Improving Building Control Methods using Real Time Location Services

Introduction

Owners and operators of commercial real estate face a complex combination of budget reductions and increasing occupant expectations. They are pursuing programs such as LEED (Leadership in Energy and Environmental Design) and Well Building, as much for their marketing value and the benefit to the tenants as for the intrinsic value of reducing water and energy use. Energy costs, which represent a significant proportion of total operating costs of a building, are constantly being scrutinized for opportunities for savings. In advanced buildings, savings are on the order of a few percentage points, meaning most of the "low-hanging fruit" of energy savings has already been plucked.

One of the largest sources of energy demand in commercial and institutional real estate is the heating, ventilation and air-conditioning (HVAC) system, which consumes, on average, between 40% and 55% of a building's total energy load. This suggests that relatively small changes in HVAC energy use can lead to substantial cost savings.

One area where energy savings can still be found is having the ability to run HVAC systems only in occupied parts of a building and turn down or shut off the system in other areas whenever possible. Studies have shown that potential savings of up to 23% savings can be attained by occupant demand control (US DOE, 2013). Traditionally, this has been an expensive and challenging task to do with any precision. For example, some buildings use motion sensors in each room while others may use a single temperature sensor in one spot in each room. The cost to connect either type of sensor is high and typically lacks the ability to determine the room's actual human occupancy in real-time, leading to limited environmental control capability.

Wi-Fi networks capable of real-time location services (RTLS) are able to offer high resolution occupancy data within a building. Linking this data with software developed by Sensible Building Science it is now possible to provide granular control of a building's HVAC system based on occupancy, while only requiring minimal capital investment. The result of combining a building's real-time occupancy data with dynamic building controls has shown to produce significant energy cost savings while improving occupant comfort.

Overview of Wi-Fi Location Services

Detection of Occupants using Wi-Fi

With an increasing number of intelligent analytics features now available in enterprise-grade Wi-Fi networking equipment, organizations can leverage new and existing data to better understand foot traffic patterns and behavior. This location information can be used to engage users and optimize business strategies.

Smartphones with Wi-Fi can now be used as an indicator of occupant or visitor presence thanks to a Wi-Fi mechanism that is common across all such devices' probe requests. These 802.11 management frames are transmitted at regular intervals from Wi-Fi devices and do not require the device to be directly associated to the wireless network. The frames contain information that can be used to identify presence, time spent, and repeat visits within a wireless coverage area. These devices can be detected by Wi-Fi access points irrespective of their association state, meaning that even if a user does not connect his or her device to the wireless network the device's beacons can be used to detect presence and location.

Since a large percentage of the population carries smartphones, probe requests can be used to build a statistical data set regarding the presence of Wi-Fi enabled devices in a coverage area. This data set can in turn be used to correlate to the number of people in a coverage area, within a calculated margin of error.

WiFi RTLS solutions, such as Cisco Connected Mobile Experiences (CMX) or Aruba ALE, are analytics solution that leverages the existing wireless infrastructure to detect and locate mobile devices and return insights on the behavior of those devices and their users. It enables organizations to detect, connect, and engage with end users while inside their venue.

Overview of Building Controls

Building Systems

Buildings are typically divided into occupancy zones that correspond to the primary air handling units (AHU). These zones generally serve several hundred square meters of floor area, though this may vary considerably depending on the type and use of the building. HVAC units deliver temperature-controlled, filtered air to their respective zones and use some form of feedback control to maintain the right settings, including temperature, airflow and humidity sensors, as well as valves, dampers and fan controllers that deliver the air as intended. Figure 1 shows an example of a building floor plan with several HVAC zones.

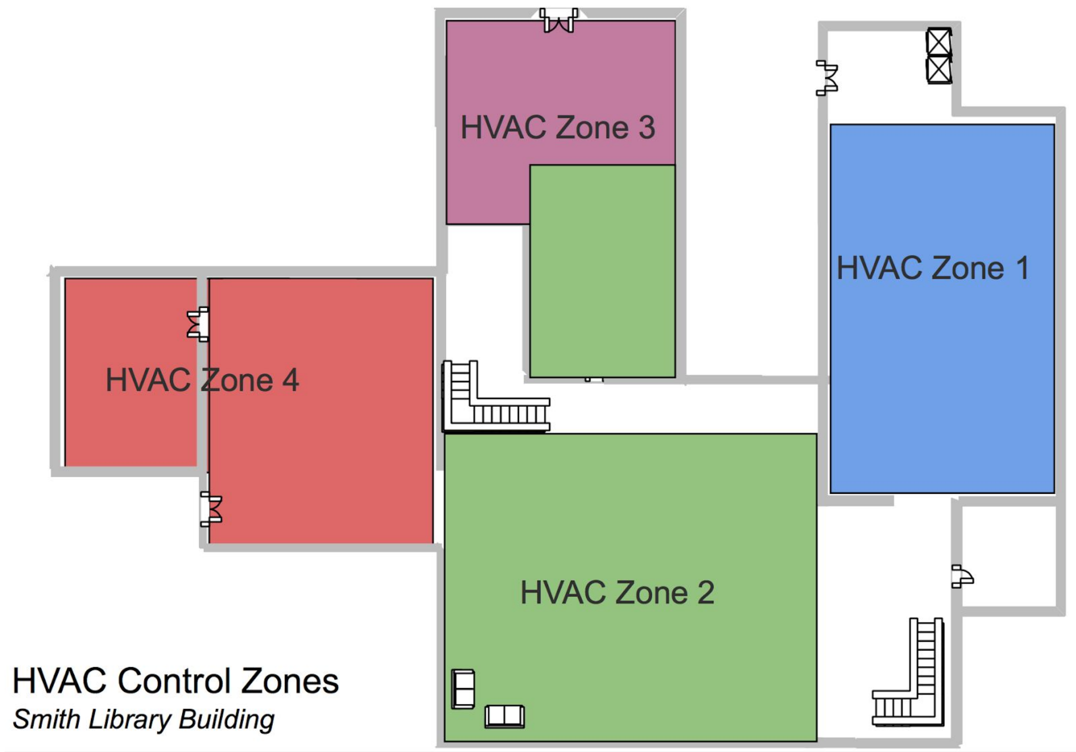

Figure 1: Typical Building Plan with HVAC Zones Highlighted

Building Automation Systems

Building Automation Systems, or BAS, are control systems that regulate the operation of various building systems. Many of these systems have historically been limited by being (a) single-purpose, (b) proprietary and (c) difficult to cross-connect. Over the past 20 years BAS have become more sophisticated and integrated. They have evolved from being proprietary two-wire systems connected by RS485 or RS232 that only connected HVAC, to relying on open standards such as BACNet running across an Ethernet and IP network that supports multiple building systems, including HVAC, elevators, lighting and security systems, to name a few.

There are a variety of competing protocols used for building automation systems, including BACNet, LonWorks, and KNX; however, BACNet is one of the most common and best integrated to modern communication systems.

BACNet is one of the most-widely implemented BAS protocols in North America. Initiated in 1987 by ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers), it was the first open-source protocol to connect HVAC systems. Since then, it has been expanded and amended many times and now includes objects for access control, lighting, elevators and escalators, life safety systems. It is able to operate over a variety of physical layers, including Ethernet, BACNet/IP, BACNet/IPv6, and ZigBee, among others.

LonWorks was developed by Echelon Corporation in 1999. Built primarily as a physical-layer system, it has a wider application than BACNet, being incorporated into industrial controls, security systems, street lighting and transportation applications, as well as building automation systems. LonWorks uses a two-wire system but can also run over IP networks using IP tunneling to connect different devices or systems.

Occupancy Management – Traditional Methods

In a traditional system, building managers must anticipate HVAC demand based on ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) Standard 62.1, which requires minimum air flow based on occupancy levels and zone usage. To comply with ASHRAE 62, building managers must ensure adequate ventilation based on the expected building schedule and taking into account time of day, day of the week, and scheduled events. The various zones are considered to be either "Occupied" or "Unoccupied" in the context of this kind of scheduling. Unexpected demand peaks due to factors like event time changes or unscheduled weekend events can overwhelm the system and lead to comfort complaints, which must be dealt with urgently. Many buildings can also experience sudden swings in occupancy, such as when a large group of people enter or exit a conference room, a lunch area, or a classroom. Accurately controlling the airflow and temperature in these areas can be difficult, as the occupancy detection may have limited capabilities.

Whether too hot, too cold or due to insufficient fresh air, occupant comfort forms the largest category of complaints for most building managers. Lack of detailed knowledge about the actual occupancy of a building means that, during occupied periods, the system must use a predicted or expected occupancy value to calculate airflow and occupancy. Unoccupied or minimally occupied areas are supplied with the same amount of HVAC as if they were fully occupied, wasting electricity and heating fuel used to move more air and condition it to a comfortable setting (see Figure 2).

Figure 2: Traditional Occupancy Management Challenges

The use of occupancy sensing can provide significant savings in a building system by ensuring that equipment only delivers conditioned air to spaces when and where it is required. Recognizing the disadvantages of a traditional system, companies are moving towards dynamic occupancy sensing. Initially, this began with wide-area (e.g. for a whole system or building) CO_2 sensing, however these types of sensors are slow to respond, experience 'drift' over time, and there is no ability to determine actual occupancy in a given space. Additionally, it can be expensive to retrofit a building with sensors in each room. Most current systems require the installation of physical occupancy sensors (e.g. CO_2 monitors, temperature, motion sensors) in every room to be monitored. Installation labour costs are high, and sensors typically need occasional maintenance and calibration and may be overwhelmed in high loading conditions. This creates additional work and cost for building managers.

Benefits of Wi-Fi-based occupancy detection

Feeding real-time location data from WiFi RTLS to the building automation system provides immediate information about the occupancy of individual rooms and spaces. This can be used to implement a more granular level of control over local HVAC systems than the traditional timetable and is usually less expensive than dedicated sensors, since Wi-Fi networks are often installed and maintained in buildings already (see Figure 3). As long as WiFi RTLS can determine location accuracy within a few meters, either by triangulation methods or by presence detection, sufficiently accurate occupancy measurements can be pinpointed within each predefined HVAC zone.

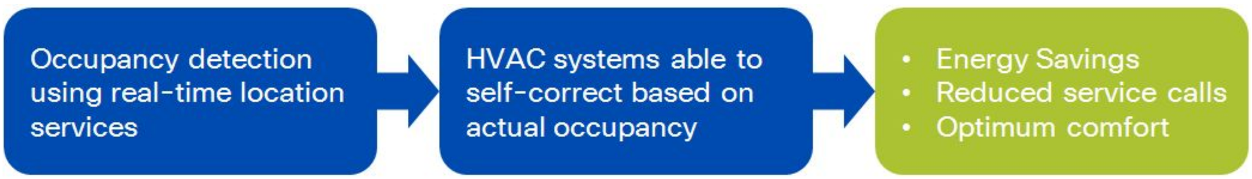

Figure 3: Wi-Fi Based Occupancy Used to Control the HVAC System

In the simplest use case for a WiFi-to-HVAC technology, HVAC zones can be set to unoccupied mode if there are not enough people in the space. This causes the air handling unit to react as a simple binary control and reduces energy use in areas with few or no occupants. The fans are either slowed or stopped, and zone temperature set points are set back to allow the space temperature to drift toward unoccupied set points. This requires less energy for HVAC, compared to the standard operating practice of using a fixed on/off schedule in the building. This use case is primarily useful in buildings which have unoccupied areas during the day.

A more sophisticated use case is to adjust the amount of air supplied to match the number of people in the space. The use of proportional control enables building managers to attain deeper energy savings by reducing energy services when occupancy demand is low. Many newer buildings have variable speed control on their AHU fans, meaning the adjusting airflow can be controlled precisely and in real-time. Currently, occupancy demand is estimated either through imprecise CO_2 sensors or regulated by design occupancy figures. Both of these have the potential to over- or under-supply fresh air to spaces. Modulating airflow according to occupancy further increases the energy savings by reducing the amount of air that needs to be moved and heated or cooled, even when the space is occupied. This has a much wider range of useful applications, as many types of buildings may experience periods when the occupancy is reduced, but not enough to switch the HVAC zone to the unoccupied mode. In areas with rapidly changing occupancies, such as departure gates in airports, this can also improve air quality.

The Bridge: Software Architecture

The Sensible Building Science (SBS) Bridge application is able to communicate with WiFi RTLS location services, extract occupancy data, perform streaming analytics, and send HVAC control commands to a building automation system in real-time. This system has been demonstrated to provide significant savings in the energy consumption (electricity and heating fuel) in commercial and institutional buildings.

The SBS Bridge is a middleware software application that does the following (see Figure 4)

- Collects client locational data from an WiFi RTLS platform, preferably via a REST API
- Translates the data into an occupancy count from user-defined 'counting zones'
- Sends the zone occupancy data to a building management system gateway through its API

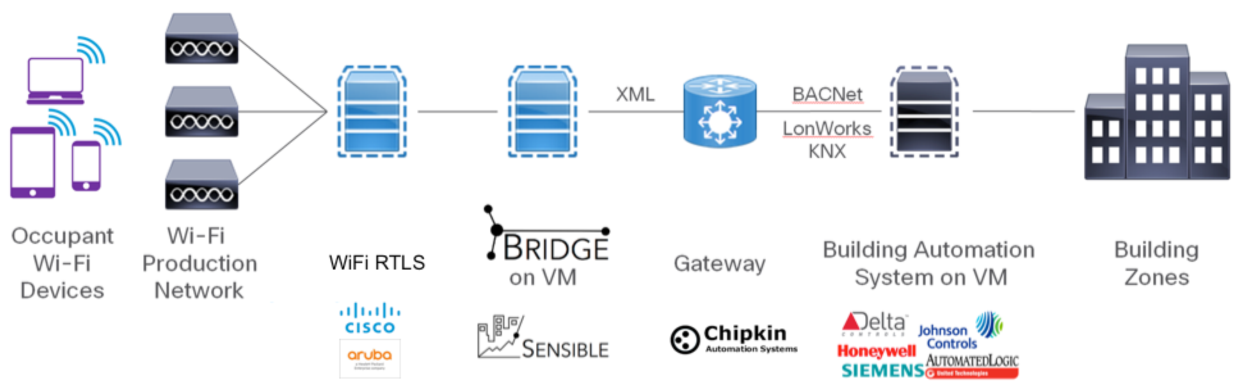

Figure 4: Sensible Bridge Architecture

The translation service running on the Bridge conducts a mathematical mapping in real-time to transform WiFi RTLS location service data into a format that is appropriate for a BAS system to use for demand control. The Bridge also contains a heartbeat signal to indicate data continuity to the BAS. If the heartbeat goes off for any reason, the BAS is programmed to revert to the time-of-day schedule so that occupants remain comfortable.

Through a translation gateway, such as a CAS Gateway from Chipkin Automation, the Building Automation System receives zone occupancy data in its preferred format: BACNet, KNX, LonWorks, etc.

Each AHU to be controlled requires a few lines of code so that it can adjust its operation to suit the apparent occupancy level that SBS Bridge is delivering. The resulting flow of data is shown in Figure 5.

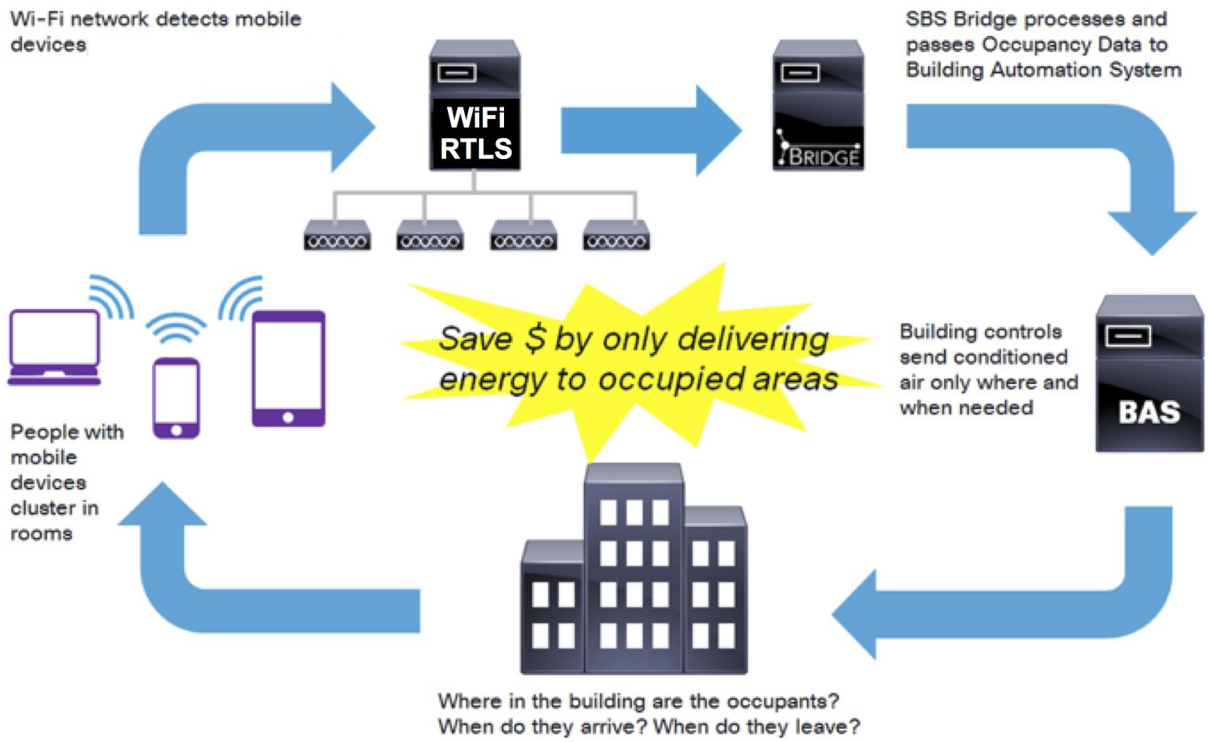

Figure 5: Schematic of Occupancy-Based HVAC Control Method Implemented by SBS

The Bridge platform installs on a virtual machine (VM) installed on the premises. Once installed, facility managers are able to log in to the Bridge and create counting zones that match HVAC zones for real-time building controls. Counting zones can also be created for space utilization analytics. The facility manager can easily add new buildings and floors, configuring the Bridge program to match the physical space.

The Bridge's web-based user interface provides visualization of space occupancy, showing how many devices are currently connected in each zone. The interface supports intuitive, drag and drop zone definition and graphical data trending (see Figure 6).

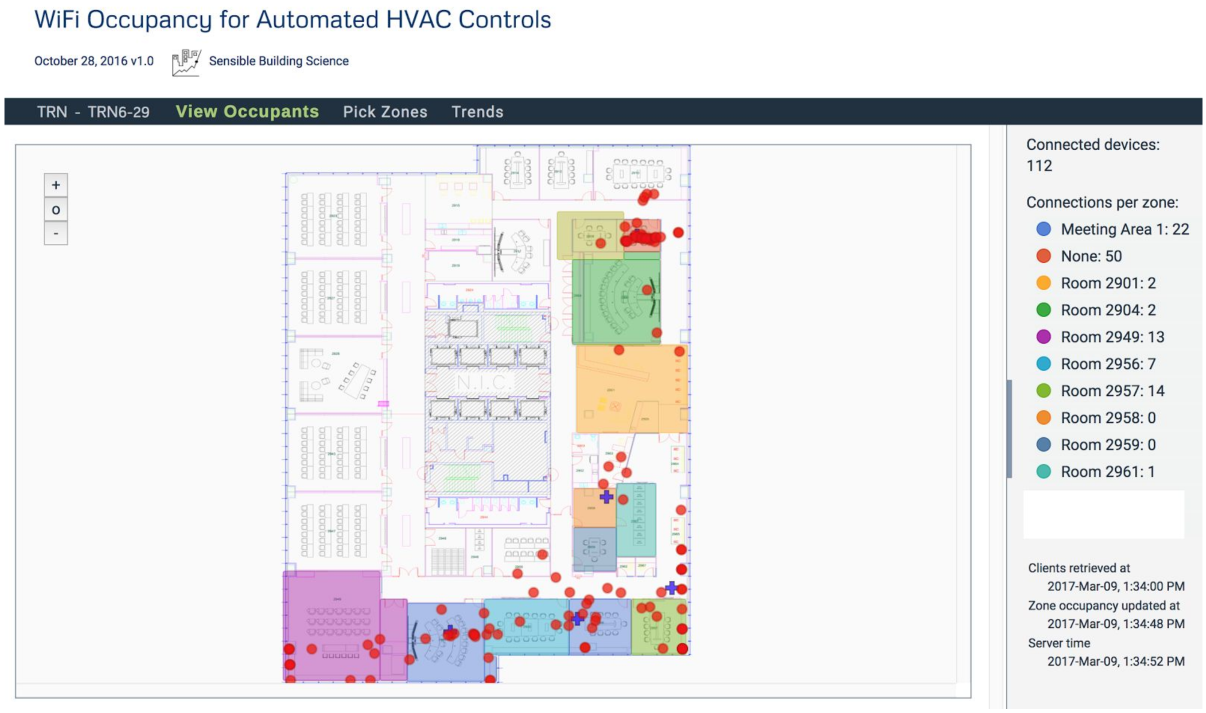

Figure 6: SBS Bridge User Interface

To preserve data privacy, the Bridge logs all occupancy data in anonymous form. It has no need to analyze or store specific user information, such as MAC or IP addresses. The only relevant information is the number of occupants in a given space. This anonymous data is stored on-site and can be downloaded at any time for further analysis.

Results

The SBS Bridge solution has been deployed successfully for many buildings and significant energy savings have been achieved. For example, at the University of British Columbia (UBC), in Vancouver, Canada, the SBS solution was deployed in the main campus library. Figure 7 shows actual occupancy for 24 hours in a 220,000ft library. Occupancy stop is observed much earlier than manually scheduled stops which saves HVAC operation time and energy costs.

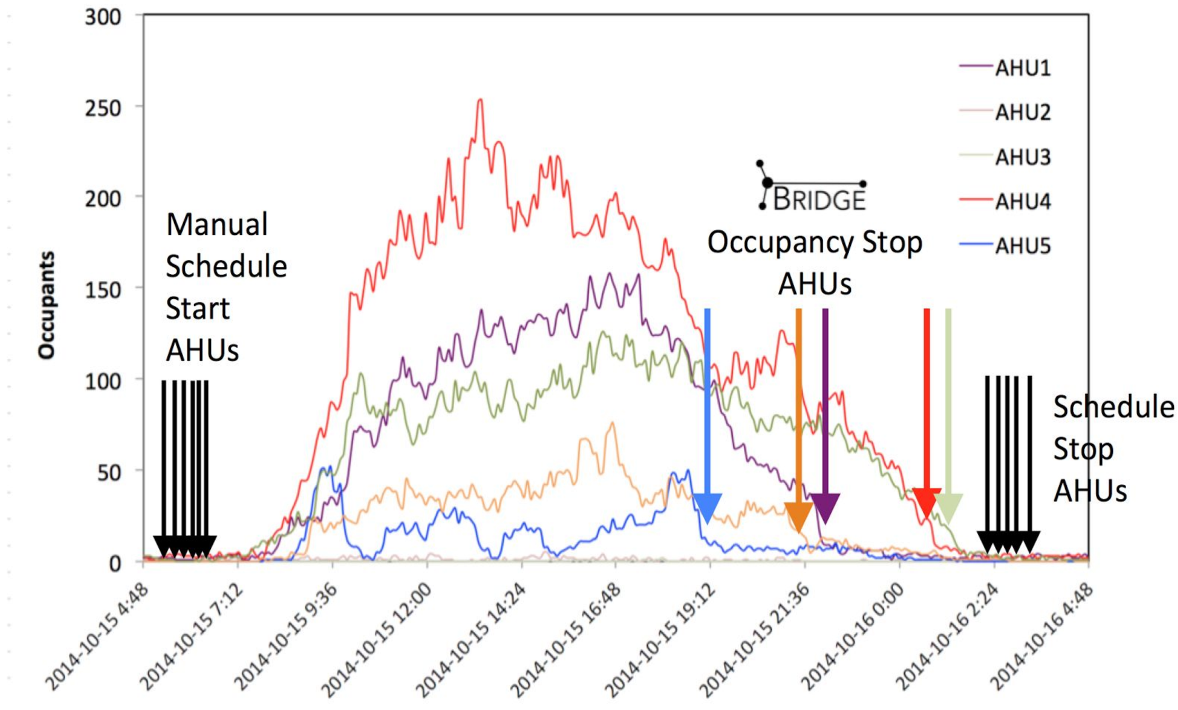

Figure 7: UBC Results: AHU start/stop time Schedule vs Occupant Control

After a nine-month deployment, the solution was immediately able to deliver 5% energy savings. A full deployment across the entire campus is estimated to help attain UBC's campus target of 33 percent lower gas emissions and on target to achieve 67 percent reduction within the next 5 years. When coupled to proportional control, Bridge is anticipated to deliver a further 6-10% energy savings, rising to between $200,000 and $400,000 on an annual basis

A short video on the UBC case study with Cisco Systems can be found here

For further information, cases studies, and software architecture documentation, please contact stefan.storey@sensiblebuildingscience.com