Migration is the Strategy for Accelerating the Modernization of Legacy Building Systems

PCN Technology, Inc. (PCN)
16450 Via Esprillo
San Diego, CA 92127

www.pcntechnology.com

Abstract: Building systems are on the verge of a complete transformation motivated by a need to improve collection and analysis of data from sensors and actuators so that hardware and software upgrades for intelligent control policies may be implemented to improve energy efficiency. This has placed a significant “stress” on existing building automation infrastructure which operate using narrowband Local Area Networks (LANs), multi-drop proprietary serial protocols and simple polling schemes for network control. This has resulted in a call to upgrade building LANs to a standardized broadband network with convergence to corporate IT infrastructure. In this paper, we highlight the application of IP-485® technology and products for building automation network expansions and upgrades, and describe how it is utilized to accelerate the transformation of legacy infrastructure into open standard Cloud connected IP LANs. The proposed solution enables a phased migration approach which ultimately serves to accelerate the technology changeover without compromising existing LAN performance and reliability while immediately allowing multi-drop access to web services such as remote monitoring, and Cloud storage and analytics.

Introduction

Building Management Systems (BMS) refer to the automatic control of heating, ventilation and air-conditioning (HVAC), lighting, and the control of physical access to facilities among other applications. Traditionally, these systems have required low bandwidth communication and facilities managers have relied on the experience of system integrators (SIs) within the automation industry to design and deploy vertically integrated BMS solutions. They have maintained their installations with direct support from SIs, with little or no convergence to their corporate IT infrastructure. When necessary, they have relied on the same SIs to design and implement network expansions and product upgrades. As a result, buildings have been
populated over the past thirty years with a wide variety of closed narrowband infrastructure, and proprietary data and network management protocols. They have little or no connectivity to infrastructure or service outside the building.

In recent years, it has become increasingly clear that the business model adopted in the past can no longer be continued. With an escalation in the cost of fuel and electricity, facilities managers are under increased pressure to reduce operating costs through energy efficiency improvements. Secondarily, they have also been asked to meet environmental metrics such as reduced carbon footprints. This is resulting in a push to upgrade HVAC and lighting products to higher efficiency counterparts, increase the instrumentation in buildings, and improve building intelligence so that energy usage can be targeted and effective. A key obstacle to these is the topology, connectivity and bandwidth limitations inherent in legacy BMS infrastructure, for instance:

- Many legacy networks operate at or close to their capacity already. So, upgrade requests can no longer be satisfied by just adding new edge devices to the network infrastructure.
- A good fraction of legacy networks still pre-date BACnet standards, and face scalability challenges when asked to increase the frequency and amount of energy data collected.
- Legacy networks also have limited means of convergence to an open standard IP LAN infrastructure and face integration challenges when connected to Cloud-based services, such as remote monitoring and analytics.

In a world where CapEx budgets are large, facilities managers would be able to overcome these challenges with simply a “rip and replace” plan to a new, open-standard broadband infrastructure capable of supporting the integration of BMS to the corporate IT network. But practically speaking what they need is a phased migration strategy from their legacy infrastructure to one that satisfies their emerging bandwidth, security and service demands. In this paper, we show that IP-485® enables a low technical and project risk and low cost strategy for the transformation of legacy BMS infrastructure into an intelligent building network.

**Challenges in Building Management Systems Infrastructure**

Building Management Systems (BMS) refer to the automatic control of heating, ventilation and air-conditioning (HVAC), lighting, and the control of physical access to facilities among other applications. They consist not only of HVAC, lighting and other equipment, but also sensors that make measurements, and control systems that utilize them to automatically regulate control variables. As an example, thermostats measure room temperature, which is then used to turn
heaters or air-conditioners on or off depending on whether the actual temperature is over or under specified value. Systems that regulate temperature have been in existence in buildings for many years, while those that sense occupancy and/or ambient lighting to regulate lights are relatively recent. As a result, BMS are populated with a wide range of network and communication infrastructure, most often incompatible with each other and operating independently.

Older infrastructure may operate at very low bandwidths (often as low as 4800 or 9600 Baud), and had very little need for network control, error correction in communication, or bandwidth/latency management. Operational reliability in these installations resulted more from careful design of the entire system, and upgrades required a re-test of the entire system in place. Some of the newer BMS infrastructure installed over the past decade has been based on the more standardized BACnet protocol with data rates as high as 76.8 kbps. These networks are managed using Master-Slave or Token Passing, with the ability to tunnel IP packets. As a result, they are scalable and easier to integrate into an IT infrastructure. While an eventual move to a full IP-enabled LAN is virtually assured, BACnet is an important step in the transformation of BMS infrastructure since it appears to satisfy much of the current and emerging needs.

The primary impediment to a plan that upgrades older installations to BACnet (and for that matter, BACnet infrastructure to IP) is that it will require a “rip and replace” of the former with the latter and involve significant capital expense. There are options involving wireless connectivity within buildings which are cheaper and far less disruptive, but these require detailed installation procedures, careful setup for performance and varying levels of ongoing support for reliable operation. As a result, building owners have been reluctant to initiate a complete technology changeover for improving energy efficiency in facilities replete with legacy BMS installations due to the capital costs, and technical and project risks involved. IP-485® technology enables building owners to take a phased migration approach to modernizing their BMS installations which, in turn, allow them to accelerate technology changeover with reduced capital requirements and disruption to their operations.

**IP-485® Technology**

At the heart of the proposed solution for BMS upgrade challenges is a technology called IP-485® that enables the simultaneous transport of both IP data and Serial data over the same multi-drop wiring infrastructure (twisted or untwisted pair, current loop, co-ax, etc.), even in the presence of significant conducted and radiated noise in the medium. The foundation of this technology lies in an algorithm called *Dynamic Adaptive Channeling* which decides, in real-time,
how to encode data payloads into communication frequency channels, so that Quality of Service (QoS) can be maintained at all times subject to channel constraints. The algorithm starts with a full spectral sweep and a determination of the Signal-to-Noise Ratio (SnR) properties across the entire channel. To make the problem computationally elegant, the algorithm divides the overall communication channel into Orthogonal Divisional Frequency Multiplexing (OFDM) sub-channels and conducts the SnR analysis at the baseband associated with each sub-channel (shown in Figure 2). This helps determine available sub-channels at a given Quality of Service (QoS), which in turn maximizes the utilization of usable channel capacity.

Figure 1: Dynamic Adaptive Channeling

Figure 2: Example IP-485® Network Architecture
Adaptive Channeling permits the deployment of robust communication networks in harsh environments. The algorithm is robust to white noise in the channels which degrade the communication bandwidth, and colored noise in the channels arising from factors such as EM interference from nearby operating equipment. In addition, it automatically discovers usable communication channels regardless of the type, gauge or topology of wiring used. As examples, IP-485® would operate successfully on 18-gauge, twisted pair, multi-drop wiring, co-ax cables or 26-gauge untwisted pair, simple daisy-chained wiring. Communication is robust to collisions arising from other applications currently using the channel, which are seen as interferences in channel analysis. This enables the technology to implement multiplexed channel access across applications at the physical level. In addition, if more than one OFDM sub-channel is available for communication, the technology enables the implementation of a Bus consisting of sub-channels that run concurrently, each of which may be multiplexed between applications.

The second set of properties manifest in PCN’s IP-485® relates to real-time network management at the application level. Concurrent with the adaptive channeling algorithm, we also implement a real-time communication engine that enables the delivery of serial data (that is multiplexed with IP data) with negligible latency, encoded in jitter free, almost copy-exact waveforms, regardless of wiring type, noise, interference of other considerations that affect signal integrity. Further, we also implement a network engine that enables network configuration and management in real-time. For example, in a Master-Slave configuration, the concept of a Floating Master may be implemented using the engine. Further, data payloads with high priority may be queued and delivered with very low latency across the network.

**IP-485® Networks**

Figure 2 shows a typical network established using IP-485® network products. It consists of a Server that is connected to the Cloud via an ISP line (T1, Fiber or Satellite) using a standard CAT 5/6 connection. It may also be connected to serial network(s) on its Low Frequency (LF) Bus(es). The PCN Single Channel Server (SCS) accepts a single serial network connection (shown in Figure 2), while the Multi-Channel (MCS) version permits the integration of up to 4 serial networks. The Server then transports both IP data and serial data on the same output channel, called the Broadband (BB) Bus. The SCS has a single BB Bus, while MCS would have as many separate BB Buses as serial network inputs on the LF Bus. In this architecture, the Shared Wire multi-channel, multiplexed access bus is implemented on the BB Bus wiring.
Each Server is connected to one or more PCN Clients on the BB Bus. A SCC would be capable of driving (nominally 4 and) up to 8 switches, while a MCS has the capacity to drive up to 32. Each PCN Client has as input the BB Bus wiring from its Server. Serial network outputs are connected to its LF Bus, while its 3 IP ports enable the establishment of a managed IP network between the Server and the Client. Network established with MCSs and Clients have the ability to integrate up to 48 IP Edge devices, and 4 separate serial networks, each potentially having a different protocol. SCSs, on the other hand, will be able to handle 12 IP Edge devices and a single serial network. In each case, the IP network would co-exist with the serial network without any impact on the performance of one network from the other. In our current product implementation the BB Bus as well as the LF Bus consists of standard twisted pair (TP) or untwisted pair (UTP). In addition, the technology has been validated on a variety of analog (current loop, co-ax, etc.) and digital (485, 422, 232, etc.) wiring.

![Figure 3: Typical Legacy BMS Network Segment](image1)

![Figure 4: Upgrading a section of the Legacy Segment using Structured Cabling](image2)
Network Transformation using IP-485® Networks

Building LANs are typically organized into device control network and riser network.

Device Control Network Segment

Figure 3 shows a typical legacy device network segment in a building. The segment is controlled by a Master Controller, which is connected to one or more Application Specific Controllers (ASCs) which, in turn, are connected to sensors (e.g., thermostats) and actuators (e.g., variable frequency drives). A network segment may be designed to control lighting and comfort of a section of, the entire floor, or multiple floors of a building. Typically, the wiring is a 2-wire infrastructure, and rated to carry serial data payloads at data rates up to 9600 Baud. A variety of proprietary protocols may be used within the network segment, including P1® (Siemens), N2® (Johnson Controls), LON® (Echelon). A technology changeover in this network would require either (i) changing the entire 2-wire infrastructure with structured cabling, and upgrading the Master and all ASCs, regardless of whether it is required, or (ii) maintaining multiple network infrastructure. Figure 4 shows an example network transformation from legacy to IP. Upgrade from legacy to BACnet would be similar, but involve structured cables that are specific to the latter. Wireless is a complex option and time consuming to deploy and maintain if a complete or partial changeover is required. In addition, facilities managers would be required to maintain and manage multiple network infrastructures in their premises. On the other hand, it can be a cost effective option if only a handful of ASCs need to be upgraded. Figure 5 shows an example of how new IP ASCs can be integrated using wireless.
The third option now available to facilities managers is the use of IP-485® to upgrade a single, a section or the entire device network segment. Figure 6 shows how the transformation can be effected without either the need to pull new structured cabling, or be forced into maintaining multiple network infrastructures - both the legacy and the new networks may be implemented and maintained on the existing 2-wire infrastructure. By re-purposing the legacy cables into a BB Bus, IP-485® enables the simultaneous delivery of the legacy data as well as IP data. As a result, any ASC may be upgraded into an IP-enabled ASC and connected to a new IP Master. The communication between the existing Master and its ASCs continue as before and the communication between the new IP Master and IP ASC occurs as if there is a structured CAT 5 cable connecting them. In the example shown in Figure 6, the existing Master is connected to the LF Bus of an SCS, and the legacy wires are connected to the BB Bus ports of both the SCS and an SCC. In addition, the continuing legacy segment is connected to the LF Bus and the new IP ASC is connected to the RJ-45 port, both available on the SCC. On the BB Bus, the IP-485® SCS and SCC pair delivers serial data rates up to 115.2 kbps, and consistent IP bandwidth of 4 Mbps in the presence of radiated and conducted noise and interference.

Figure 6: Upgrading a section of the Legacy Segment using IP-485®
IP-485® may also be used to upgrade the legacy network segment to BACnet instead of IP. This is a path many building owners have adopted since the costs associated with BACnet upgrades tend to be lower. Figure 7 shows the flexibility that IP-485® can offer when infrastructure upgrades are considered. It can simultaneously support the legacy, BACnet and IP networks on the same 2-wire infrastructure, and provide facilities managers a great deal of flexibility in how they phase their upgrade projects into their capital budgets.

**Riser Network Segment**

Riser networks may be used to connect Master Controllers to a central (in-premise or in the Cloud) Building Controller. Examples of building controllers include Apogee® (Siemens) and Metasys® (Johnson Controls) and numerous others. Upgrading the riser networks may be considered in a manner similar to the flexible approach described for the device network segment.

**Acceleration through Migration using IP-485® Networks**

In terms of real-world applications, PCN products have been successfully applied on a variety of proprietary bus protocols, BACnet as well as IP. In all cases, serial data rates up to 155.2 kbps have been handled successfully without any impact on the operation of existing devices and controllers. In addition, consistent IP bandwidth of 4 Mbps have been recorded with burst rates
well in excess of 20 Mbps. In the process, the technology has demonstrated its ability to support
the upgrade of a wide range of legacy networks on 2-wire infrastructure. In addition, it has
supported with equal ease, single device upgrade requests as well as the transformation of
entire network segments. In all cases, customers have found the overall cost of deployment as
well as the project and technical risks involved far more attractive than that of wireless or
structured cabling options.

With the obstacles to network upgrades removed, IP-485® is beginning to show clear
evidence that a phased migration approach with the technology would meet all the customer
upgrade requirements with far less risks, downtime and capital expense. This is causing
building owners to view their energy efficiency projects in new lights and consider accelerating
the transformation of their legacy infrastructure so that their building system LANs may support
real-time energy management, with monitoring, analytics and services delivered directly from
the Cloud. Convergence between building systems and the IT infrastructure has also become
relatively easy to design and implement.

**Conclusion**

In this article, we have presented IP-485® technology and products and have described how
they may be deployed to transform existing BMS infrastructure into one that can support IP-
enabled devices connected to the Cloud through a phased migration approach. The technology
has been applied successfully on a variety of BMS configurations and data protocols, and has
operated on both twisted pair and untwisted pair wiring. Both daisy chain and multi-drop wiring
topologies have been utilized. The technology and products are transforming energy efficiency
industries and demonstrating phased migrations are the key to the acceleration of the
transformation of building systems from old to new.