an automation segment in the commercial automation and controls domain. Other sub-segments in the commercial automation domain include:

- home automation
- intelligent building control and management
- integrated building management systems

BAS is commonly deployed in commercial buildings and complexes such as office buildings, shopping malls, warehouses, and public facilities such as airports, bus terminals and courthouses. The main goal of BAS is to facilitate the efficient operations and maintenance of a living modern building. Examples of building systems which may be interfaced to the BAS includes Fire and Smoke Control, Heating Ventilation and Air Conditioning (HVAC) Systems, Lighting Controls, Security and Access Controls, Power Generation, Management and Alerting, and IT Network Monitoring Systems. Essentially, BAS has the capability and potential to integrate a building's systems to a centralized control location.

Commercial Buildings Energy Consumption

According to the International Energy Agency (IEA), commercial buildings accounted for around 40 percent of the world's energy consumption and 21 percent of total energy-related greenhouse gas emissions in 2005 … Steadily rising energy costs – coupled with government programs for environmental protection and tightened environmental regulations such as stricter limits on CO_2 emissions – are giving this market an additional boost.

Source: Siemens

There are three key areas where IA or Intel-based technologies could be used in this segment.

1. BAS Controllers architectural conversion to IA.
2. Utilization/Innovation of IA based technologies.
3. Next generation Wired/Wireless communication technologies.

Typical BAS Configuration

Building Automation Systems are typically configured like in Figure 1. There are four main layers typically built into a BAS.

1. Human Machine Interface Layer (Database, and Operator Interaction)
2. Distributed Network Controllers
3. I/O Modules or Low Level Controllers
4. Sensors and Actuators

Figure 1. Typical Building Automation System Network and Configuration

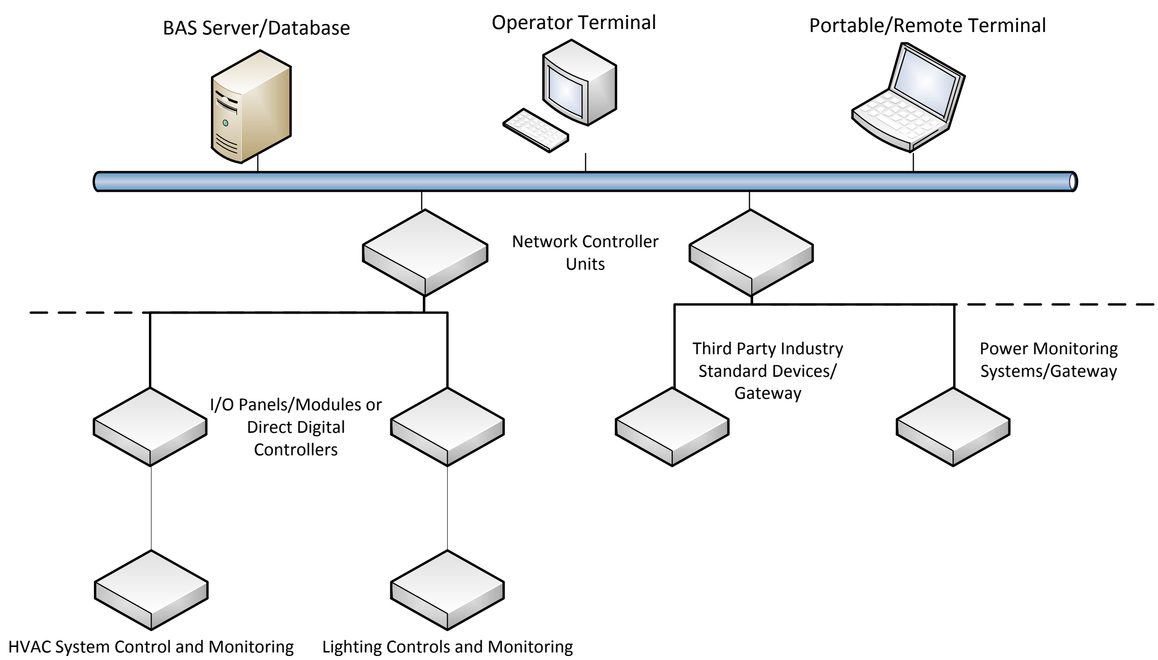


Table 1. Functional Description of BAS Layers

Layers	Functions	Vendor Specific Names
Database/HMI Layer	Centralized Data Management and Control. Provides user access to system.	N/A
Distributed Network Controllers	Distributed controllers for data management and control within its sub-branch. Can be independent of Database Layer.	Network Controllers, Management/Automation Level Network
I/O Modules or Low Level Controllers	Low Level Controllers provides IO interface between Network Controllers and Sensors/Actuators.	Direct Digital Controllers, Field Level Network
Sensors and Actuators	Sensors and Controlled Devices/Actuators.	N/A

Database/HMI Layer

The Database/HMI Layer provides the user with centralized control and monitoring. Data from the various Distributed Network Controllers is constantly synced with a centralized server/database on this layer. The consolidated information can then be interpreted by software on the server to provide a Graphical User Interface (GUI) representation on the state of the building's services and systems. This GUI would also provide the control interface for the operator or user to control the systems in the building.

The Database/HMI layer generally operates on an ethernet backbone, providing access to the system to other clients connected to the network. The wide availability of IT networks in most commercial buildings helps reduce the cost by eliminating the need for an independent backbone for the BAS system by piggy-backing on existing ethernet networks.

Distributed Network Controllers

The network controllers in a BAS network function as a distributed control system. The network controllers function independently from the database and perform the bulk of the data processing and translation from the low level controllers back to the database. The control algorithm of the various systems controlled by the BAS is also usually stored on these controllers, making the controllers an essential and critical component to any BAS.

I/O Modules or Low Level Controllers

I/O Modules, low level controllers or direct digital controllers provide the termination points for the sensors, actuators and other I/O signals and performs necessary digitization and data packaging to conform to industry standard communication protocols. The I/O modules and controllers may consist of a combination of digital and analog termination points. The I/O modules or low level controllers will perform basic ADC operations to digitize analog signals. These controllers may have some form of basic computation capabilities such as basic programmable capabilities or may just be a dumb I/O module.

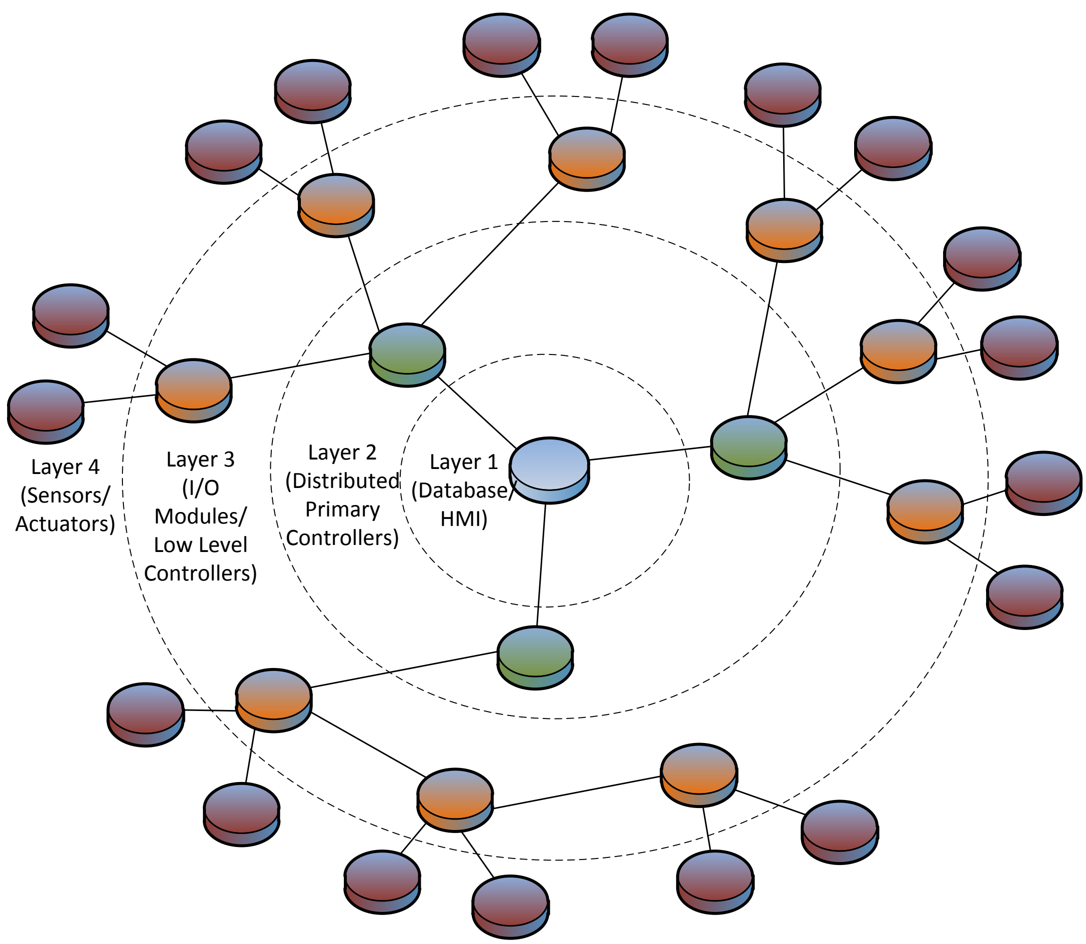
Sensors and Actuators

Sensors in this context may include various devices which provide information or state of a building to the user via the BAS. Examples of sensors generally linked to a BAS includes temperature sensors, humidity sensors, air quality sensors, light level sensors, air flow sensors, power on/off status sensors, and digital power meters.

Actuators may include various devices which require a control signal to operate. The actuators in a BAS are control points in which a BAS or the user can manipulate to achieve certain environmental conditions or state in the building. Examples of actuators include control valves, power/light switches, air dampers, and high power contactors.

The various operational layers BAS design and architecture are more easily visualized as propagating spoke and hubs from a central location as shown in Figure 2.

Figure 2. Typical BAS Topology and Architecture



BAS networks can also be configured in various configurations depending on the different network media available.

1. Star/Bus Topology utilizing ethernet TCP/IP protocol.
2. Star/Daisy Chained topology using traditional twisted-pair cable topology on multi-drop RS485 protocol.
3. Mesh topology utilizing proprietary/open wireless technologies.

4. Hybrid/Combination of various media and topology for specific projects.

Table 2. Comparison of Communication media used for BAS

Topology/Media	Advantages	Disadvantages	Cost
Star-Bus Topology/ Cat5,Cat5e,Cat6	Higher Bandwidth, especially for Layer 1 application Robust Scalable Compatible/Integration with IT network.	Maximum single-span length limitations.	Medium
Star-Daisy Chained Topology/ STP,UTP	Maximum single-span length up to 1.2 km Cheap and simple installation.	Difficult to scale after installation – Limitation of daisy chain topology.	Low
Mesh Topology / Wireless	Cable-less	Expensive and segmentation of wireless technologies (no industry standard)	High

Note: STP (Shielded Twisted Pair), UTP (Unshielded Twisted Pair)

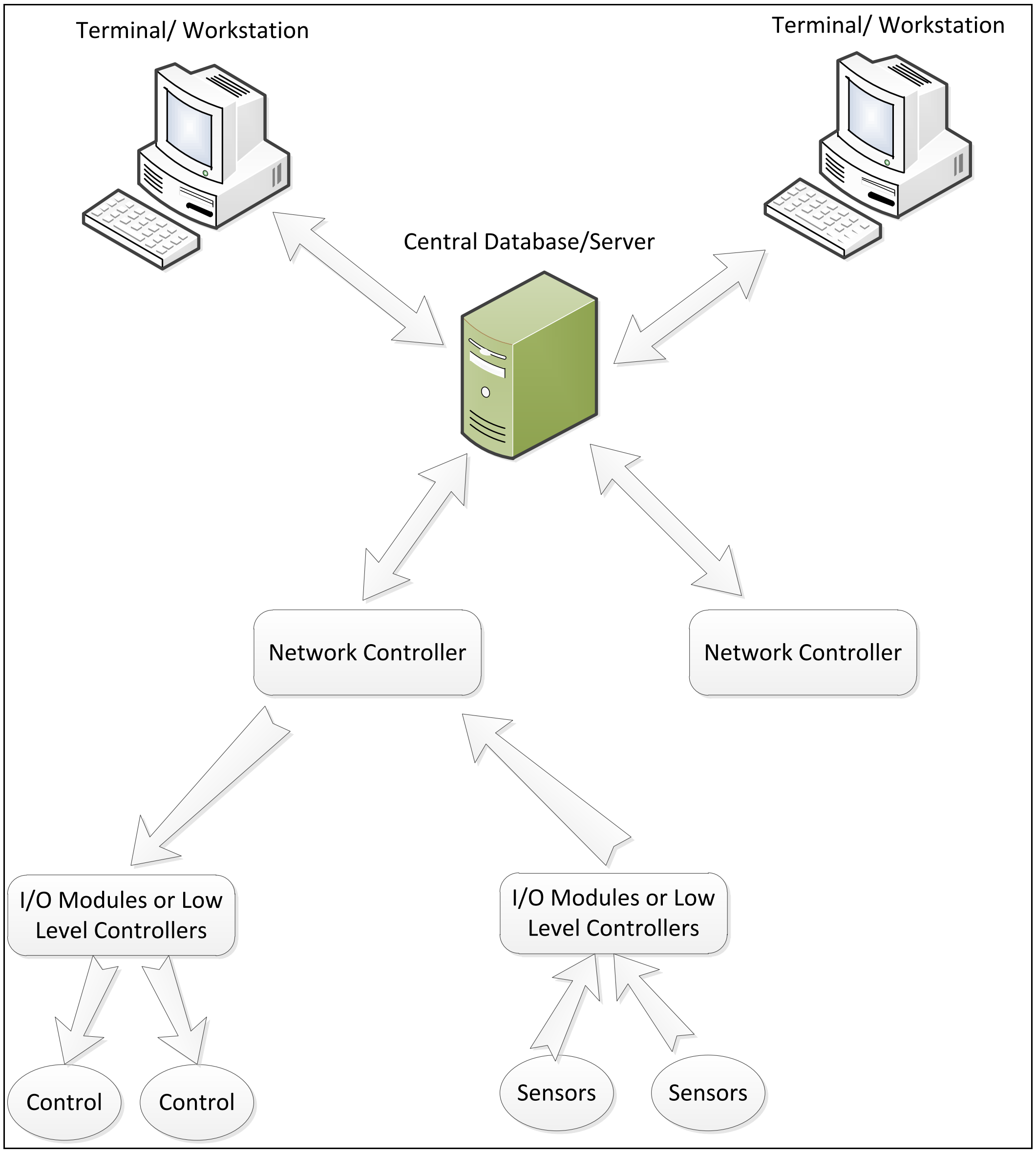
When designing BAS topology for specific projects or architectural in general, some of the factors that need to be taken into consideration are:

1. Length of spans (distance between one node and the other)
2. Bandwidth (for HMI which is graphics intensive)
3. Reliability (redundancy capabilities and signal integrity)
4. Scalability and Maintenance (ability to add on nodes in future and maintenance and troubleshooting)
5. Cost

Functional Diagram

A typical BAS network flow is depicted in Figure 3. The Central Database functions as the host for all data in the network and usually hosts the system's interface software where the GUI is hosted to the various clients and terminals in the network. The control and sensor information to and from the building machines and various devices are first conditioned and converted to appropriate signals before being collected by a network controller unit. The network controller functions as the brains of the system. The network controller stores and constantly synchronizes important information data such as control states, schedules, alarms and etc. The network controller in a BAS system is the most important element. In some installations and vendors, the network controller may also function as the central database and server, eliminating a central server to collect the data, as shown in Figure 3. The user then accesses the system through the GUI hosted on the network controller.

Figure 3. Functional BAS Network Diagram



BAS Benefits

This section attempts to calculate the feasibility and potential savings of a BAS in terms of energy consumption, initial investment cost as well as the projected return on investment.

Scenario: Three floors office building accommodating 1500 employees

Estimated Energy cost/month: **$400,267**

Percentage of Energy for HVAC: **60% ($240,160)**

Projected Savings by efficient Energy management through BAS from original HVAC usage: **10% ($24,016)**

Energy savings per year with BAS**: $288,192**

Capital investment for BAS: **$833,890**

Simple Return of Investment Calculation: 2.89 years **~ 3 years**

Note: Calculation is estimated for energy usage of $67 per person per month in today's energy rates. Savings after installation of BAS assumes effective management and utilization and does not include savings from other subsystems such as lighting. As such, ROI calculations may differ case by case. The values are converted from an example in Malaysian Ringgit to USD.

Crucial Design Requirements

System Requirements

There are a few crucial design requirements for Building Automation Products available in the market today.

Table 3. System Requirements

Control Layer	Key Requirements/Capabilities	Possible Product Range
Database/HMI	Data Processing and Storage Accelerated Graphics and Hosting Network capabilities Ethernet Serial (RS485)	Intel® Core™ microarchitecture, Enterprise
Distributed Network Controllers	Limited Data Processing and storage Basic Graphics and Hosting Network Capabilities Ethernet Serial (RS485) Communication Expansion Busses RTOS	Intel® Atom™ microarchitecture, SOC, Embedded
IO Modules/Low Level Controllers	Analog to Digital Converters Analog and Digital Output Support Network Capabilities Ethernet UART (RS485)	Low Power SOC, Embedded

Communication and IO

This section describes the various communication media and protocols used by the major vendors in BAS today. To achieve design wins in this segment, IA products tailored for this segment should meet these minimum standards.

Table 4. Communication Media and Protocol

<table>
<tr><th>Communication Media</th><th>Key Requirements</th><th>Key Industry Standard Protocols</th></tr>
<tr><td>Ethernet</td><td>TCP/IP
Console and Communication</td><td rowspan="2">BACnet
Modbus
LONWorks
Vendor Proprietery</td></tr>
<tr><td>Serial</td><td>Console and debugging
RS485 and RS232</td></tr>
<tr><td>Wireless</td><td>Low Power
Range and Reliability</td><td>Zigbee
Vendor Proprietery</td></tr>
</table>

Note: Vendor proprietary protocols example:
Siemens – P1,P2 Protocol, Johnson Controls – N1,N2 Protocol

Industry Standard Communication Protocols

There are many Communication Protocols commonly used in Building Automation Systems. The three protocols presented in this paper are the more common protocols which are BACnet, Modbus and LONWorks. These protocols are more widely adopted by the industry. There are many more open and vendor proprietary protocols which are not listed here.

BACnet

The BACnet protocol defines a number of services that are used to communicate between building devices. The protocol services include Who-Is, I-Am, Who-Has, I-Have, which are used for Device and Object discovery. Services such as Read-Property and Write-Property are used for data sharing.

The BACnet protocol defines a number of Objects that are acted upon by the services. The objects include Analog Input, Analog Output, Analog Value, Binary Input, Binary Output, Binary Value, Multi-State Input, Multi-State Output, Calendar, Event-Enrollment, File, Notification-Class, Group, Loop, Program, Schedule, Command, and Device.

The BACnet protocol defines a number of data link / physical layers, including ARCNET, Ethernet, BACnet/IP, Point-To-Point over RS-232, Master-Slave/Token-Passing over RS-485, and LonTalk.

Source: Wikipedia

Modbus

Versions of the Modbus protocol exist for serial port and for Ethernet and other networks that support the Internet protocol suite. Most Modbus devices communicate over a serial EIA-485 physical layer. There are many variants of Modbus protocols

Modbus RTU — This is used in serial communication & makes use of a compact, binary representation of the data for protocol communication. The RTU format follows the commands/data with a cyclic redundancy check checksum as an error check mechanism to ensure the reliability of data. Modbus RTU is the most common implementation available for Modbus. A Modbus RTU message must be transmitted continuously without inter-character hesitations. Modbus messages are framed (separated) by idle (silent) periods.

Modbus TCP/IP or Modbus TCP — This is a Modbus variant used for communications over TCP/IP networks, connecting over port 502. It does not require a checksum calculation as lower layers already provide checksum protection.

Modbus over TCP/IP or Modbus over TCP or Modbus RTU/IP — This is a Modbus variant that differs from Modbus TCP in that a checksum is included in the payload as with Modbus RTU.

Modbus over UDP — Some have experimented with using Modbus over UDP on IP networks, which removes the overheads required for TCP

Source: Wikipedia

LONWorks

Two physical-layer signaling technologies, twisted pair "free topology" and power line carrier, are typically included in each of the standards created around the LonWorks technology. The two-wire layer operates at 78 kbit/s using differential Manchester encoding, while the power line achieves either 5.4 or 3.6 kbit/s, depending on frequency.

Additionally, the LonWorks platform uses an affiliated IP tunneling standard—ISO/IEC 14908-4 (ANSI/CEA-852) -- in use by a number of manufacturers to connect the devices on previously deployed and new LonWorks platform-based networks to IP-aware applications or remote network-management tools. Many LonWorks platform-based control applications are being implemented with some sort of IP integration, either at the UI/application level or in the controls infrastructure. This is accomplished with web services or IP-routing products available in the market.

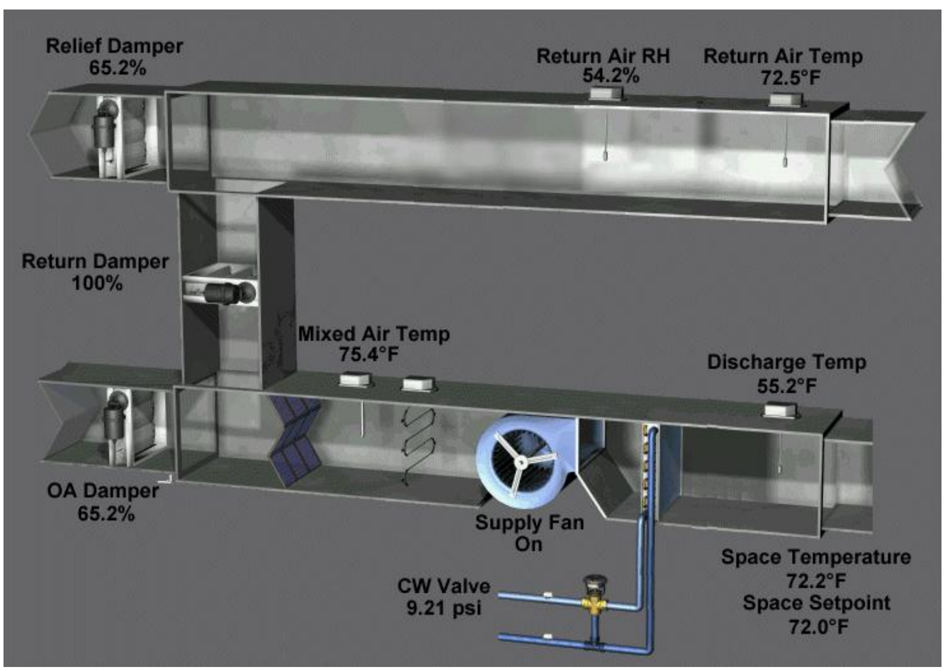
Source: Wikipedia

Graphics

The graphical user interface in a BAS provides the primary mode of access to the system, allowing for command and control functions, monitoring functions through the use of mimic and actual layout diagrams, as well as allowing for advanced control features such as scheduling, providing alarms, web interface and remote control capabilities.

The GUI for BAS systems have been evolving from low graphics, schematic representations of mimic diagrams to 3D and animated graphics used in today's mimic diagrams. Accelerated graphics will eventually become a standard requirement in BAS GUI.

Figure 4. Sample Graphics for Mimic Diagram in BAS



Source: Celebbest

IA Conversion

Potential for IA in BAS

The BAS segment relies on SOC solutions in its products. The potential for IA conversion in this segment is significant due to the fact that no BAS products in the market out there today uses IA.

> The market for building automation and energy management will top $32 billion in 2011 and jump to $37 billion by 2016. North America is the largest market, but the highest percentage gains will be in Asia Pacific. A big part of the boom comes from the (relatively) newfound ability to hook smart buildings to the smart grid, allowing them to tap into revenue streams from demand response. **- By Jesse Berst**
>
> Source: Smart Grid News

IA and its various other associated technologies can potentially bring innovation and next generation features to the BAS. The potential of IA in the BAS segment includes the following:

1. Improved performance, scalability and graphics.
2. Create computing continuum within the segment and ecosystem as a whole.
3. Potentially bring many IA related features and strengths to the industry such as:
    - Security
    - Device Management (vPro)
    - x86 compatibility with the rest of the ecosystem, which improves user experience
    - Powerful industry-leading processor/architectural capabilities
    - Reduced development costs due to x86 architecture
    - SOC solutions for compact and smaller designs
    - Customized SOC

Competitive analysis

Table 5. Comparison of Controllers

Specification/Vendor	Siemens APOGEE Building Automation	Johnson Controls	Tridium
Model	PXC Modular Series	NCM45x0-2 Network Control Module	Vykon JACE-600*
Processor	133 MHz MPC885 (PowerPC*)	192 MHz Renesas* SH4 7760 RISC 32-bit processor	PowerPC 440 524 MHz processor
Memory	64 MB SDRAM, 8 MB Flash ROM	128 MB Flash nonvolatile memory 128 MB Synchronous Dynamic Random Access Memory (SDRAM)	128MB DDR RAM & 128 MB Serial Flash Optional 256 MB DDR RAM
Operating System	N/A	Microsoft Windows CE embedded Release 5.0*	QNX Real-time Operating System

Source: Johnson Controls, Siemens, Tridium

Innovation

The BAS segment may benefit from a number of recent innovation and technologies from Intel Corporation including Connectivity, Manageability and Security.

Intel® vPro™ Technology and Security

The management of BAS devices across a large installation or project site can be more efficient and effective utilizing Intel vPro technology currently available to mainstream or enterprise customers utilizing the Intel Core processors. Intel vPro technology may reduce the requirement for frequent on-site maintenance of BAS and its associated equipment and potentially be managed as part of an IT infrastructure of a corporation, further reducing the need for special groups or divisions dedicated to this task.

Smart security and manageability on every chip

Embedded in hardware, Intel vPro technology capabilities are accessed and administered separate from the hard drive, OS, and software applications—in a pre-boot environment. This makes management less susceptible to issues affecting these areas and allows remote access to the PC regardless of the system's power state or OS condition. Key encryption components are kept in protected flash memory, separate from the data they protect, making it easier to secure and harder to penetrate and access sensitive information.

Source: Intel

Next-Generation Communication and IO

The BAS segment utilizes older communication and IO technologies and may benefit from adopting the latest Intel offers such as Thunderbolt™ technology and WiMAX to replace traditional wiring in a project and installation.

WiMAX technology holds a particularly high interest due to its range and bandwidth capabilities. In the future, buildings may deploy internal WiMAX hotspots and all the BAS and other devices in a building may wirelessly interconnect, eliminating the need for expensive cabling within a building. Cabling costs for a BAS project may run up to 30% of the entire project cost. Re-cabling or retrofitting of older buildings to enable BAS may cost even more in addition to the disturbance to the operation of the building and its inhabitants. A scalable powerful wireless solution to replace traditional cabling may prove to be an important innovation in which Intel may bring to this segment.

Note: Communication technologies employed in the BAS industry includes serial and twisted pair based systems which may be converted to newer technologies available today.

Industry leading processors and fabrication process

With the introduction of next generation Intel processors fabricated using the latest 22 nm tri-gate technology, the industry could benefit from the significant improvement in computation performance with lower power consumption and increased reliability.

Recommendations

- Engage and penetrate segment for IA conversion and design wins.
- Engage vendors and board vendors to design future BAS products with IA.
- Engage end users or vendors for other Intel Technologies such as communication, security and management features for future designs.

Conclusion

Intel Architecture offers several advantages in the Building Automation and Commercial Automation segment, including cost savings, technological innovation and energy savings.

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Authors

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Acronyms

3D	3 Dimensional
ADC	Analog to Digital Converter
BAS	Building Automation System
GUI	Graphical User Interface
HMI	Human Machine Interface
HVAC	Heating Ventilation and Air Conditioning
IA	Intel Architecture
I/O	Input Output
IT	Information Technology
ROI	Return of Investment
RTOS	Real Time Operating System
STP	Shielded Twisted Pair
UTP	Unshielded Twisted Pair

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