Moving from Connected Buildings to Smart Buildings

WHITE PAPER

1.0 Introduction

Since the early twentieth century when the father of modern air conditioning Willis Carrier invented air washers to cool air and control humidity in printing press warehouses, building engineers have struggled to keep occupants comfortable. Facility managers have relied on building control systems to optimize this conditioned environment. Over time these systems have progressed from analog to pneumatic to direct digital control giving managers better and better control. There have also been other advancements supporting building managers: open protocols, relational databases, larger hard drives, faster computers and better staff training. The result is that today's modern office building is analogous to a living and breathing organism with connected systems monitoring its environment. But can the modern building learn from its environment?

2.0 What is a Connected Building?

A typical high-rise office building of today may have 30 or more disparate systems controlling various functions of the building. One system monitors and controls the heating, ventilation and air conditioning (HVAC) functions of the building. Overseen by the building engineering team, the system controls the various equipment types that regulate the indoor environment. Multiple set points trigger equipment to open or close, turn on or turn off, and more. Temperature sensors feed information in to the system across a multitude of zones.

While the HVAC system is humming away, the fire control system is monitoring alarms ready to activate water pipes or release inert gas to quickly dispense flames. In another room a separate system is monitoring the stored power in the uninterruptible power system batteries. These batteries are expected to carry the building's load while generators crank up to full power should the building lose its utility power. The rooms that house those batteries are likely equipped with hydrogen sensors with alarms to ensure no dangerous off-gassing.

While some systems keep the lights on and the temperature constant, other systems control building access for employees and visitors. Badge readers open doors, call elevators and continually log access. Closed-circuit television cameras record all entries and exits for the last 30 days.

There are also related systems that pull information from the primary building systems. A facilities management dashboard may aggregate information from several other systems to make it easily accessible. In turn, the building's electricity meters may feed information in to a company's financial planning systems to estimate costs. This trend of cross platform sharing allows use of common resources through databases. Cross platform sharing also makes data available in a central location, which facilitates reporting.

Connecting these disparate systems gives the impression that we have intelligent buildings. Imagine the company CEO that arrives at her office on a weekend. As she enters the parking garage, the access control system calls an elevator and triggers garage lights. The HVAC system and building lights turn on by zone or floor. All of these connected actions give the appearance of building intelligence. But in actuality, each action is simply following a sequence of operations or planned steps.

3.0 Sequence of Operations Methodology

Connected buildings with systems following a sequence of operations are analogous to actors following a screenplay. The script identifies how and when each actor will interact with others. When they will speak, what they will say, and under what circumstances will they leave the stage. Building operations is really quite similar.

On a projected hot day, start chiller #4 at 4:00 am to pre-cool the building. If #4 reaches 90 percent load, start chiller #5. If outside humidity is “x” and outside temperature is “y” enable free-air cooling by turning on outside economization units and reducing chiller #3 output. These are pre-defined rules set by the building engineering team.

The challenge is the increasing complexity of possible scenarios. There is a limit as to what can be pre-programmed and only a finite number of operations can be managed using this approach. There are also some operations that cannot be fully managed with a rules-based approach. How does a facility manager identify an optimized morning start and when is the ideal time to start the HVAC system? The facility manager could simply start the systems at 3:00 am and guarantee that the building will be at the proper temperature at 8:00 am. But couldn’t the manager start at 4:00 am and save an hour’s worth of energy and costs? What about 5:00 am?

With today’s existing controls approach, facility managers look to the immediate past to plan for tomorrow. Yesterday it took 42 minutes to cool the building so today it will take 42 minutes. But what happens if outside air temperature is hotter. It takes longer. How does a rules-based approach account for this?

One way to overcome day-to-day variation is to rely on building sensors that adjust systems based on performance. However, a failed sensor may cause the building to run 24 hours per day. Too much or too little conditioning (and the subsequent occupant complaints) oftentimes results in a manual override by facility staff. Existing control systems also do not know what happens as systems interact.

The ideal solution is to know how the given building will respond under certain circumstances. When facility staff requires an indoor temperature of 74 °F on 90 °F day with 98% humidity, how will the building respond? If staff want to take that ambient indoor temperature from 74 °F to 71 °F over 4 hours how do you do that and what are the tradeoffs? Cooling time, energy costs, maintenance implications, and more should all be considered. Understandably, this scenario is very complex and beyond the ability of a traditional sequence of operations approach. These are the smart buildings of the future.

4.0 Smart Buildings of Today

Smart buildings are automatically generating awareness and continually making complex decisions. Mathematics is well suited for making complex decisions. How can we best leverage the existing building systems and overlay mathematics to aid in decision-making? The first step is leveraging the existing control systems and the connected building databases. Control systems are very good at certain tasks—usually mechanical tasks such as setting the position of a damper or valve, or measuring outside air flow rates. The connected building databases are also valuable for reporting functionality.

Connected Buildings	Smart Buildings
Single portal access for all systems	Attend meetings to negotiate contract
Cross system functionality	Develop coordination meeting schedule
Consolidated data collection and reporting	Contractor Approved by CCCSWA Board
Possible maintenance cost reduction	Continuous and intelligent grid participant (smart grid, micro grid, electrical vehicles, etc.)

Figure 1: *Benefits of Connected versus Smart Buildings*

Truly smart buildings automatically build awareness and learn by listening. Listening to real-time data—from existing systems and interfaces—is far cheaper than unleashing hoards of onsite engineers to physically measure and model the building. The key is to identify those key dynamics that help describe the building at the macro level. For example, the temperature rise of the building space at end-of-day. In this example the rate at which the temperature of the building space merges with outside air temperatures at the end of the day, you could better understand and characterize the thermal mass of building, the impact of equipment use, and influence of building occupants. This is just one dynamic among many others that can be learned by listening.

One thing is clear—every building is unique. To create a smart building, the facility staff needs to understand how it interacts with its environment. What is needed is a model, for example, that knows how long it will take to reduce temperature from 74 °F to 71 °F if it is 98 °F outside, and what are the corresponding tradeoffs. Can you do that over 4 hours? Over 2 hours? How can you optimize the building's performance given this knowledge?

5.0 Role of Optimization

Optimizing a building is similar to playing a game with rules and objectives. First you create a model of how the building performs using the key dynamics discussed previously. Then you overlay constraints or rules that must be adhered to regardless of outside factors. An example constraint is a lease term that requires the building owner to maintain a particular floor or suite between 71 °F and 74 °F degrees at all prescribed times. The building staff cannot take steps that might jeopardize this temperature range in this location. Once constraints are accounted for in the model, other inputs such as weather forecasts, power prices, demand charges and more are built in to the model and building managers can optimize based on multiple, interrelated objectives.

The old approach to optimization was one-dimensional. Start the HVAC system as late as possible to save money while guaranteeing the building will be ready for occupants. With smart buildings, multiple objectives are now possible and can be modeled. The price of power may be significantly cheaper before 6:00 am. Should engineers pre-cool the building using cheaper power then rebalance closer to start time? But how does this approach affect the ENERGY STAR score or energy budget? What if there is a chance of a demand spike? What is most important depends on the building owner's objectives—which may change over time. With sophisticated models, weighting is possible too.

By optimizing the building in real time thanks to complex algorithms, it is possible to tap in to opportunities that exist throughout the day such as load shifting, avoiding demand charges, or pre-cooling to participate in a planned demand response event. Running a smart building is now like search. Taking inputs for constraints, rules, weather and then hand over to a complex algorithm that will converge on the optimal solution. The best models create an optimized approach for next 24 hours. Now building managers can create a smart building game plan with the necessary transparency to set the rules, load inputs, and allow a computer to optimize the outcome.

6.0 Conclusion

Technology is fundamentally redefining the opportunities around smart buildings. Decisions on how best to optimize today's building operations are becoming so complex, so conflicting and so continuous that advanced algorithms must play a role. But with complexity, comes opportunity. When transitioning from a connected building to a smart building, any solution must provide facility operators with timely, accurate and consistent information through as few separate systems as possible. As complex as it can be, it is always best to start simple and learn by listening.

About BuildingIQ

BuildingIQ provides advanced, cloud-based software to reduce HVAC costs in commercial buildings. Customers save 10-25% of HVAC energy and can add 20 points to their LEED score. BuildingIQ software continuously monitors inputs including weather forecast, occupancy, energy prices and demand response events. It makes small changes in HVAC settings that result in large financial gains without impacting occupant comfort.

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