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An Enterprise Model for the Interoperability and Data Exchange Among Building Automation Systems and Related Business Applications

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Introduction

The automation industry is a globally diverse structure of business organizations that provide a wide range of technological products and services to discrete sectors of the economy. The industry is comprised of a wide variety of business entities ranging from the larger Fortune 50 companies such as Siemens AG and Honeywell to a significant number of very small systems integration companies. Overall the automation industry supports markets, with aggregate revenues totaling nearly 150 billion dollars annually[1]. The discrete business sectors contributing to this aggregate revenue include industrial, utility and commercial building automation markets. The industrial and utility markets, while representative of the largest percentage of total automation sales, appear to be declining in growth at a rather significant rate. Conversely the building automation market is increasing at a rate of nearly 10% annually with revenues projected to be nearly 35 billion dollars by 2007[2].

Over the years automation systems supporting the infrastructure in the industrial and utility business sectors have maintained a reasonably aggressive, although very costly approach to systems integration. Many of the larger and moderate size industrial companies have implemented an integration strategy between their business and process automation systems[3]. The success with this IT convergence has often been accompanied with business re-engineering activities, which have shown significant cost savings in the displacement of personnel with technology along with the implementation of "Just-in-Time" production and delivery methods. The building automation sector, however, has not benefited from this same business model. Market demographics find these systems in widely diverse geographies, often accompanied by a lack of corporate support and vision with regards to technology integration. As business investments in "Brick and Mortar" assets continue to increase, it is imperative that building and facilities management leaders take a more aggressive approach to systems integration. This paper focuses on the trends which, have and continue to plague this industry along with the identification of technologies and system architectures that can be adapted from the "IT Tool Chest" which will ultimately enable facility managers and executives to better manage their physical assets and related infrastructure.

INDUSTRY TRENDS AND TECHNOLOGY APPLICATIONS

The Building Automation Market

The building automation sector provides products and services to a vast range of physical properties, which support the needs of institutional, commercial and public organizations. These products and services are, typically, engaged to provide control and monitoring of subsystems within building structures such as heating, ventilating and air conditioning (HVAC), fire detection and alarming, electrical distribution, security and conveyance systems (elevators and escalators). System controls prior to 1980 were generally comprised of electro-pneumatic devices with little to no capability of any data transfer or exchange. Although lagging behind the evolution of the IT industry that exploded during the next two decades, Building Automation Systems (BAS) began to adopt certain elements of electronic hardware, software and network architectures being embraced by the office product market[4]. Figure 1 provides a historical prospective of how the system architecture for the IT industry evolved over the last several decades.

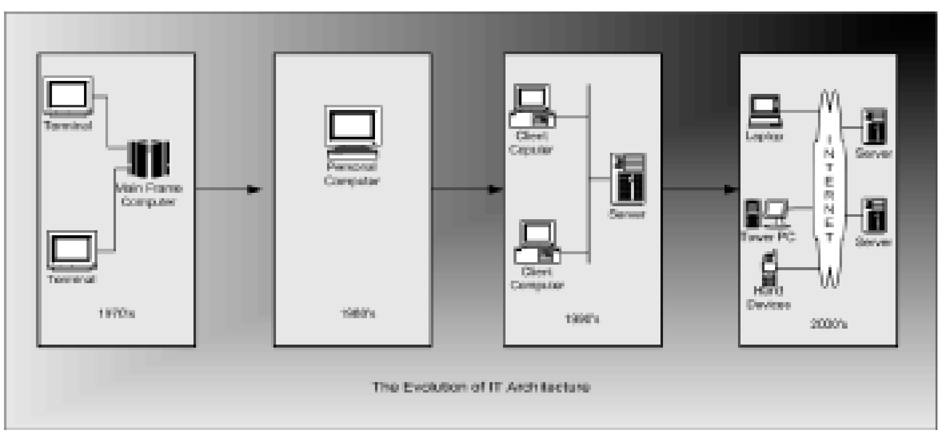

Figure 1: Information Technology Evolution

[1] "Economic Future for Total Automation Market in Discrete Industries", ARC Advisory Group. http://www. Arcweb.com/community/arcnews, March 8, 2004.

[2] "External Factors Affect BCS Market", Energy Users News. http://www.energyusers.com/CDA/Articles. August 28, 2003

[3] "Real Time Systems Integration", Jack McGowan, Engineered Systems. February 2003. pp 38-52.

[4] "Information Model: Key to Integration", Eric Craton. http:// www. Automatedbuildings.com/news/jan02

Technology Evolution

Many of the early developments found in the IT industry were far too costly to be used in building automation systems. Prior to 1980 most of the IT infrastructure was supported by mainframe computers and relegated to the use of "business critical" applications such as human resources and accounting/finance systems. By 1980 decentralized computing began to emerge, which not only made the cost of computing more economical but also exposed a larger element of the workforce to computing technologies. Still, the building automation market was largely slow to respond since so much of the market was very comfortable with electro-pneumatic technologies along with the advantage of this technology's extremely competitive cost. By 1985 many of the major control organizations such as Johnson Controls, Honeywell and Barber-Coleman, along with HVAC manufacturers such as Carrier Corporation and Trane Company, began to release their first sustainable products that supported the decentralized digital computing environment. The birth of the current problems with systems integration began.

Each of these vendors (there were many more than noted herein) envisioned they had the answer to BAS control and implementation technology. To reinforce this conviction they each adopted their own proprietary communication protocol. Fundamentally stated, only systems procured from the same manufacturers could communicate with one another. The roots of this dilemma became manifested in the ISO standard 7498- Open Systems Interconnection Model (OSI Network Model)[5]. Figure 2 identifies the various layers of the original network communication model established by the International Standards Organization in 1994. Of course, early developments of products within the BAS market did not adhere to any concept of the OSI model being formulated and manufacturers continued to pursue product development relying on direct serial communication between proprietary controllers. Figure 3 represents the early persistent model of BAS architecture and networking concepts. Figure 4 represents the inevitable outcome of multiple protocols.

As network communications became more prevalent, the manufacturers adopted their own versions of the OSI model, allowing only devices made by the same manufacturer to communicate at the network layer.

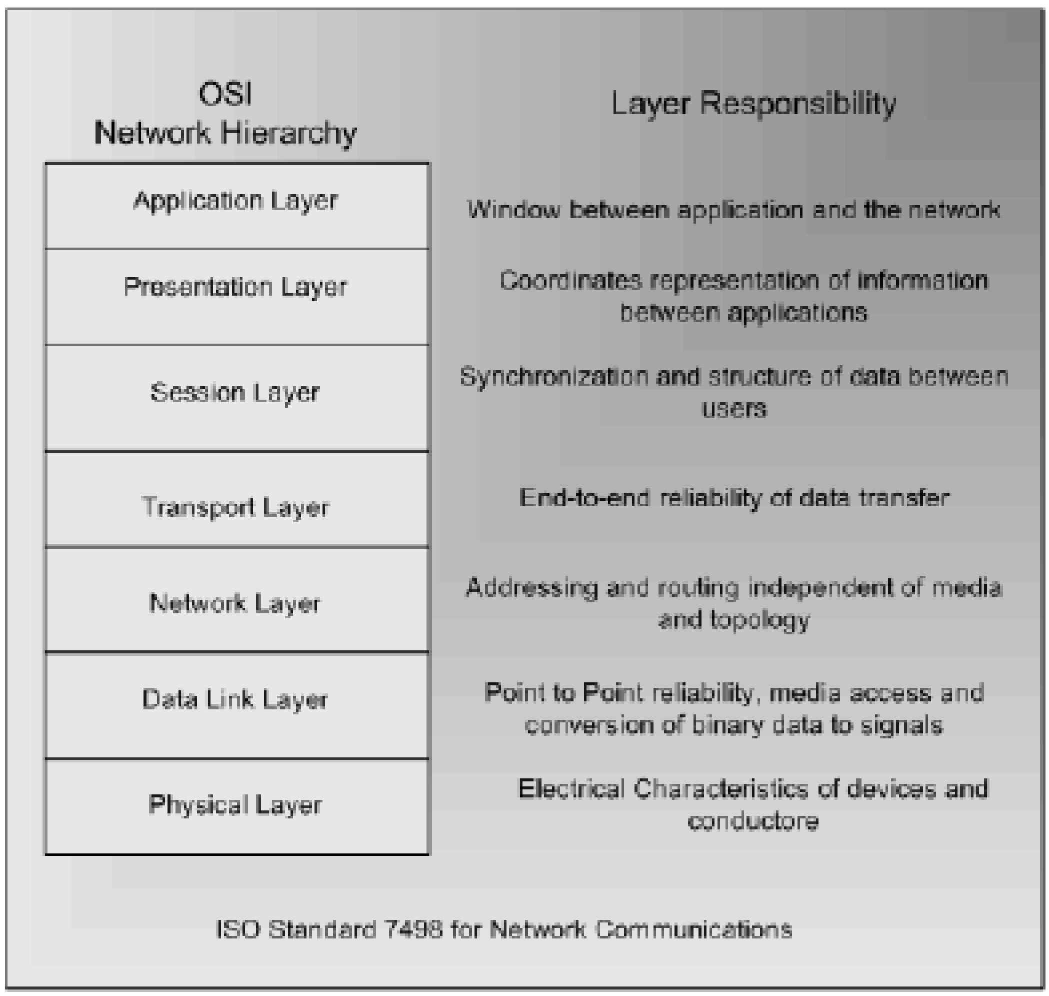

Figure 2: OSI Network Communication Standard

[5] "Communication Networks for Building Automation", ASHRAE Handbook Chapter 3, Jan 2002.

By Early 1990's the industry leaders, fueled by infuriated facility managers and executives started to push for the adoption of industry standards for common communication protocols. These early standards such as MODBUS were adopted from the industrial markets and were also somewhat proprietary and very cumbersome to use. The data structures were flat and independent of unit descriptions. For example the number,"55" might represent temperature in degrees Fahrenheit, however the unit relationship was not stored with the value. This complicated programming interfaces and also was a root source of many errors in the control loops. Additionally, where multiple "standard" protocols existed, this flat data structure complicated the translation elements between systems and these almost became a defacto standard in all integrations designs. These translational elements were embodied in elements referred to as Gateways.

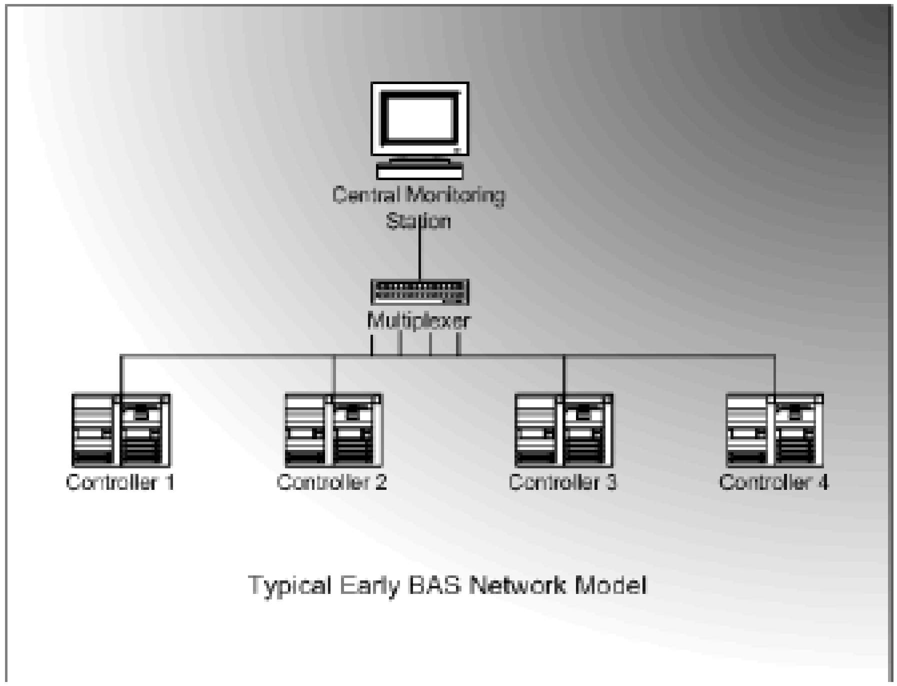

Figure 3: BAS Architecture without the OSI Structure

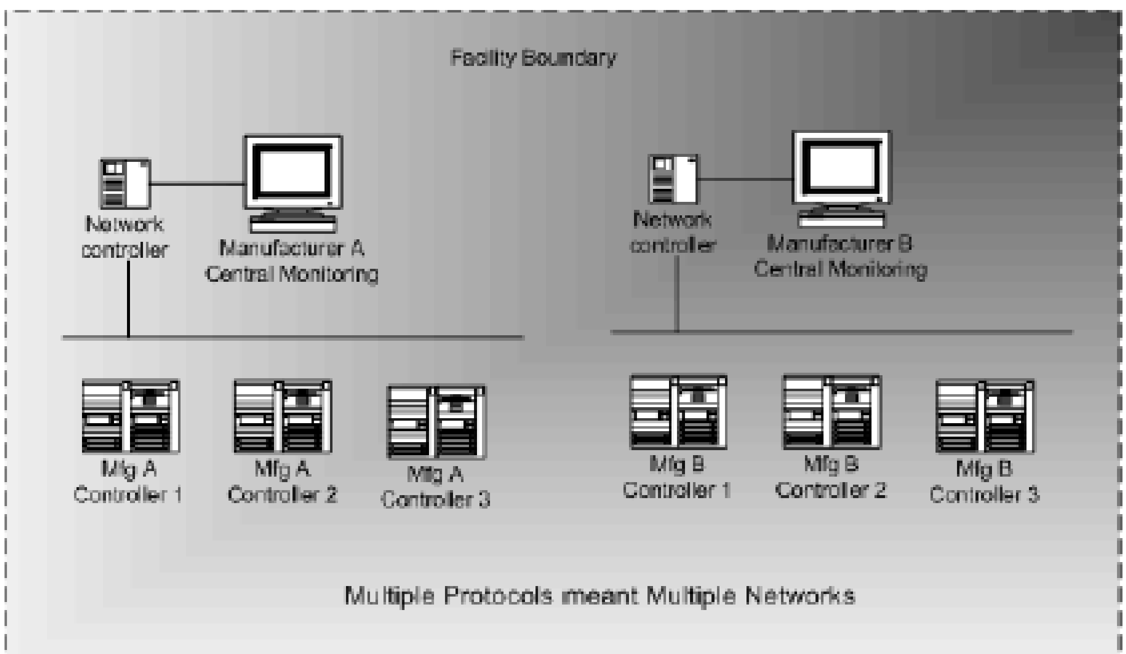

Figure 4: Facilities Forced to Manage Multiple Dissimilar Networks

[5] "Communication Networks for Building Automation", ASHRAE Handbook Chapter 3, Jan 2002.

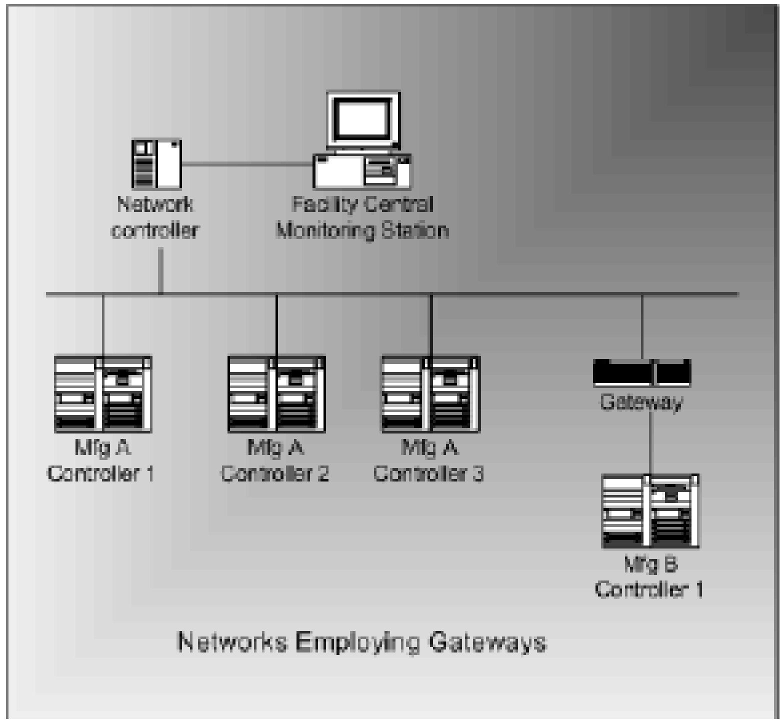

Figure 5: Gateways became the Defacto Standard for Network Integration

Integration Models

By the late 1990's, the integration movement at least at the network layer of OSI model had become more structured around standard protocol adoption and concepts. The evolution of a smaller subset of industry standards came about with the maturity of object oriented models and related programming interfaces[6]. These models allow data elements to be classified as objects. For example the number "55" could now be packaged with its context such as degrees Fahrenheit. This facilitates translation issues between systems since the object is defined in its entirety. The standards which became persistent in the BAS industry and gained more universal acceptance included BACnet, OPC-Foundations and LonTalk. Figure 6 identifies the transformation between the earlier, flat data translation structures and the object models.

[6] "Evolution of Building Automation Systems", Automated Logic Corporation –White Paper, July 2006.

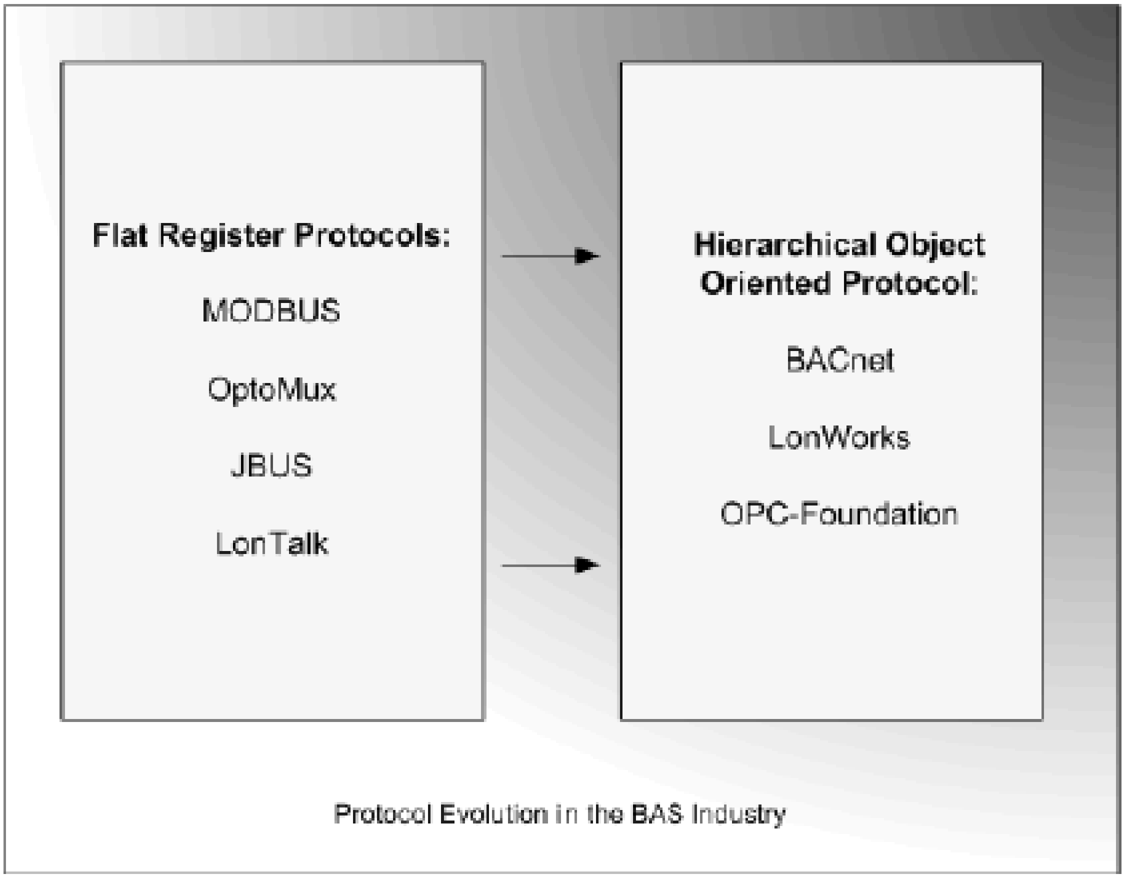

Figure 6: Evolution From Early Flat Protocols to Object Oriented Context

BACnet Protocol Standard

BACnet is the term, which refers to the ANSI/ASHRAE standard 135 and was formally recognized and published in 1996. As with most of the standard protocols being developed at this time, the focus of communication was with the client server network architecture and required the use of a "Thick Client" application running at the nodes and interacting with the server. To date, this standard has become very successful in defining and contributing to a standard method for devices on a common network that need to share information. This is accomplished by defining a number of details in the OSI structured model. These include elements such as LAN topology (Ethernet, Arcnet, MS/TP), message structure, services, objects and object properties. Compliance with the standard requires that any manufacturer of a controller (Device that produces binary data for message transfers) that is required to deliver and/or receive data across the network must comply with a BACnet defined Protocol Implementation Conformance Statement (PICS)[7]. Figure 7 is a representation of the BACnet standard at the device level.

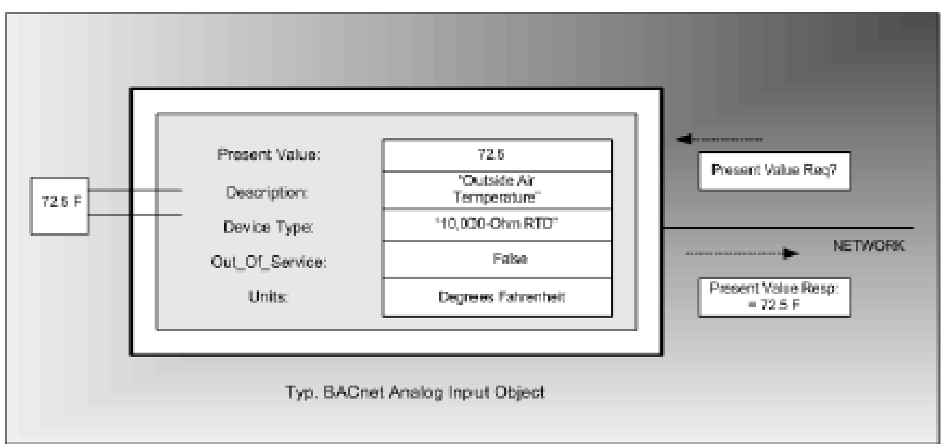

Figure 7: PICS Representation for a BACnet Object Device

[7] "Specifying BACnet Based Systems", Larry Haakenstad. Allerton Technologies White Paper, September 2004.

Lonworks

Lonworks is a non-industry or defacto standard that evolved from the more proprietary protocol LonTalk. LonTalk was initiated using a firmware coupled, proprietary, architecture used to establish a link to the OSI model at the physical layer. For this reason, early adoption of this standard was generally confined to small automation devices on a common network such as thermostats and local sensors. Like BACnet, Lonworks compliant devices require conformance to a common set of specified attributes. These include Standard Network Variable Types (SNVT), configuration properties, functional profiles and program identification numbers. The later attribute is used to identify the properties for the proprietary neuron chip (firmware interface)[8].

OPC Foundation

OPC is an open data access system based on Microsoft's OLE/COM technology. This protocol is also somewhat of a defacto standard in that OPC servers are provided by different vendors and are usually "customized" for specific applications. The server is comprised of several objects, server groups and items. Figure 8 is a representation of the OPC model and object groups. In many respects OPC is a type of client/server architecture that acts much like a gateway between elements of the network, which have dissimilar data constructs and need to share data for common application requirements.

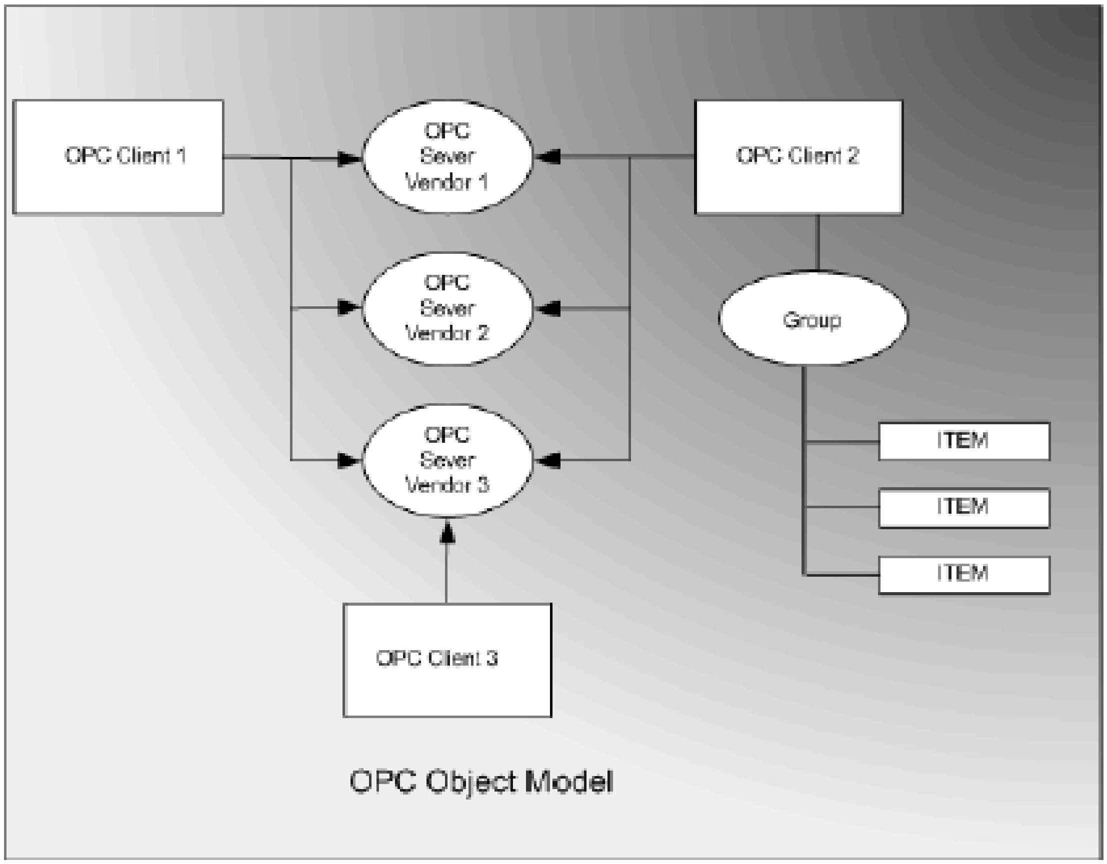

Figure 8: Arrangement of OPC objects in the Protocol Model

As figure 9 indicates, the various standards are frequently grouped into a common architecture, however as is generally the case, multiple interfaces are needed to translate between protocols. This can add an extreme amount of complexity and cost to the overall network both in terms of initial cost but more importantly ongoing maintenance costs are very high.

[8] "Introduction to Lonworks", Echelon Corporation, 1999.

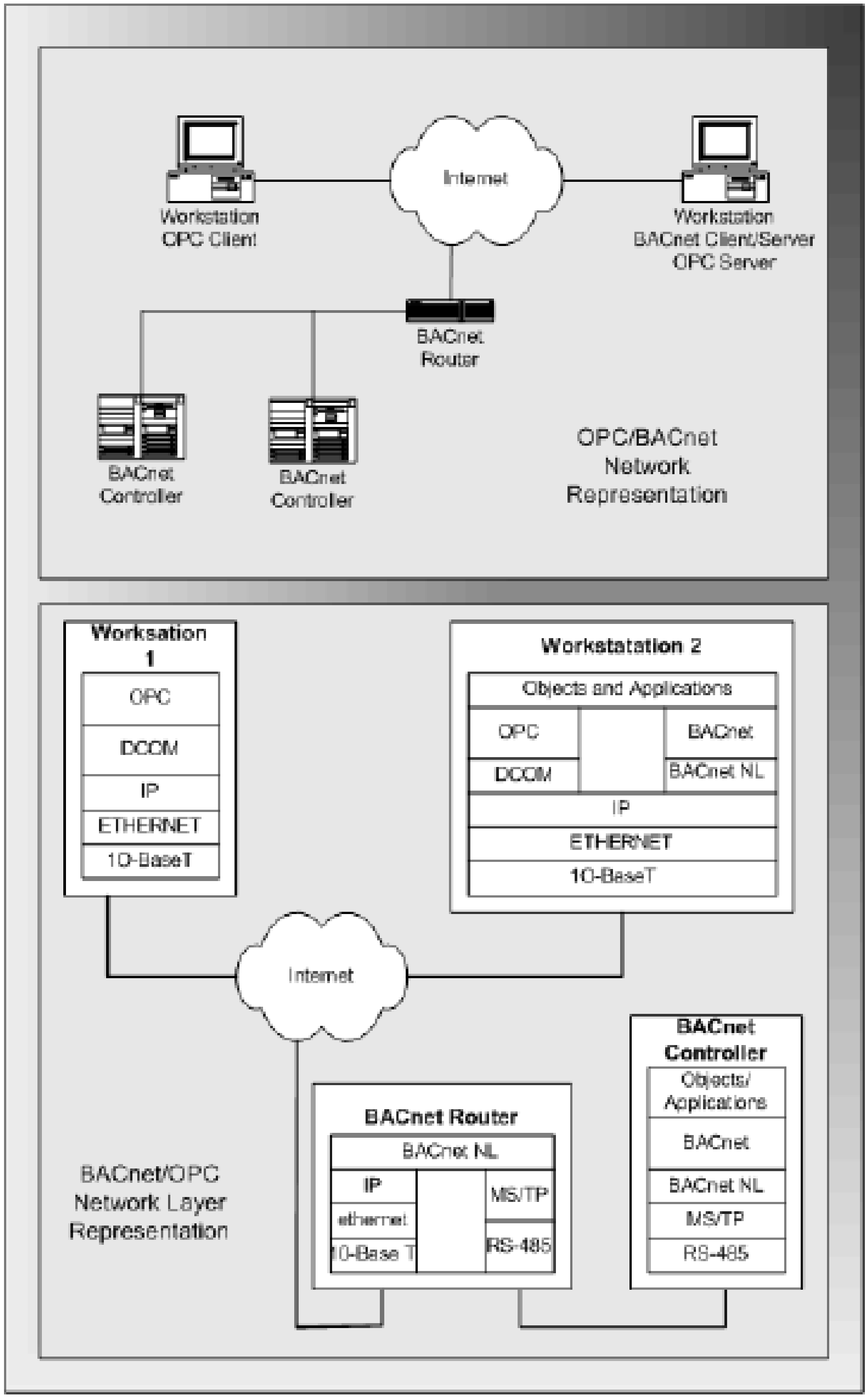

Figure 9: Common Network Integration with Multiple Protocol Models

The Age of Web Services

The IT world has embraced the technologies associated with web-based applications since the later part of the 1990's. The Internet has brought forth the ability to connect to virtually an unlimited number of remote networks and with the ability to transport and receive data from a vast geographic expanse. For the most part, the primary focus of the standard protocol models that have been defined for the BAS industry has been at or below the network layer of the OSI model. Although technologies supporting Internet protocols and operability have been commercially existent for almost a decade, the majority of manufacturers and industry professionals have yet to really embrace Web services in their portfolio of product and service offerings. According to IBM[9], there are several trends becoming apparent with the use of the Internet:

- Content is becoming increasingly dynamic with real time information available continuously through the browser.
- Bandwidth is abundant and inexpensive with the continued forecast of decreasing cost in bits per second.
- Storage, like bandwidth is decreasing in cost.
- Enterprise computing is becoming more important not only for convenience but for competitive advantage.

Even with such standards and technology templates available today, there are still abundant numbers of networks comprised of expensive and maintenance intensive gateways that are used to bundle together proprietary and semi-proprietary protocols. Figure 10 represents a network configuration that is very typical of many designs found in the current market place.

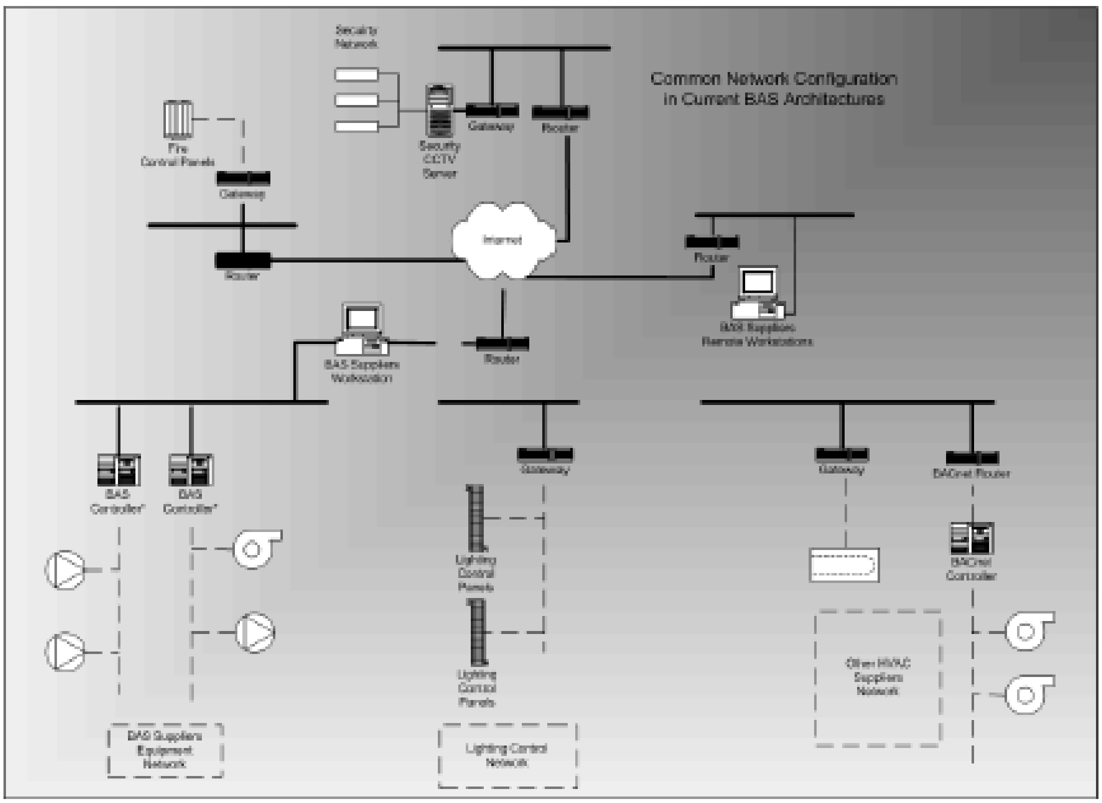

Figure 10: Typical BAS Network Architecture and Configuration

[9] "Web Services Architecture- The Next Revolution for Business", IBM Web Services Team, September 2004

CURRENT LIMITATIONS IN NETWORK INTEGRATION

Manufacturers and service providers in the BAS industry have made incredibly poor progress in incorporating the standard Internet protocols referenced in the OSI model as part of their architectural configurations. The IP (Internet Protocol) communication layer permits a conduit to exist between nodes on dissimilar networks, which facilitate the ability to share common data. This form of communication is being extensively used in local area networks as well. There are several reasons why BAS manufactures and providers have failed to adopt these standard protocols[10]. Internet protocols are more sophisticated and require more bandwidth and processing capacity than was available on small inexpensive controllers in the past. Internet protocols do not address the means by which low-level data needs to be exchanged and used between network devices. Standards groups, which began formulating the charter for open protocols such as BACnet and Lonworks, did not have the vision of the IT community which, at the time, was just starting to introduce the commonly known ISO and IEEE standards being used today across many different industries.

The standard protocols being used among the various manufacturers in the BAS industry have done very little to address the need for enterprise management of facility related data. The primary focus of these standards has and continues to be the interconnection of devices at the lowest layer of the OSI model. The focus of both BACnet and Lonworks has recently started to extend beyond the local network. This is being done by appending the current IP standard to the existing local network standard. BACnet/IP, for example, is an extended protocol, which basically allows the BACnet message to be routed across the Internet to another BACnet host. Although a start, this can hardly be classified as an enterprise solution by other comparisons to the IT world.

INTEGRATION OPPORTUNITIES FOR THE BAS INDUSTRY

The Industry needs to become more aware that the data available through the BAS network, both in a persistent and real time state are potentially very valuable to other aspects of a business enterprise. Web based control systems are a critical step in sharing important facility data11. Facility managers use a variety of business and analytical software systems that have a reasonably high level of integration with other business applications. Such systems include:

Computerized Maintenance Management Systems (CMMS) are application modules used to track resources needed to maintain and operate a facility. Typically this system is an extension of an organizations accounting, human resource and EDI (Electronic Data Interchange) system.

Utility monitoring and data collection systems use real time monitoring and trending measurements of energy and power usage that provide information to utilities for load management and spot market pricing.

Property management companies monitor access and security controls to define and react to tenant occupancy needs.

Beyond the need to exchange subsets of data between such systems the databases associated with the BAS present a wealth of information that can be archived or warehoused. When collected and stored from a number of federated systems these data can provide an invaluable pool of information for data mining and analytical processing. A recent concept being employed by the National Institute for Standards and Technology (NIST) being termed Networked Building Systems (NBS)[12] makes extensive use of warehoused data from the BAS. The NBS engine uses sophisticated OLAP methods against data trends collected throughout the BAS networks of a facility. Additionally, related data that is also collected into the warehouse from such applications as the CMMS can be statistically evaluated against the information from the BAS to provide facility managers a predictive method to better analyze equipment failures, energy trends and usage and optimization of equipment operations based on historical trends. Operational and maintenance related costs have been reduced by as much as $0.80 to $1.00 per gross square foot of building area using analyses based on the NBS engine.

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[10] "Using Standard Internet Protocols in Building Automation", Mike Donlon. http://www. Buildings.com /articles, December 2007.

[11] "Adopting Networking and Communications Technologies to Enhance Bldg Automation" Mike DeNamur. HPAC Engineering. http://www.hpac.com/microsites/networedcontrols/denamur.htm, June 2008.

[12] "Networked Building Systems- the Revolution is Upon Us", Jim Lee, HPAC Article, pp 61-65, October 2006.

INTEGRATION OBJECTIVES WITH BUILDING AUTOMATION SYSTEMS

Before we can define the manner in which the BAS should fit into enterprise architecture, it is important to understand the definition and elements of such architecture[13]. The Institute for Enterprise Architecture defines enterprise architecture as the mechanism, which enables communication about essential elements needed for an organization to most effectively, and efficiently function. The architecture needs to incorporate three interdependent parts:

- A set of models that effectively map areas of responsibility.
- Governance providing a vision of the future and a plan to get there.
- A global repository of shared information

In reviewing the trends in information technology relative to the building automation industry several prominent elements seem to be required to facilitate integration of applications into an organization's enterprise architectural model. First and foremost, models need to be clearly defined around a specific and consistent set of standards that will be universally adopted by the industry. Although significant achievements have been gained through such standards as BACnet and Lonworks, neither has been globally embraced by the industry at large. It is evident that the strength and commitment of these standards remains at the lower layers of the OSI model. Extending these protocols to the Internetwork or web services layer will dilute their ability to be integrated into an enterprise architecture since these protocols are foreign to applications outside the BAS network.

BAS manufacturers and integrators need to be proactive in embracing technologies derived and being applied in other sectors of the IT industry. A significant lag seems to be occurring in the deployment of recognizable and mature web technologies. BAS manufacturers are struggling with adapting to the trends identified in the IBM white paper, "The Web's next Revolution". Web services are well suited to address and capitalize on:

- Increased need for dynamic content and real time information exchange
- Availability of less expensive bandwidth
- Lower cost of storage media
- Importance of enterprise computing

Specific technologies are needed to be incorporated into the BAS architecture to support the organized and structured approach of transmitting information across networks using standard application level protocols. These technologies include Extensible Mark-Up Language (XML) and Simple Object Access Protocol (SOAP). Java Script Object Notation (JSON) is a more recent methodology being used in lieu of XML.

XML (Extensible Markup Language) is a Meta language, which has no attachment to a specific program language, operating system or software vendor. This language can provide access to any number of unrelated applications and provides the ability to manipulate, structure, transform and query data within and across multiple networks. SOAP (Simple Object Application Protocol) provides a mechanism of using XML between networks. SOAP, like HTTP provides a local computer with the ability to obtain and read contents of an XML file. Nearly all of the major business applications running on enterprise platforms support the use of XML and SOAP. JSON is a more simplified and human readable format for organizing attribute –value information. JSON is a Representational State Transfer (RESTful) application program interface and considered by many to be a more robust and lighter method for achieving data transfer through web services and between servers and browsers. Integration of the BAS network at this level of the OSI model will be a significant step forward with an enterprise solution.

Even with the recommended approach for the use of web services, lessons from the past should not be overlooked. It is imperative that in developing an integration strategy using such standards as JSON and XML, the BAS industry will need to a find strong consensus towards the development of an industry wide schema. From an intellectual perspective, this should not be a difficult undertaking since the type and structure of data collected among different BAS manufactured products is very much the same. However, if this process is left unregulated by an industry representative group, it is likely that multiple schemas will evolve, thereby creating the next generation of translational problems. Finally, facility managers and building maintenance professionals have seen a dramatic shift in their work environments during the last decade. These groups of individuals have, until recently, been more comfortable in a room of air compressors, pumps and gages than in an environment of network routers, hubs and discussions of Internet protocols. As such, it will be incumbent on business managers to effectively train and educate this element of their organization on the methods needed to procure, implement and operate a system that will be a critical block in the structure of the organization's enterprise architecture[14]. Figures 11-13 represents various abstractions for a proposed solution to integrating the BAS into an organization's enterprise architecture using a web service layer among various applications, which will benefit from the exchange of data.

[13] "Enterprise Architecture Methods, Tools and Framework", http://www.Enterprise architecture.com.

[14] "Integration of Building Automation Systems and Facility Information Systems", Andras Bozany, Budapest University of Technology, May 2004.

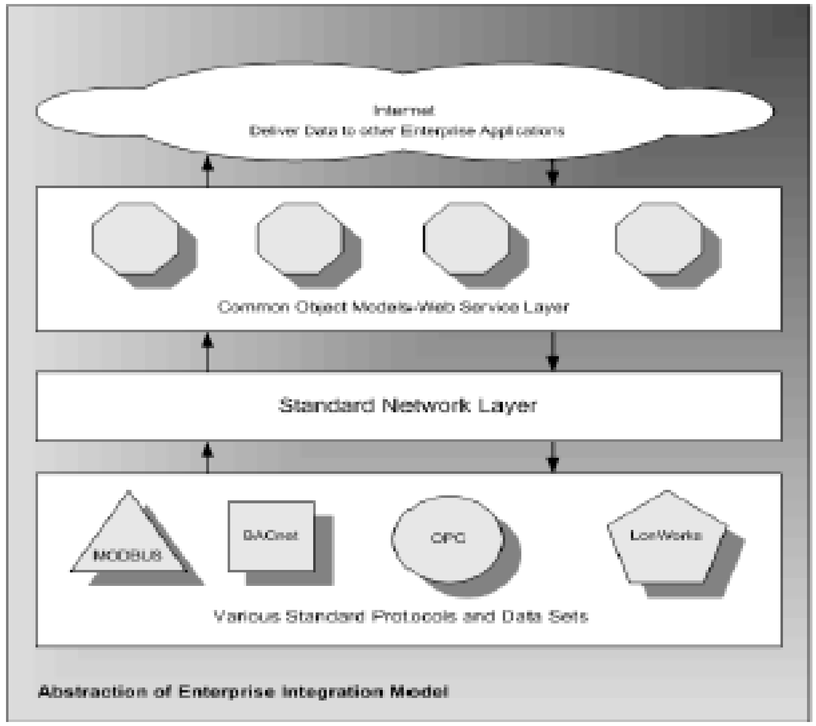

Figure 11: Proposed Web Service Abstraction and Common Object Models

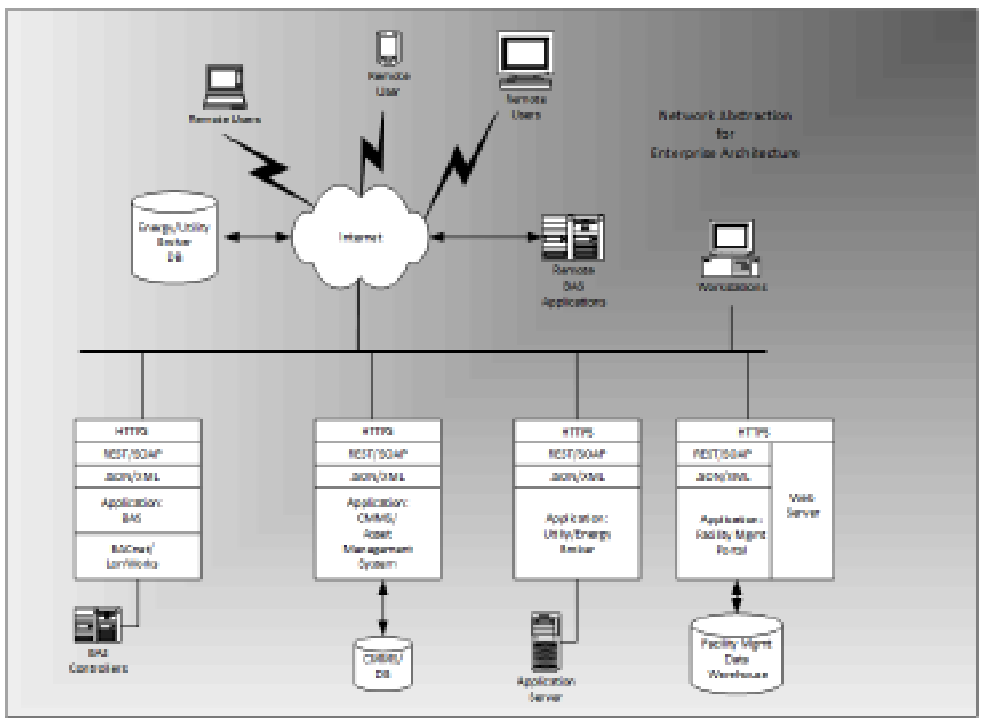

Figure 12: Network Abstraction for the Proposed Integration Model

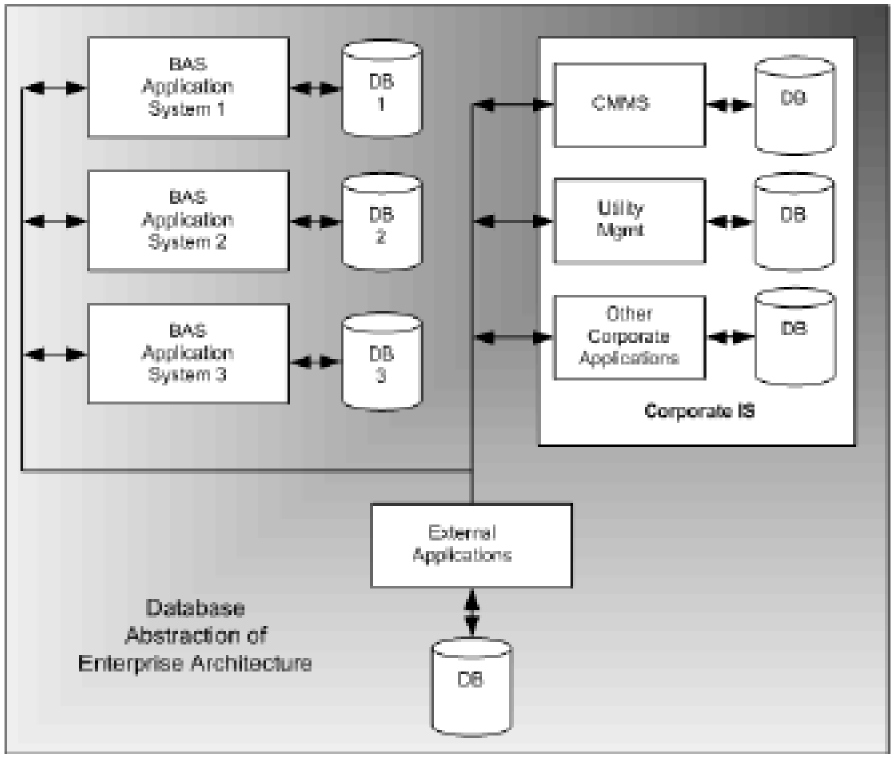

Figure 13: Database View of the Proposed Integration Model

CONCLUSIONS

The automation industry and, in particular, the building automation industry sector has struggled with the appropriate implementation of technologies needed to support effective and efficient exchanges and translations of data across dissimilar networks. In moving forward it is essential that the industry universally accept and standardize on a low-level communication protocol to capture data at the physical and media layer of the OSI model. At the network level these protocols need to be translated to a set of globally recognized services that are readily adopted across all industry sectors. A regulated body representing the BAS is required to develop, adopt and maintain sets of universal schemas for use at the web services layer. Finally, facility managers, engineers and business partners need to become more educated regarding the benefits of enterprise software architecture, the importance of their role in this information sector and the methods to effectively manage and implement the BAS interface into the business enterprise.