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Supplement 31

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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS AND NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

ITU-T Y.4550-series – Smart sustainable cities – Intelligent sustainable buildings

ITU-T Y-series Recommendations – Supplement 31

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International Telecommunication Union

ITU-T Y-SERIES RECOMMENDATIONS

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Supplement 31 to ITU-T Y-series Recommendations

ITU-T Y.4550-series – Smart sustainable cities – Intelligent sustainable buildings

Summary

The concept of "intelligent buildings" has been around for a number of years and has relied on the ability of individual systems within the buildings to communicate, to integrate and to perform in a manner allowing for numerous and complex controls to generate a much-enhanced response to many kinds of stimuli. Thus, the argument of intelligence can reasonably be associated with the ability of these buildings to function in an enhanced manner yielding many benefits for the occupants, the operators and the owners. Supplement 31 to ITU-T Y.4550-series Recommendations provides a number of examples of "intelligent buildings", while describing the benefits and efficiencies generated by such integration.

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Introduction

The implementation of intelligent and sustainable buildings is another key step in the journey to smart sustainable cities. To understand the scale of the issue, buildings are responsible for 40% of global annual energy consumption and up to 30% of all global energy-related greenhouse gas (GHG) emissions. Also on a global basis, the building sector is responsible for one-third of humanity's resources consumption, including 12% of all fresh-water use and produces up to 40% of our solid waste. As buildings become more intelligent and more sustainable, the possibility exists to reduce this impact dramatically.

The concept of "intelligent buildings" has been around for a number of years and relies on the ability of individual systems within buildings to communicate, to integrate and to perform in a manner allowing for numerous, complex controls to generate a much-enhanced response to many kinds of stimuli. Thus, the concept of intelligence can reasonably be associated with the ability of intelligent buildings to function in an enhanced manner yielding many benefits for the occupants, the operators and the owners and reducing the overall environment impact.

Definitions of intelligent buildings have been proposed by different user groups and have also evolved during the last few years. Some view the ultimate benefits of intelligence to be the provision of a more efficient and effective working environment for the occupants while others define such intelligence as providing greater economics for the building operators. However, some others conclude that automated responses, in particular to security and emergency situations, are of particular importance.

The thesis of intelligent buildings, therefore, is that base building systems can be designed in a manner which permits their intercommunication and which also allows for communication between the building and individual tenant. The benefits are not always the same for each group of interested parties, nor are all the benefits evident when not all buildings include the same features.

Intelligent building technologies open the opportunity to facilitate the monitoring of a building's overall condition. Transducers and sensors are available to measure most building related parameters and in any given situation there may be particular needs driving their specific use.

The significant advantage of intelligent buildings is that they can constantly monitor current operations in context and automatically adjust resources for optimum efficiency while identifying and accurately informing key decisions in a timely manner. It is the optimization of efficiency that will lead to reduced environmental impact and a more sustainable built environment.

It is also evident that the standards applicable to the provision of an Internet protocol (IP) infrastructure are one possible mechanism by which an intelligent building can be implemented. Depending on the jurisdiction, there may be a need that some of the systems require special considerations in order to comply with all aspects of the building code (e.g., fire safety code or electrical code).

Objectives of intelligent buildings have been described in general terms but nevertheless there are often strenuous professional arguments as to what should be the primary objectives of an intelligent building. Is it more important that the building be more efficient, i.e., that the operating costs are reduced or, is the effectiveness of individual occupants in the building the more important objective.

Depending on the particular structure, its purpose, the technologies which are prevalent in the building and other factors, there will often be different objectives. With ever rising energy and labour costs it is obvious that if those costs can be kept in check, or preferably reduced, opportunities for financial savings will provide an immediate return on any extra investment in building an intelligent building. A building which is operated continuously, e.g., a hospital, or which is operated by individuals who pay fees such as condominiums are less likely to see immediate benefits from the functions available in intelligent buildings.

Many modern buildings today have heating, ventilating and air conditioning (HVAC), lighting, security and communication systems that use information and communication technology (ICT) networks for management and control. This can provide the foundation to develop intelligent buildings. It is therefore possible to implement policies that enhance building efficiency and effectiveness consistent with changing business requirements and user needs.

In addition, climate change related severe weather events are increasing in frequency and severity. These severe weather events include urban floods, extended heat waves, ice storms, extended cold spells and high winds/tornadoes/hurricanes.

These weather events have both a long term and short impact on the building infrastructure in cities. During short-term events, building infrastructure may be impacted by major structural damage, damage to a building's support and utility systems, closure and loss of revenue among other items. Over the long term, severe weather and more extreme temperatures lead to accelerated degradation of a building's envelope, utility systems and infrastructure.

Steps need to be taken to maintain the building's exterior and envelope to prevent damage to the building and its equipment. At the same time, the design and intelligent infrastructure of the intelligent building can assist in minimizing the effects of extreme events.

Supplement 31 to ITU-T Y-series Recommendations

ITU-T Y.4550-series – Smart sustainable cities – Intelligent sustainable buildings

1 Intelligent sustainable buildings

1.1 Introduction to "intelligent sustainable buildings"

Cities cannot become smart and sustainable unless the issues of the built environment and in particular of buildings are addressed. On a global basis, buildings are responsible for 40% of global annual energy consumption and up to 30% of all global energy-related greenhouse gas (GHG) emissions. Also on a global basis, the building sector is responsible for one-third of humanity's resource consumption, including 12% of all freshwater use and produces up to 40% of our solid waste [b-UNEP]. In order to address the issue of climate change through the reduction of GHG emissions the impact of buildings must be reduced. It is therefore important for buildings to become more intelligent and more sustainable in order to dramatically reduce this environmental impact.

The concept of a "smart" or "intelligent" building may seem to be an oxymoron. Intelligence is normally indicative of a human (or animal) attribute in which individuals are capable of making interpretations, deductions or inductions, related to observations and to stimuli. Great individuals, such as Einstein, have been described as extraordinarily "smart" or intelligent" and so at first glance, it may seem that making these associations with inanimate objects such as buildings is an inappropriate association.

The concept of "intelligent buildings" has been around for a number of years and has relied on the ability of individual systems within the buildings to communicate, to integrate and to perform in a manner allowing for numerous and complex controls to generate a much-enhanced response to many kinds of stimuli. Thus, the argument of intelligence can reasonably be associated with the ability of these buildings to function in an enhanced manner yielding numerous benefits for the occupants, the operators and the owners. This Supplement will provide a number of examples of "intelligent buildings", while describing the benefits and efficiencies generated by such integration.

Definitions of intelligent buildings have been proposed by different user groups and have also evolved over the last few years. Some view the ultimate benefits of intelligence to be the provision of a more efficient and effective working environment for the occupants, while others define such intelligence as providing greater economics for the building operators and yet others conclude that automated responses, in particular to security and emergency situations, are of particular importance.

The following definitions for intelligent buildings should be considered:

– The use of integrated technological building systems, communications and controls to create a building and its infrastructure which provides the owner, operator and occupant with an environment which is flexible, effective, comfortable and secure;
– Use of technology and processes to create a building that is safer and more productive for its occupants and more operationally efficient for its owners;
– A building in which, those responsible for its operation, those benefitting from its operation and those ultimately responsible for the safety of all its occupants can share a view and a vision of the building status at all times;

– "Smart" buildings should take advantage of dynamics, characteristics of building shell and HVAC systems, automation, communications and data analysis technologies in order to operate in the most cost-effective manner[1].

Clearly, these definitions are not very different. Additionally, these definitions require an understanding of the building's systems and their abilities to interact with each other.

1.2 The fourth utility

Traditionally building structures, all around the world, are built in accordance with similar principles in which individual specifications and typically vendors, devise and implement operational components of the building in a manner, which is often described as "the three utilities." In traditional buildings, these three utilities are electrical, mechanical and plumbing, which are integrated with the base building. In such traditional constructions, the tenants become responsible with respect to a variety of different plans for implementing their "tenant improvements" which are fed from the three utilities and which have been integrated with the building.

Notably, communications are traditionally omitted from the base building services and it is the responsibility of the base building utility providers to install any communication services necessary for the provision of those utilities. As examples, the reader should consider elevators, which clearly include significant communications requirements dedicated to the elevator and which are an independent installation used exclusively for this one application. The communications requirements for the heating, ventilating and air conditioning (HVAC) mechanical systems, monitoring of electrical usage and potentially other systems are equally repetitive, isolated and not able to promote or address the abilities for these systems to become a true basis for any form of intelligence.

The thesis of intelligent buildings, therefore, is that base building systems shall be designed in a manner which permits their intercommunication and which also allows for communication between the building and individual tenant. The benefits are not always the same for each group of interested parties, nor are all the benefits evident when not all buildings include all the same features. This Supplement describes some buildings in which such systems have been employed and which have, in most cases, functioned successfully for a number of years, allowing for many parties to enjoy some of the benefits.

Consider some of the following examples of the benefits and opportunities which these intercommunications, or intelligence, can provide.

1.3 Access control and security systems

The access control system should be integrated with the fire system, lighting system and the HVAC system. With these forms of integration, the system "intelligence" can allow a user to enter the building and the information that this user has presented in terms of his credentials will be signalled to a number of independent systems. As a result, when the user approaches his/her workspace, the lighting, HVAC controls (and potentially other systems) can each have been adjusted to meet that user's preferences. In the hotel industry, for example, empty rooms are normally not ventilated or lit so as to reduce energy usage. When the room is "rented", the necessary adjustments can be made long before the new occupant reaches his/her temporary front door.

When the fire alarm notifies the access control system of an emergency, provision can be made that no unauthorized individuals can enter the building while everybody who is already in the building can exit without constraint. Alarms caused by magnetic locks which have been released owing to

[1] ASHRAE, The American Society for Heating, Refrigerating and Air-Conditioning Engineers as part of their Technical Committee 7.5 (http://tc75.ashraetcs.org/).

the fire alarm, will be ignored and lights throughout the building can be automatically energized so that first responders are not faced with a situation wherein they looking for the light switches.

1.4 Elevators and escalators

Through suitable programming, the number of elevators being used at any one time can be optimized to address schedules, loads and potentially, emergencies; e.g., if paramedics require an elevator, it can be automatically configured to provide exclusive use for such purposes under an emergency situation. There are many advances in elevator programming which have been pioneered by some of the large elevator manufacturers, e.g., provision of call buttons on the main entrance floor which allow random selection of elevators which will provide express rides to the floors identified by each individual's access credentials. Thus, different users going to the same floor will all be channelled into a common elevator cab, which will then go directly to that, or those, selected floors. The primary benefit as a result of this intelligence will be the ability to use fewer elevator cabs, i.e., lower energy costs and provide a faster service.

1.5 Lighting

The traditional large office buildings in which light switches are "hidden" are probably a thing of the past. The current trend to individually controlled lights, with the ability for each individual user to select their preferred lighting levels, is potentially a significant power saver and the use of more modern lighting technologies also reduces the amount of heat generated by more efficient luminaires. These trends can be integrated with many additional benefits, some of which have been noted in the foregoing comments; e.g., when an individual arrives, the lights in that person's area may be illuminated. When the individual goes home, the lights will be extinguished. In an emergency, activation of all lights will enhance the ability for responders to attend to any situation without themselves having to activate any lights.

Furthermore, the use of automated lighting controls allows an evaluation of the lighting utilization so that any re-lamping procedures can be scheduled based on actual hours of usage and not based on calendar activities. Such lighting systems also permit potential charge backs from the building owners to the tenants based on the actual electricity used. The system can monitor any lights which have failed and which can automatically be reported to those responsible for maintenance.

Needless to say, the addition of such intelligence will also identify room occupancy and allow for the measurement of lighting levels and the automated compensation of lighting settings as a result of daylight shining in through windows or skylights (daylight harvesting). Automated blinds can also be used to adjust lighting levels to the desired value. It can be noted that electrical switch manufacturers have brought very economical, motion activated light switches to the market, thereby allowing for some measure of intelligence in the simplest of applications.

1.6 Signage

There have been evident changes applicable to signage technology. Signage can readily be shown on screens and can include any required graphics thereby ensuring that language and situational variations are readily addressed. Thus standard signage can carry routine messages including hours of operation or the length of line-ups or delays. Such signs already appear in large buildings such as hospitals, universities and museums. The public is surrounded by these "computerised" signs in transportation systems, such as airports, highways, police checkpoints or customs applications. Nobody thinks twice about the information presented on luggage carousels at airports, which change continuously (and are not always 100% accurate) and the concept of having time-dependent signage or situation-dependent signage does not come as a surprise. Thus, particularly in Europe, where great emphasis is placed on visitors to buildings being well-informed upon arrival, of how they may need to exit if an emergency arises, automated signage is widespread. For example, electronic signage can be changed in an instant, should a building evacuation be necessary, so as to point out the emergency stairs as opposed to the elevators.

1.7 Building condition monitoring

Intelligent building technologies open the opportunity to facilitate the monitoring of a building's condition. Transducers and sensors are available to measure most building related parameters and in any given situation, there may be particular needs driving their specific use. Under appropriate conditions some or all of the following may be appropriate and would then be communicated to a central monitoring facility.

– Areas with heavy snowfalls or other weather extremes may wish to monitor snow load or wind load on roofs;
– Exhibition halls or bridges may wish to monitor key structural components affected by wind loads, suspension of exhibits, loudspeakers (in musical performance facilities);
– Moisture detectors can be laid beneath membranes protecting roofs (especially green roofs which are now mandated in many cities) or bridges;
– Monitoring the temperatures of electrical panels, switch gear and transformers;
– Metering current flow in electrical conductors;
– Providing sub-metering for tenants;
– Monitoring oil condition in bearings, transmissions, etc.;
– Monitoring pressure drop across filters, etc.;
– Measuring hours of usage of many components, such as filters, belts, lamps and pumps;
– Routine testing of critical devices such as pumps, loudspeakers, alarms, etc.

No further comment needs to be made with respect to some disasters which have occurred and which might have been prevented if some or all of the building monitoring technologies alluded to above had been in place.

Clearly it can be added that these concepts are consistent with measuring and monitoring practices which have evolved dramatically within recent years.

1.8 Underlying philosophy

The preceding examples are comparatively superficial with the potential of an intelligent building concept providing far greater benefits. The single spine is usually represented by physical security information management (PSIM). The significant advantage of intelligent buildings is that they can constantly monitor current operations in context and automatically adjust resources for optimum efficiency while identifying and accurately informing key decisions in a timely manner. This can range from the routine such as variance to preventative maintenance schedules to automated restocking and repair according to changes in the normal pattern of use.

For example, the Canadian Forces Station (CFS) Alert shown in Figure 1, is the most northerly, permanently inhabited location in the world, located only 817 kilometres from the geographic North Pole. CFS Eureka is a intelligent building that advises the Canadian Department of Defence Headquarters in Ottawa, Canada when it is in use and automatically compiles its resupply and repair requirements for each season deployment to the High Arctic. The expectation is that it will in the future inform and enable change of use capabilities, enhancing value through its lifetime.

Figure 1 – Canadian forces station alert

Photo credit: courtesy of IBI Group

Thus, the most important components for the purposes of providing an intelligent building are:

– A diverse, reliable and accessible communications system;
– Use of devices and systems which adhere to communication standards which provide bi-directional signalling;
– A clear commitment by the building owners, operators and designers to work together in order to ensure the provision of opportunities for the exploitation of communications infrastructure and;
– Recognition of the roles played by each of those participating in the design, implementation and operation and maintenance of these systems.

The benefits which accrue to the building have been briefly described and may be summarized by:

– A more efficient building;
– Implementation of communications as a "fourth utility" which results in only one communications backbone for all applications (in some jurisdictions, fire or other life safety systems may need to be segregated into an additional communications infrastructure to comply with local ordinances) and;
– Energy savings, maintenance savings and staffing savings will generally arise as an indirect benefit of each of the individual efficiencies.

1.9 Standards, codes and initiatives

Communications standards are well documented in many environments. For the purpose of the systems contributing to a building, there have been various initiatives. Different manufacturers have all promoted proprietary solutions at different times, leading to incompatibilities and non-standardized solutions. If the communications infrastructure is built in accordance with recognized standards, the interfaces developed by other industries generally become applicable. These approaches have allowed the development of niche solutions, all of which operate using standards such as:

– RS 232;
– RS 485;
– Ethernet-TCP/IP;
– BACnet;
– LONworks.

Interfaces for each of these communications protocols are well-defined. As a result, an infrastructure capable of reaching all parts of any building, can readily be provided and can interface with each of the building's systems.

Typically, most of the communication requirements are interpreted as different layers in the "OSI 7-Layer Communication Model".

Using the approach of the open system interconnection (OSI) layers, it is possible for proprietary communications to be carried over a common and shared backbone. This common shared backbone, or communications highway, can easily be made redundant allowing for numerous components to automatically fail and switch over to alternative devices, thereby ensuring that the building systems are not at risk of losing their integrity.

The concept of using a digital IP backbone, which can interface to almost any control or monitoring system has gradually become pervasive. Solutions carried over IP networks are sometimes well-publicized and at other times well-hidden from the public. Examples of systems which are readily compatible with an IP backbone include:

– Audio paging;
– Fire alarm systems;
– Telephone systems;
– HVAC systems;
– Surveillance systems;
– Access control and intrusion alarms;
– Lighting control systems;
– Elevator control systems.

Based on these systems and others, each of which have the ability to communicate over this common backbone, it is evident that the standards applicable to the provision of an IP infrastructure are one possible mechanism by which an intelligent building can be implemented. Depending on the jurisdiction, there may be a need that some of the systems require special considerations in order to comply with all aspects of the building code, fire safety code or electrical code. The discussion in this Supplement will not address any constraints imposed by such regulations. However it does provide an assurance that there are solutions which are available for all requirements.

2 Intelligent sustainable building roadmap

Cars are very heavily integrated with alarms and information messages all displayed through a single driver interface which may inform the driver of issues related to tire pressure, bulbs which have failed, engine performance issues and many other components.

Current generation airplanes are all designed to operate using "fly by wire" meaning that communications for all of the operational aspects of the aircraft are carried over one or more communication backbones in a manner not dissimilar to that being advocated for an intelligent building.

The difference between these two examples and the building industry is however the legislative requirements for reliability, safety and accountability which do not apply in the same manner in the heavily divided building industry.

Many of the concepts which have been described briefly in this document may be found in documents such as the Technology Roadmap [b-IC] adopted by Industry Canada and subsequently updated and reissued through the continental automated building association (CABA) which has been a market driver in the development of industry discussion and cooperation related to intelligent building technologies.

2.1 Subjective versus objective evaluation

Objectives of intelligent buildings have been described in general terms but nevertheless there are often strenuous professional arguments as to what should be the primary objectives of an intelligent building. For example, which is the more important objective:

– that the building be more efficient, i.e., that the operating costs are reduced, or

– that the effectiveness of individual occupants in the building is optimized.

Depending on the particular structure, its purpose, the technologies that are prevalent in the building and other factors, there will often be different objectives. With ever rising energy and labour costs it is obvious that if those costs can be kept in check, or preferably reduced, opportunities for financial savings will provide an immediate return on any extra investment in building an intelligent building. A building which is operated continuously, e.g., a hospital, or a building which is operated by individuals who pay fees such as a condominium is less likely to see immediate benefits from the functions available in intelligent buildings.

By contrast when the building is one which should respond rapidly to dramatic changes, clearly the intelligent building will respond more effectively.

The other significant component in deciding the evaluation and benefits of intelligence relates to whether the building is occupied by a consistent population such as in a residential building or whether the building is occupied by an itinerant population such as a sports arena, a concert hall, or even a hospital. In the sports arena example, the occupancy and therefore the building operating mode will change dramatically depending on whether or not there is an activity currently in progress.

The labour components required to monitor and manage a building are clearly dramatically reduced when the building network allows a single console to monitor all aspects of the building while fully meeting all of the requirements which may be applicable for monitoring of HVAC, fire and security considerations.

One evaluation tool which was developed some years ago and which is currently undergoing revisions is the building intelligence quotient (BIQ) tool. The BIQ was developed on the assumption that communications is the dominant characteristic of any intelligent building.

The emphasis on communications however, which is prevalent in the original BIQ, seems to disregard some of the economic benefits available as a result of a more efficient building. Options such as the ability to select the least expensive fuel or to generate local power will, for example, have a significant impact on the bottom line costs of running a building and yet will also depend heavily on the building's intelligence.

2.2 Buildings versus community

Emphasis in this Supplement is focussed on the intelligence of a building. Ultimately an intelligent building does not need to limit its intelligence or local capacity to a single building. A greater benefit in all aspects will clearly accrue, if a single building can enjoy the benefits of joining one building into multiple buildings thereby forming a community, a campus, or possibly even a city. As is evident to many tenants of rental properties there is a trend to such centralized operating facilities which has been adopted by many building operators and owners. For example, universities are typical campus facilities, which in many cases are monitored and controlled by a central facility. Frequently however, the interest of the central control facility is limited to a specific aspect of the campus, e.g., security or computer networking for student or library use.

The benefit of an intelligent building networked into an entire campus has been demonstrated in a number of situations including some components of the Canadian government managed through the Public Works and Government Services (PWGSC) or large shopping centre operators, both of which manage very substantial real estate portfolios and are anxious to keep their operations as efficient and economical as possible. Thus, it is not unusual in such situations for the call for service related to lighting or HVAC to end up in a central facility where the call centre is staffed by technical experts who are not only able to understand the problem remotely but may also be able to address and correct the problem. There are many examples in the communications industry of this trend to centralized, often off-shore, call centres.

Many call centres operate in India, El Salvador, Egypt, the Philippines, etc., where calls related to many aspects of our society are addressed. The technicians in these low labour cost facilities have full network access to the corporate entities, accounts and control facilities and have the ability to run diagnostics and if required, dispatch a local technician to address a problem. These local technicians will then arrive with the diagnostics completed and with any required parts in hand to address the original complaint. The corporate entity considers that this is part of an intelligent environment in which they can deliver a solution more effectively and more economically. In addition if they are resourceful they can even track individual failure rates and operate in conjunction with the original equipment manufacturer to improve reliability and thereby further lower their costs.

The argument from the perspective of the operators (or owners) is that reducing their overhead expenses in this manner provides an incentive to providing cost effective, speedy and competitive solutions to the market place. The community, i.e., campus or city, becomes a wired entity. The network which serves a large group of users can be designed to be extraordinarily reliable without needing any continuous staffing or maintenance to ensure that reliability.

The reader will doubtless have raised concerns regarding the risk of hackers, viruses, or other malicious approaches to the integrity of the environment. The building control network has to be protected and experience to date has generally shown that providing that the network is not exposed to a public internet and remains as a private infrastructure there is a strong ability to ensure a very high level of protection. Since the intelligent building is largely a real time operation monitoring a fixed number of fixed devices there is little opportunity for miscreants to have access or to inject undesirable code or devices into the network. However, if a high value operation of a client is involved in the building, such an attack does become an attractive proposition. Increasingly, the security integration and resilience parameters are showing greater through life efficiencies by not outsourcing but rather by having localised community networks with intelligent local response. This ensures continued operation in the event of an ice storm of similar 'global' event in which large area access to the cloud and other public communication networks is lost. External monitoring is therefore sufficient and allows effective firewalls around the operational system.

2.3 Technologies

The subject of individual and specific technologies related to the intelligent building has been raised through the earlier discussion and provision of definitions for the intelligent building. These technologies are therefore seen to depend heavily on communications in order to perform the monitoring and provision of data to those responsible for controlling the buildings.

Currently the communications technology of choice is generally based on an IP-based network running at any one of the standard protocols and speed. If video is not part of the intelligent building (which is often the case) then the amount of data actually exchanged between devices is relatively small. For example reporting on the status of a lighting controller, the status of a fan motor, or the credentials presented by a user wishing to gain access to an elevator floor are all very limited. Video cameras, particularly those using 360° viewing fields, colour images and real time imaging will generate vastly more data. Provision of fibre-based networks easily accommodate these kinds of volume and images and the data used for such images can be significantly reduced by using well established technologies only recording when the data changes, i.e., the use of an analytic process to control data flow. Therefore it is not easy to generalize what solution is most appropriate for the communication infrastructure in any given application.

The redundancy or resilience of the communications infrastructure is however paramount, particularly if many disparate systems are going to share this infrastructure as is being advocated by this Supplement. Use of a single infrastructure is desirable but clearly occupants will become very frustrated if the communications infrastructure suffers a malfunction and if as a result elements such as lighting, telephone, signage, computer networks and access control all in turn become victims of that single failure.

Adoption of an appropriate communications protocol to operate with each of the sub-systems is a function which requires cooperation between all of the design engineers. While there are lighting control systems, access control systems, sound systems and signage systems, etc., all of which can communicate using an IP protocol, the base commands used by some of these systems may invoke other protocols or may restrict the selection of systems. For example industry standards have evolved for access control systems, which have traditionally used RS 485 based communications. While this is a changing situation, it is appropriate to analyse and decide whether a purely IP solution meets all of the needs for the project. Clearly, reliable power, i.e., use of uninterruptable power supplies (UPS) or generators is as crucial as needing the provision of network infrastructure which has resilient paths, ports and devices. Self-healing networks are common today but detailed analysis is require to ensure that there is no single point of failure so as to ensure continuity of service as a result of any anticipated problem. Recent publicity of the Heartbleed[2] vulnerability as well as the legions of patches, issued for all of their operating systems by Microsoft and other suppliers have provided ample evidence of the challenges of providing totally reliable solutions.

Therefore there are two schools of thought with regard to the provision of a reliable and secure solution for controlling an intelligent building. These two approaches are:

– Provision of a single system with all of the capabilities as is to some extent advocated by a number of the traditional HVAC systems often referred to as building automation systems (BAS) which have gradually expanded their capabilities to include a number of non-traditional BAS functions such as security, lighting control;
– The other alternative is to use an integration solution capable of talking a common language with a specialized individual system providing access control, fire system, lighting system, etc.

This latter approach has the advantage that each of the systems can ultimately be operated as an individual, non-integrated solution and provide assurance to the owner/operator that if there is a problem, the isolation will rapidly establish which component is causing the problem and which component can therefore be temporarily "shed" from the integrated solution.

Unifying software (such as in the former solution) has in some cases been developed by one or two specialised companies, which provide such integration to a very wide range of individual systems provided by other manufacturers. The result of this solution is a single screen on which all individual systems can be viewed.

Another subset of this solution is to use a number of independent systems all of which operate using a single communications protocol and which therefore can all sit on the same network and be addressed from any authorized computer on that network. The absence of a single screen integrating all of the status information is generally not a major disadvantage although the size of the network, the number of points being monitored and the nature of the messages from each individual system can clearly lead to significant impacts.

2 Please see: https://www.openssl.org/.

The above comments demonstrate that the design decisions for an intelligent building are not predicated on a preconceived solution as they must depend on the particular implementation. It should also be noted that the design of a new building is a very different undertaking than the retrofit of an existing building. All these factors need to be analysed in order to assess and evaluate the optimal technology and solution for any situation. Selection of the designers who are going to perform this analysis is equally important and the owners, developers and operators all need to be involved to ensure a successful project.

3 Types of buildings

3.1 Single family

It is unlikely that a single family dwelling would really benefit significantly from significant application of the intelligent building technologies concepts. There is little room for interaction between systems, in particular, as a single family dwelling does not generally have many of the systems which are found in larger or more complex buildings. Thus a single family home is not likely to have a fire alarm system although many homes today have a security system of some kind. Obviously the security system can in itself monitor for fire, smoke, or even temperature rise. Access control in a single family unit is limited probably to the front door and since all those normally living in such a unit are related to each other it is assumed that they would all also trust each other. Lighting may be automated and most residential HVAC systems use only one thermostat and do not have any form of direct digital control (DDC) or equivalent although some larger single family dwellings may indeed have HVAC zones which are controlled in some appropriate manner. Economic benefits, efficiency benefits or interactions of other kinds are therefore likely to be minimal.

3.2 Residential multi-unit

Typically a residential multi-unit is either a rental building or a condominium building in which centralized management of electrical usage, HVAC operation, security systems, guests, parking, fire alarm systems and common area lighting are all candidates for being managed in an effective and direct manner. By providing the central control with all of the foregoing and possibly also surveillance cameras the control desk can manage the building with just one single individual who can monitor, control or adjust as may be required. Without the integration of all the systems this individual would need several support individuals to review and adjust each of the individual systems. The intelligent building will allow monitoring and management of ongoing costs including maintenance activities in a manner, which will provide significant improvement in the services to the residence. In addition, depending on the configuration of the multiple-units also known as multiple rental units (MRUs) or the individual units there is an opportunity for tenants to adjust their suites to meet their needs on a scheduled basis allowing special provisions, for example, for any residents who may be away on vacation, at daily scheduled work or otherwise to provide significant economies by optimizing the use of the HVAC and lighting systems.

3.3 Commercial buildings

Typical commercial buildings employ a combination of systems including all the systems found in a residential multi-unit environment together with a significant number of the functionalities appropriate to an office or even a retail environment. Some commercial buildings would also provide locations for retail, restaurants and for entertainment such as cinemas or conference facilities. Without going into infinite detail all of these functions rely heavily on various forms of automation ranging from parking and subsidized parking, through inventory management, music systems, paging systems, escalators and elevators and food storage systems. The integrated building technology (IBT) systems can provide for monitoring and measuring any or all of these operations so as to alert individual tenants if their food storage systems fall outside acceptable temperatures or if sales inventories have been exceeded. According to the policies, which may be appropriate to any given sales facility, there may be pressures exerted on retail merchants to pay a portion of their profits or sales volume as "rent" to the landlord. The intelligent building can provide a means of measuring the income or sales volume in an objective manner which would allow the landlord to measure his percentage. Evidently lighting, emergency signage and regular signage are all additional functions which can be readily introduced.

3.4 Hotel

A hotel is normally very open to benefit from IBT technology as, depending on the season, the city and general circumstances, including the day of the week, hotel rooms may be at a premium or guests may be at a premium. From the hotel perspective its ability to adapt to the current occupancy rate is much aided by the use of IBT. The ability to "shut down a room" or to "open up a room" in response to an arriving guest or a departing guest can provide a significant impact on the bottom line. With accurate and complete information planning the goals of only cleaning rooms which have been used, to only heating and only lighting rooms which are occupied, are easily achieved. Individual staff members can be readily monitored as part of the overall building effectiveness. Many hotels already provide suitable "intelligent" links between the television and the hotel's billing system. It is now regular practice for there to be a keyboard in each room and for one of the channels to provide a screen and communication so that guests can check out, settle accounts and order special services as they may wish. In summary, the hotel is a fertile ground for increasing the benefits of automation through an integration of its operational systems, thereby yielding an intelligent building.

3.5 Hospital

A hospital is very sophisticated in some of the "intelligent" applications which are already widely used. Those functions are however largely related to the delivery of medical services. For example, many hospitals have developed or acquired special software used to track patients who arrive in the emergency room and require significant testing and processing within the emergency room, often before they are then discharged without having entered the hospital's system.

Patients are booked into clinics, laboratory requisitions are filed, hospital cards are provided and psychiatric wards are managed. The intelligent building aspect however is left far behind because there is very little scheduling that can be accomplished in a manner which will yield significant benefits to the hospital's bottom line. HVAC is required 24 hours per day and lighting can only be "reduced" during "sleeping hours". The requirements of maintaining a hospital as "a publicly accessible facility" and to "provide effective security" is without question a contradiction. In many hospitals entrances are now being locked except for the emergency room which are still open 24 hours daily even when some of the other locations conform to a consistent need at all times. The requirements to ensure that standby generators are always ready to provide their services, that patient records are always available to the physicians providing treatment are two very different needs and there is little room to provide integration of these two requirements. The legal requirements to ensure confidentiality of all patient information is a good reason to consider segregating the networks used for building control and those for providing medical services.

3.6 Factory

Factories are usually custom built in order to manufacture a car, a computer or another manufactured product. As such the processes necessary for the manufacturing are quite secondary to the control and management of the building. For this reason the intelligent building aspect addresses only the maintenance of the building(s) to ensure that the environment provided by the building is appropriate for the machines and processes carrying on the manufacturing of defined products. In other respects maintaining, managing and informing on the operation of the building itself is no different than the functionalities called for in a multi-unit residential or commercial environment.

3.7 Intelligent buildings and new business opportunities

The "intelligent building" concept goes far beyond supporting sustainability goals, saving energy, enhancing efficiency and reducing costs. The concept also represents processes as well as services, profits, job creation and capacities enhancement in the ICT and building industries. The concept continues to be widely adopted in the market due to the fast expansion of mobile, cloud, grid and big data applications and networks connectivity benefits.

4 Other aspects

4.1 Operating costs and occupant comfort

A major objective of an intelligent building is to provide a building which can be operated at a lower cost, (i.e., to cut the unnecessary expenditure of energy when it is of no benefit, e.g., do not heat or light areas when they are not occupied) and ensure that the systems are there to evaluate costs and to quickly respond to occupants' needs and maintain occupant comfort.

4.2 Tenants' satisfaction

The investment and efforts to make a building intelligent are ultimately all part of a marketing campaign by landlords and developers to ensure that the building becomes a "desirable" facility. This is only one small part of the overall thrust of developing a new building where the architect will endeavour to make it as appealing as possible, the engineers will endeavour to make it as comfortable as possible and the interior designers will take great care in ensuring that the "form" of the interior design makes people want to work in that environment. The function provided by the engineers and implementers will augment that capability, thus for example, attractive features can be added such as putting lights on the building which change with the season, or with the time of day, or, with the weather, or with the extent to which the building is occupied meaning that the building when fully occupied may be coloured red or when the building is empty may be coloured blue.

With the widespread development of smart telephones with enormous capabilities further opportunities exist that tenants or guests may be able to download suitable information for their own smart phones to ensure that their particular interests, e.g., calling of an elevator or modifying their work space environment can easily be achieved by requesting different lighting levels, background music, or room temperatures. Fire alarm or other emergency information can be clearly defined in messages sent to the smart phones of all tenants. Instantaneous electrical utilization or billing can be monitored. With time of day pricing, instantaneous monitoring of electricity meters or sub metering becomes crucial to maintaining close control on overall costs.

4.3 Maintenance

One of the key issues related to any intelligent building is that on-going maintenance of the facility is absolutely critical to maintaining the benefits of building intelligence. While most intelligent buildings will operate using less energy and water, equipment throughout the building needs constant maintenance to ensure that optimal performance is maintained.

The key is also to ensure that sensors are cleaned and calibrated on a regular schedule. Poorly performing sensors can be one of the main reasons that an investment in building intelligence does not result in reductions in energy and water usage.

Tables 1 to 3[3] show examples of preventive maintenance schedule best practices. Such a schedule can be automated within the framework of an intelligent building thereby ensuring more efficient and cost effective facilities management.

Table 1 – Examples of preventive maintenance schedule best practices

Checks on boiler systems and measurements of boiler efficiency. To monitor for proper combustion efficiency, carry out efficiency tests at least annually and calibrate burners so that delivered efficiency meets manufacturer specifications.
Checks on the correct operation of ventilation and cooling controls. This involves checking that all set points are adjusted to meet efficiency requirements as well as seasonal and operational needs of the occupants for each day (including holidays) and time-of-day.
Checking of temperature and humidity controls to ensure they are set correctly and are responding as intended. There should be bi-annual evaluations of the control systems.
Checking of air supply grilles to ensure they are not blocked and are delivering air as required.
Checks for refrigerant leaks. For systems using refrigerant, maintain the refrigerant charge per the manufacturer's requirements. Keep refrigerant leakage under 5%.
Checking of cooling towers. This should include reviewing water treatment, bleed control and cycles of concentration, water temperatures, pump operation and sequencing and sump during operation.
Scheduled filter replacement. Replace or clean filters in accordance with manufacturer's recommended schedule or design pressure drop. Ensure correct size and type of filter.

Table 2 – Examples of preventive maintenance schedule best practices

Every Five Years:
Total quantity of outdoor air measured at minimum damper position, compared to total occupant requirements, based on published standards such as ASHRAE.
Annually:
Outdoor air intakes – obstructions, bird droppings, standing water, proximity to cooling towers, trash compactors, exhausts and other pollutant sources.
Minimum outdoor air damper setting.
Coil drain pans – cleanliness, presence of microbial growth, proper draining.
Minimum VAV box settings.
Duct and terminal coil cleanliness.
Duct insulation liner – cleanliness, adhesion, coating.
Ceiling plenum cleanliness (if used as a return air plenum).
Controls – ensuring continuous fan operation during occupancy, and correct positioning of dampers and VAV box valves.
Fire dampers – open.
Boiler combustion air – clear; sized per code requirement.
Cooling towers – water treatment functioning as intended.

[3] BOMA BEST Canadian Building Environmental Standards requirements.

Table 3 – Examples of preventive maintenance schedule best practices

Semi-annually:
Floor and equipment drain traps – properly sealed.
Air quality measurements in select occupied areas of the building.
Quarterly:
Operation of outdoor damper actuators.
Monthly:
Air filter loading.
Standing water in air handling units (esp. cooling coils).
Air handling unit interior cleanliness.
It is suggested that HVAC systems be re-commissioned every five years.

4.4 Evaluation – How intelligent is an "Intelligent" building?

With a strong push towards intelligent buildings, there is an increased need to develop an independent and unbiased mechanism to evaluate how "intelligent" a given building is within a set of given attributes such as the individual systems and how well they are integrated.

There are a number of standard tools being used by different organizations to measure the effectiveness of intelligent building technology

As an example, BIQ is part of an evolving set of self-administered on line questions through which a particular project can be given a standardized score. This score is intended to reflect the intelligence of the building, which has little bearing on its energy efficiency. The original BIQ evaluation addressed the intelligence as a result of the integration of the communication requirements, signals and protocols. The evolving process is placing a much heavier emphasis on energy management including the ability to select the lowest cost of energy, i.e., the ability to change energy sources as a function of spot pricing and to evaluate the benefits accruing to the overall project.

Reports are generated which benchmark the different sub-systems with recommendations for improvement in multiple categories including communication systems, building automation, annunciation, security and control systems, facility management applications and building structure and systems.

4.5 New business opportunities for the building sector and ICT industry

The expanded capabilities of smart services and the data they generate are ushering in a new era of innovation and competitive advantages for building owners. Buildings that are operated efficiently, at lower costs and reduced energy expenditures also enhance building tenants' satisfaction and create new business opportunities for all.

City authorities should focus on innovation, policy, economy and infrastructure matters to build a strong framework to strengthen intelligent building initiatives so that they can gradually upgrade pilot areas which will become models to be imitated on a wider scale. This will help them to implement smart sustainable cities and buildings, in the next few years.

The convergence of building and ICT industry enables all players to:

– Create new business opportunities in the intelligent buildings and ICT industry;
– Satisfy the technical demands of the intelligent building market surrounding big data and data analytics applications;

– Bring more investments from vendors of both industries as a result of strategic partnerships between data analytics and building technology providers, which may include tenants and building owners.

5 Climate change adaptation

Climate change related severe weather events are increasing in frequency and severity. These severe weather events include (but are not limited to):

– Urban floods;
– Extended heat waves;
– Ice storms;
– Extended cold spells;
– High winds/tornadoes/hurricanes.

These weather events have both a long- and short-term impact on the commercial building infrastructure in cities.

During short-term events, building infrastructure is impacted by major structural damage, damage to a building's support and utility systems, closure and loss of revenue among other items. Over the long term, severe weather and more extreme temperatures lead to accelerated degradation of a building's envelope, utility systems and infrastructure. Steps need to be taken to maintain the building exterior and envelope to prevent damage to the building and its' equipment. At the same time, the design and intelligent infrastructure of the intelligent building can assist with minimizing the effects of extreme events.

In order to prevent damage from flooding events, major HVAC, electrical and communication equipment should not be located below or on grade locations or if it is not possible to move equipment above grade then equipment rooms should be sealed against water intrusion.

Elevator hoist ways should similarly be sealed and procedures developed to ensure that elevators are automatically sent to higher floors in the event of a flooding event.

Demand response capability means that the intelligent building is able to reduce the building's electrical load for HVAC and/or lighting during periods of high system wide demand, typically at the request of and perhaps with incentives from the utility. This is particularly needed during extended heat waves to ensure that power grids are not overly stressed.

Proper design of external landscaping and storm water management facilities can reduce the potential effects of severe rainstorms and urban flooding.

Intelligent buildings normally also have backup power systems that can automatically provide power for short or extended periods of time to allow for evacuation or to maintain building operations.

6 Typical systems in an intelligent building

A typical intelligent building can be broadly classified into 3 systems:

(1) Physical;
(2) ICT/data;
(3) Building control.

The integration of these broad categories is what constitutes an intelligent building as shown in Figure 2.

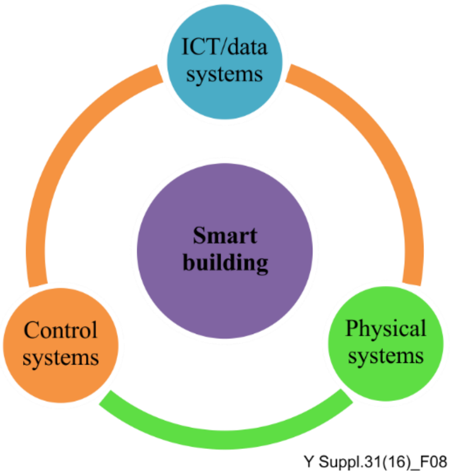

Figure 2 – Typical systems in an intelligent building

Photo credit: courtesy of IBI Group

6.1 Physical infrastructure

Physical infrastructure is a "given" in an intelligent building, in terms of systems that will be independent whether the building is a smart or not. Therefore, these aspects are not discussed in detail in this Supplement. However, it is important to recognize that it is these very systems which need to made more intelligent and which need to communicate with one another in an intelligent building. These aspects are covered in what is being termed as "building control systems".

– Air Conditioning;
– Lighting;
– Elevators;
– Water and plumbing;
– Electrical;
– Fire alarm;
– Façade and interior décor.

6.2 Data and ICT infrastructure

An intelligent building is predicated on the use of data and communications and typically includes all the aspects both physical (hardware) and software related to data and communication.

1 Networking infrastructure;
2 Includes cabling, IP networks, voice, video, data and wireless;
3 Data security.

It is essential to make the different systems talk to each other and for software based smart decisions, the ICT/data infrastructure is critical. This ICT infrastructure is not only for ICT related systems such as voice, video, data, wireless, data security, etc. and associated enterprise software applications, but also forms the basis on which the different control systems can communicate with one another.

6.2.1 Overview

One of the key aspects of an intelligent building is the ability it has for the different sub-systems to communicate with one another. This communication will occur over the ICT infrastructure. The ICT infrastructure is the transport medium (wired and wireless) that carries all the data: voice, video (multimedia), security, voice over IP (VoIP), power over Ethernet (PoE), etc., throughout the building or campus. It forms the backbone through which data travels from one location in the building to another, allowing the different sensors and actuators communicate as well as allowing different systems (HVAC and lighting for example) to communicate with one another. It can include everything from the data-centre to the desktop, wired jacks at the wallplate, wireless access points, structured cabling and associated equipment.

Hence, many intelligent buildings try to optimize the use of ICT infrastructure across the different systems in a building for example access control, video surveillance, building automation and other functions in the building. Such an ICT infrastructure balances the wired infrastructure with the use of wireless systems such as Wi-Fi and other wireless technologies throughout a building. As ICT continues to converge with traditional building control systems this infrastructure becomes increasingly a critical and key attribute of an intelligent building.

It is important that an intelligent building not only has a secure, converged data network but also the following attributes:

– Integrated voice, video and data;
– Data security measures – including encryption, admission and intrusion detection;
– Data quality of service (QoS);
– Bandwidth management;
– Redundancy (to account for failure) including uninterrupted power supply (UPS);
– ICT device management.

Typical technologies that are part of a data/ICT infrastructure include:

– Networking LAN infrastructure;
– Core routing switching;
– Access switching;
– Wireless networking;
– Firewalls and network routers.

In addition to the above technologies, the same infrastructure will have the capability to provide support and connectivity to other building related technologies and services like:

– Building automation and HVAC control/energy management systems;
– Lighting control systems;
– Building security and access control;
– Video surveillance systems;
– Fire and safety systems;
– Car parking systems.

6.2.2 Networking infrastructure

The local area network (LAN) is the mechanism by which access to network communication services and resources is enabled for end users and devices spread over a single floor or entire building. Since doing this in a "flat" manner is not efficient, a hierarchy or tiered model is often used. This allows the network to be broken up into groups or layers.

Such a modular approach allows each layer to implement specific functions, thereby simplifying the network design, deployment and management of the network. Modularity enables the creation of elements that can be replicated throughout the network and is therefore a simple way to scale the network for the entire building.

Another advantage of such a modular and hierarchical approach is that if there are some fixes due to faults to be made to a given subset of the network, such changes are contained to that subset and the other parts of the network are not impacted. This improves network efficiency and resiliency.

A common approach to LAN design includes the following three layers:

– Access layer: Provides endpoints and users direct access to the network;

– Distribution layer: Aggregates access layers and provides connectivity to services;

– Core layer: Provides connectivity between distribution layers for large LAN environments.

Such a network would run throughout the building.

6.2.3 Access switches

At the bottom access layer, the access switches aggregate all the end user's traffic from desktops, laptops, smartphones, IP phones, and videoconferencing terminals. Typically access switches can be placed on a per floor basis. One expects 1600 users, an average of 65/floor and the switching bandwidth and port stacking needs to be sized accordingly.

6.2.4 Wireless access points

As a result of increasing use of laptops, tablets and smartphones, it is also imperative that WiFi access be provided. The average area of a floor is around 4000 sq. ft. This area and wall partitioning and users/floor should be considered while sizing the access point count and placement on every floor. The WiFi controllers can be placed in the server room.

6.2.5 Core switches

The core switch performs the function of interlinking the access switches and providing user connectivity to servers and also to the Internet. The core switch placement must be optimized such that LAN/Ethernet cables that run from all the floors to the core switch do not cross the specifications. Where there is issue, fibre connectivity must be considered.

6.2.6 Firewalls

Firewalls offer protection in the following ways:

– Protect servers (e.g., email servers, web servers) from malicious external attacks such as email spamming, website defacing, etc.

– Protect network from malicious external denial of service attacks through incorrect or malformed IP packets.

– Protect users from malicious external attacks through incorrect or malformed HTTP data.

6.2.7 Routers

Routers provide connectivity to the external world of Internet service providers (ISPs). Some basic routing may be needed within the building based on the requirement assessment to provide network isolation (also called subnets) between various departments occupying the building. This is also termed Layer 3 switching.

6.3 Building control systems

While there are a large number of different possibilities, the list below provides examples of common "smart" control features which integrate with the different physical systems to ensure that all the systems act together in an optimized and efficient fashion thereby improving efficiency and reducing cost.

– Building automation system (BAS), HVAC and energy management;
– Lighting control system;
– Fire and life safety control systems;
– Access control;
– Video surveillance systems;
– Parking guidance and management systems;
– Integrated building management system.

6.3.1 Building automation – smart HVAC systems

Typically, when there is a reference to a building automation system (BAS), it refers to the various components of the HVAC control system. HVAC equipment is one of the most complex aspects of a building since it has many components such as chillers, boilers, air handlers, fan coil units and associated electrical and mechanical systems to mention just a few.

While an HVAC system has one primary goal, to keep the occupants of the building comfortable, it also is the single highest consumer of energy in a building, over 60% of a building load. Hence, the balance of what can be done to ensure it meets the comfort and wellbeing of its occupants while minimizing energy use is the key to a good BAS. This means that many parameters need to be measured and analysed and then appropriate action or control needs to be performed. For example indoor environmental parameters may include occupancy, temperature, humidity, noise, air quality and ventilation while outdoor environmental parameters may include outdoor temperature, solar radiation and other weather variables. The operations of the HVAC system must concurrently optimize all of these parameters and many more to minimize energy use.

The large number of variables and components in an HVAC system necessitates extensive automation and system integration. For example, in a smart building the HVAC system may have the ability to sequence chillers, pumps and boilers automatically based on the different conditions and constraints including but not limited to run time, time of day, occupancy and other similar parameters.

6.3.2 Smart lighting control

Lighting is a critical aspect to any building. It is both aesthetic as well as practical. Buildings need to provide sufficient lighting to enable their occupants to work and perform their tasks effectively. Finally, lighting typically consumes approximately 20% of a building's energy load.

An intelligent building typically has a lighting management system across all the usable footprint of the building. It needs to be energy efficient with LED fixtures, have dimming capability and be networked and controllable from almost any location. It should also have a local, zonal and global (building) wide schedule and override capabilities. Daylight harvesting, that is maximizing the use of sunlight to minimize artificial lighting is also important. This is typically achieved using manual or automated shading, photo sensors in lighting zones and rooftop solar intensity sensors.

Finally, an intelligent building could utilize information from the lighting system to help influence other systems, for example if a building floor is dark, it implies no one is in the office and therefore the HVAC system can also be turned off.

6.3.3 Fire alarm and safety systems

The primary job of Fire alarm systems is to ensure the safety of occupants by providing them with a warning of smoke and fire. Manual detection is still prevalent, but increasingly buildings have automatic initiating devices such as heat (thermal) detectors, smoke detectors, flame detectors and even cameras. While detecting a fire is important, supressing the fire is critical and therefore, most intelligent buildings will have an automatic fire suppression system with a centralized fire alarm panel.

Other attributes of a fire alarm system in an intelligent building may include:

– Addressable sensors;

– Intelligent sprinkler heads;

– Notification devices such as strobe lights and integration with public address (PA) systems;

– Smoke management and containment;

– 24-hour alarm monitoring and recording of response;

– Integration with other building sub-systems:
  - HVAC allowing for restriction/containment of smoke through dampers/fans;
  - Integration with access control allowing automatic unlocking/opening of doors.

It should be noted that due to the nature of the life safety aspects of such systems, redundancy and fail-proof backup is critical and in many cases required by law. These control systems are often not directly linked to other control systems to ensure that they are isolated from potential faults in other systems impacting the fire systems.

6.3.4 Access control systems

Physical security in a building is something that we now take for granted and it is accepted that most buildings will have restricted access. With security becoming a critical aspect of daily life, access control systems are a critical component in smart buildings. Such a system also interfaces with life safety systems, fire alarm systems and other smart building systems such as video surveillance and HVAC. It can also act as a proxy to verify the presence of a person inside the building for human resources/attendance purposes.

In an intelligent building, an access control system should be deployed with multiple levels of authentication as needed. The access control system is normally designed to maximize security and include specific access privilege allocation (role based access), access to elevators, parking garages and is also supported by other security systems such as an intrusion detection system. An access control system can also be used to provide data related to occupancy statistics, which then can be used for helping optimize the building automation systems for improved HVAC and lighting control.

6.3.5 Video surveillance and analytics

Almost all buildings now have video surveillance or closed-circuit television systems (CCTV). These are typically part of the building's security and life safety system. Along with the trends in the marketplace, the technology for video surveillance has migrated from analogue to digital technology. Internet protocol (IP) based systems are now common, so the data can be transported over the standard building ICT network. Digital camera image sensors are based on complementary metal oxide semiconductor (CMOS) sensors which use a "progressive scanning" technique. There is no need for alternate odd and even frames in this case. Still images are perfectly clear and face recognition is now possible even when video is paused.

IP-based video surveillance utilizes the existing ICT network infrastructure and therefore reduces costs. The ICT infrastructure allows for improved network security, remote access to the systems, integration of wired and wireless technologies for video transmission and remote notification of events and alarms. It also enables the integration of the video surveillance systems with other building technology systems such as access control, enabling more functionality.

Some of the benefits for physical security using surveillance cameras include:

– Reduce the risk of thefts and burglary;
– Protect communities or high-rise buildings from strangers;
– Record violence, assault or theft as evidence in prosecution;
– Reduce bullying and loitering;
– Improve discipline and behaviour;
– Detect entry of unauthorized people into buildings or communities;
– Detect bad behaviour in public places such as government offices, etc.;
– Safety and security of staff, employees and visitors;
– Remote management observation.

6.3.6 Smart connected workplace

The office space has many different systems such as audio-visual, voice, video conferencing and e-mail systems and a smart office building can leverage these systems to act together. There are a number of examples related to the use of ICT to make the operations of a building smart. As examples, two systems will be discussed in more detail:

– Digital signage and displays;
– Conference/meeting room scheduling.

6.3.7 Digital signage systems

Digital signage allows different messages to be delivered to the target audience in a very visual manner, in real time. Digital signage is a compelling communications technology that is effective, immediate and dynamic. In the spirit of "real time" communication, messages are relayed instantaneously and these messages can change constantly depending upon the context and situation, messages can also be changed instantaneously. It can be utilized in a variety of building types. Digital signage typically enhances the user experience since it is used to inform, entertain, communicate and can also be a potential source of advertising revenue.

Like any computer-based system, digital signage comprises software applications running on hardware devices. Most digital signage software has three parts: (1) Content management, (2) Device management and (3) Data management. The hardware components of a digital signage system include displays, servers and data storage. These are determined by the technical requirements and size of the network the digital signage is operating in.

Recently, one of the most innovative uses of digital signage has been for life safety, where it complements the fire alarm and life safety systems. In an emergency such as a fire, if the stairwell is not safe for evacuation, the digital display located at egress points (next to the "Exit" signs) can provide appropriate safety messages.

6.3.8 Room scheduling software

Most large buildings have numerous conference and meeting rooms. There is a case to be made for to control the scheduling of meeting and conference rooms in order to not only manage any meetings/events in those rooms but also be able to integrate energy and other savings measures. Using software applications which are integrated with the HVAC such as lighting and occupancy sensing systems, a person can effectively find and book space, and also reserve equipment, unlock doors, change the temperature set-point, or turn on the lights and eventually revert the room back to unoccupied mode. This helps optimize the energy use in the conference rooms so that the room is lit and cooled (or heated) just prior to the scheduled meeting and brought back to unoccupied status once the meeting is over.

6.3.9 Visitor management system

Visitor management refers to tracking the use and movement of visitors to a building or site. Visitor registration and management is a now an integral part of an intelligent building. There is a case to be made to screen and track the many visitors who pass through the entrances to a facility. Such a system will contribute to the safety protection and wellbeing of the occupants and employees in the building.

A visitor management system will typically provide a record of building use and therefore is often used to complement building security and access control systems.

6.3.10 Parking guidance and management systems

An intelligent building will need to have a sophisticated parking control mechanism not only from a convenience perspective for drivers but also from a security and fee collection perspective. A good parking management system ties into the other building systems as well.

Parking guidance and management systems provide a way to help drivers park their cars quickly, safely and easily and at the same time keep the parking lots, safe and secure. It typically ties into the access control and video surveillance systems.

Normally the following is included: (1) software to tie in all the components of the parking management system, (2) automated access control system: automatic gates, barrier controls, ticketing systems, (3) security: video surveillance, under vehicle scan system, licence plate recognition systems, (4) automated fee systems, (5) real-time vehicle counting and (5) real-time parking guidance showing the empty slots at every level.

6.4 Integrated building management systems

An integrated building management system (IBMS) acts as the "heart" of the intelligent building. It is a holistic platform designed to manage all the disparate individual systems in a building including for example BAS (HVAC), lighting, security, surveillance, access and life safety. Each of these individual systems typically acts individually and does not communicate with the other systems. For example, the HVAC system is independent of the access control system and the lighting system. If these systems were integrated, then it could be arranged so that the HVAC and lighting turn on only when the access control system shows someone to be inside a room, floor or building.

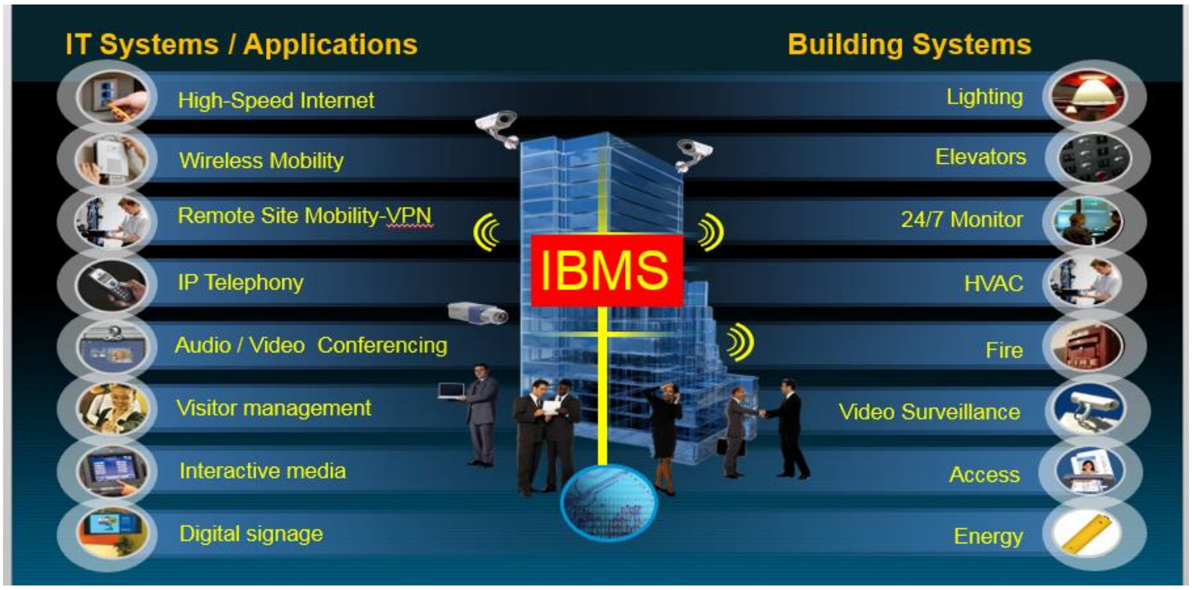

Figure 3 – Example of an IBMS

Photo credit: Cisco

When all of these systems are brought under a single umbrella as shown in Figure 3, such a system is known as an integrated building management system (IBMS). Such a centralized system enables real-time centralized monitoring and control of infrastructure systems such as building systems (HVAC equipment, thermostats, lighting, life safety and security systems, physical security, elevators, energy, water and gas meters, sewer system, etc.). It will be a comprehensive, standards based, communications network-based solution for intelligent building automation and enterprise management.

Using advanced software tools, the IBMS provides a smart building with the long term capabilities needed to save costs, efficiently manage and optimize building operations and ensure long term sustainability.

6.4.1 Combining multiple systems

Typically, an IBMS can monitor and manage every data point from every building system. The integration of all the data points of all the building subsystems is relatively new and has great potential to monitor and manage a building's performance.

As an example, in the San Francisco Public Utility Commission building, the systems monitored and managed by the IBMS include:

– Elevators;
– Waste water treatment system;
– Mechanical direct digital controls;
– Digital network lighting controls;
– Power monitoring and control system;
– Fire alarm and detection system;
– Solar energy collector metering;
– Wind energy power generator metering;
– Interior and exterior shade control system;
– Weather station monitoring system;
– Window washing system;

– Water reclamation.

Most IBMS systems will incorporate all the traditional building management functions such as document management, trending, system scheduling and data archiving. However, in addition there is integration into the facility management (FM) systems such as work orders, asset management, inventory and maintenance. Further integration with the building information management (BIM) systems of the building will map the building, its systems and components in 3D. This will allow for a truly integrated and optimized building where an alarm in the IBMS triggers the FM system and the BIM system provides a real time 3D view of the situation, its location and possible fix. This creates a "meta" building database to help improve building operations and engineering.

Other aspects that could be part of an IBMS system include performance analytics which tie in automatic fault detection and diagnostic (FDD) applications to optimize the performance of the building systems. It provides on-going commissioning, keeping the largest energy consumption system at optimal performance.

6.4.2 Dashboards

With a highly instrumented building, there will be lots of data which will become available. Data from sensors, meters and databases will all provide the basis for not only energy management but also the overall comfort and well-being of occupants in the building. However, "raw" data is really not of any value unless it is processed, analysed and then combined with other pieces of data to establish some manner to "act" or control or make a change to improve.

In order to understand what data is available and the results of analysis, visualization of this information is paramount and this is normally provided in the form of some form of user interface (UI) or building dashboard. With the many different stakeholders in a building, there will be different "views" for dashboards. In the San Francisco Public Utilities Commission (SFPUC) building, there are over 400 dashboards which provide the facilities team, building operators, executives, employees and even visitors with information specific to their needs. Users of this information then use this data to improve the building performance and operation.

6.4.3 Analytics

A state of the art smart building typically will have analytics as part of the software suite along with the IBMS and dashboards. Once data is available in a building, the next step is to analyse the data and then determine how to improve the building performance using that data. This analysis is achieved through dedicated analytics software. Such software will help organize, manage and analyse data collected from various building systems and present them in a clear and concise manner via the dashboard. This provides a good insight into the operational performance of the building.

Analytics enables the operations and facilities teams of the building to find patterns and issues that they were not aware of, patterns that were not anticipated, expected or even imagined. Analytics provide results that show how the building actually operates versus how it was either designed to operate or expected to operate. Examples of benefits include immediate notification of system anomalies for proactive maintenance, building equipment lifecycle extension, reduction in energy consumption, identification of energy savings opportunities and validation of energy savings.

7 Trends in intelligent sustainable buildings

Intelligent buildings are becoming more common, more complex and provide the ability for significantly reducing the environmental impact of our built infrastructure.

7.1 Vision

The ultimate vision of an intelligent building is one in which a very small group of individuals can monitor, manage, diagnose and sometimes correct most building operational issues without ever leaving their desks which are equipped with little more than a computer screen. Individuals given the right tools have the ability to monitor the security, the temperature, the lighting, the occupancy, the safety, the ventilation and the electrical consumption of the building. There is no longer a need for a patrol guard to move through the building in order to investigate if all individual doors are properly locked. As these systems become more trusted and more reliable the vision is that a smaller group of people can manage a large building autonomously, reliably and with traceability. The economies of reduced staffing, immediate response and operational statistics are significant. The ability to perform maintenance on the basis of actual hours used or defects which have been identified, will provide considerable savings. The ability to use electronic controls which ensure smooth starting and stopping of all machines, the gradual activation of luminaires and the smooth shutdown of luminaires all lead to significantly reduced operational failures and significantly extended operational life thereby providing further economies.

7.2 Future considerations

Key areas that need to be addressed to gain the full benefit of intelligent buildings include:

– Understanding the goal of design and operation of an intelligent building.
– Is it more important that the building be more efficient, i.e., that the operating costs are reduced?
– Is it more important that the effectiveness of individual occupants in the building are positioned as the most important objective.
– Adoption of an appropriate communications protocol to operate with each of the ICT sub-systems through cooperation between all of the design engineers.
– Visioning a greater benefit in all aspects will accrue if a single building can enjoy the benefits of joining one building to multiple buildings thereby forming a community, a campus, or possibly even a city.
– The provision and ability to communicate over a common IP infrastructure, is a mechanism by which an intelligent building can be implemented. However, depending on the jurisdiction, there may be a need that some of the systems require special considerations in order to comply with all aspects of the building code, fire safety code or electrical code.
– Base building systems that are designed in a manner which permits their intercommunication and which also allows for communication between the building and individual tenant improvements.

Intelligent and sustainable buildings can form one of the pillars of a smart sustainable city. Buildings are a major contributor to global GHG emissions and the implementation of intelligence within our building stock can provide a method for reducing these emissions.

The ITU has a role to play in determining and facilitating the development of standards and protocols to ensure the intercommunication and interoperability of the ICT systems that make up an intelligent building which forms one of the foundations for a smart sustainable city. The ITU should continue to interact with other bodies and industry groups to ensure that the required standards for intelligent and sustainable buildings are developed. These standards need to be developed in concert with other "smart sustainable city" standards to ensure compatibility and seamless adoption.

Appendix I

Examples of intelligent buildings

I.1 Molson Centre

The Molson Centre, is a 20 000+ seat capacity arena located in Montreal, Canada. In this facility the inactive building can be safely managed and monitored by two individuals monitoring the screen with the ability to occasionally dispatch the second individual to validate, verify or to address a situation should it arise. The integration of the systems includes access control, intrusion, surveillance, hold-up alarms, elevators, fire alarm system, paging system, television displays throughout the building, emergency evacuation systems/address systems, ice surface management, voice, data and restaurant systems, beer dispensing systems, food storage and kitchen systems, parking systems, water leakage systems, electronic photoflash systems and systems for the hard of hearing and for simultaneous translation.

While the list is extensive there are some key novel features which were introduced into this building. The authorities having jurisdiction (AHJ) permitted the use of the public address system for emergency evacuation purposes providing certain safeguards were fully demonstrated (which was successfully accomplished). The building may be locked when occupied under special provisions permitted by the AHJ.

All communications are handled through a single common utility (common backbone) thereby eliminating individual and independent communications systems used for each application.

Figure I.1 – Molson Centre Montreal, Quebec, Canada

Photo credit: courtesy of IBI Group

A single access card is used for all access purposes, although in some specific high security applications a door will only open when two cards are independently swiped within a short delay.

Special features were incorporated on the telephone and audio systems for broadcasting and reporter purposes.

Access control cards used by guards automatically form a "guard tour" reporting on the progress of a guard moving along a randomized but defined sequence of doors. Aberrations and unexpected delays automatically initiate alarms. These same cards can function as a signal to activate or extinguish selected lights.

Lighting control is fully automated through graphic screens allowing for all kinds of different configurations in accordance with different uses to which the facility is exposed. Cameras are directly associated with alarm conditions so that in the event of any kind of alarm suitable camera images are displayed and recorded. In particular the crucial alarm images are always displayed on a dedicated alarm screen.

The building access control system has been integrated with the Municipal subway because the Metro has an emergency exit in the building to which the Metro staff require independent access.

The fire alarm system is fully integrated with the security system so that any fire alarm is evaluated, reported and displayed in detail on the security console. As this console is part of a network, it is also available to any other authorized individuals such as the building manager. When a fire alarm incident occurs this information is made available to the access control system through a listed interface which then leads to the printing on a dedicated printer of the suitable "response plan". This response plan contains whatever information is designated for that location and may, for example, include contact information for the occupant of that location.

I.2 Windsor Station

Windsor Station is a railway station for commuter trains serving the west island of Montreal, Canada. The key elements of this intelligent implementation relate to the automated coordination of all the station functions with the train schedule.

Thus, for example, platform doors are normally closed and as passengers approach, the doors will open if those doors are scheduled to allow boarding of the train. Just prior to the scheduled departure time the doors will no longer open in response to passenger approaches.

All of the door functions are indicated through schedule update information displayed on monitors around the station. Scheduling of the doors has also been organized to allow passengers to go from the station to the platform for departing trains or from the platform to the station for arriving trains with special overrides for stations staff who may be permitted to go onto the platform or into the station even when trains are not necessarily at the platform.

Automatically paged messages announcing arrivals and departures are again integrated into the scheduled operations. The back office maintains the schedule on an active basis so that when the trains do not adhere to the schedule, minor modifications to the schedule are easily introduced and will govern the operation of the platforms.

I.3 Flint Mass Transportation Authority downtown terminus

The downtown terminal for the Flint Mass Transportation Authority (Flint MTA) was totally renovated and during this renovation numerous forms of integration and intelligence were incorporated into this building. The location where the downtown terminus is located is a fairly high crime area so there are significant concerns related to the security of staff, passengers and vehicles in the parking lot. Considerable efforts were therefore made to restrict and control any criminal activities.

A complex interlock system with respect to arriving buses and departing buses allows passengers to transfer from one bus route to another. This system ensures that the automatic doors from the bus platforms into the bus terminus and from the bus terminus onto the bus platform are only active during the times when the buses are present and are not yet scheduled to depart. Furthermore only one bus can depart at a time using a mechanism of automatic lights so that the possibility of collision or colliding with a passenger is minimized.

Surveillance cameras, up to date bus scheduling information, television displays and a small conference facility are all incorporated into this design.

There is full integration with a fire alarm system and a stand by generator so as to ensure that the electromagnets used to control the doors operate in full compliance with the local ordinances.

All communications wiring is carried over a single networking infrastructure. The communications facility at the Flint downtown terminus is part of the overall Flint MTA communications network and is linked via a wireless link from this facility to the MTA head office.

Figure I.2 – Mass Transit Authority downtown terminus facility Flint, Michigan, US

Photo credit: courtesy of IBI Group

I.4 Wellesley Central Health Corporation

All communications are carried over a single communications infrastructure including nurse call, telephones, data, access control and integration with a fire alarm system, elevators and parking.

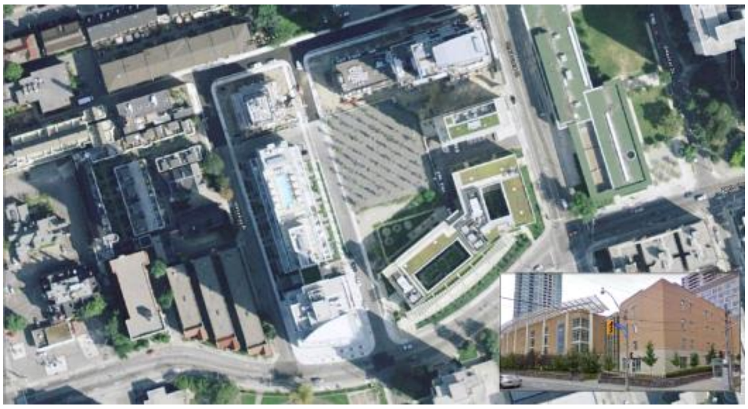

Figure I.3 – Wellesley Central Health Corporation Toronto, Ontario Canada

Photo credit: courtesy of IBI Group

I.5 World Trade Centre

The World Trade Centre (WTC) serves as international ecosystem of a global network and integrated trade services under the umbrella of a prestigious brand. The WTC stimulates trade and investment opportunities for commercial property developers, economic development agencies and international businesses looking to connect globally and prosper locally.

Services provided by the WTC include:

– Market research and trade information services;
– Business centre, trade show and exhibit facilities;
– Meeting venues and translation services;

– Video conferencing capabilities;
– Temporary and permanent offices;
– Access to key governmental agencies in over 100 countries;
– Trade development and services (trade missions).

I.6 Microsoft's building pilot programme

The Microsoft corporate headquarters in Redmond was used as a living laboratory to pilot several intelligent building solutions. This was part of the firm's efforts on environmental sustainability, aimed at cutting their emission footprint and reducing overall operating costs. Most importantly, the firm believes that technology can help improve efficiency in all areas of energy and resource use [b-ESBuilding].

The focus study initially began with 13 buildings of about 2.6 million square feet, with the age of the buildings varying from over twenty years to buildings that were almost new. The Redmond Operations Centre (ROC) as shown in Figure I.4, was located in a drab, nondescript office part, with a new state-of-the-art 'brain' within it.

Figure I.4 – Microsoft's Redmond Operations Centre

Equipment level data collected from either the control panel or BMS servers is sent to the middleware server and for some this is carried over an open protocol (BACnet). There are energy meters present to provide the sub-metered electricity consumption data for the utilities. The internal enterprise data warehouse also consists of contextual information such as building type and headcount. The middleware server acts as an aggregator for all on-site data and transmits this data securely to the intelligent building solution vendor, who runs the analytics and shares the output with Microsoft staff via an interactive graphical interface on the web.

Plug loads were a focus for this facility. The high plug load accounted for the same amount of energy as the building base load. Intelligent building solutions allowed for the tracking of plug loads based on the area, which serves as a live indicator to all the building occupants as to how much electricity they are consuming. Electricity was usually consumed by building occupants' devices such as their laptops, cell phones, etc. Thus, Microsoft could leverage on the information provided to motivate users to reduce their plug load.

Besides plug loads, Microsoft also utilized an intelligent building solution that serves as an analytical layer above the BMS. This creates a consolidated view of granular energy and operational data across Microsoft's building portfolio. The main idea is that buildings will be managed holistically through a unified interface, instead of through many disjointed systems, where the existing management systems are all connected to an analytical layer. The key objectives were to save energy and manage resources and there is a focus on fault detection and diagnosis as well as alarm management.

Another objective was to identify any building faults and inefficiencies in real-time by analysing the data streams extracted from the building systems. Through this new approach, engineers or facilities managers can identify faults according to the prioritized faults provided automatically by the intelligent building solution. This provides not only the prioritized equipment faults but also the estimated cost of wasted energy. This facilitates quick and efficient decisions as to which faults require immediate attention and whether the savings justify the expense for repair.

When a particular system is faulty or inefficient, it might require a lot more energy to tackle the same load and it might consume energy without performing its task. Software analytics are also able to provide useful information such as quantifying wasted energy from each identified fault in terms of dollars per year. Software analytics are also beneficial because it the visibility of systems is increased, allowing Microsoft to identify a faulty control code issue that a conventional BMS would miss.

In terms of alarm management, the issue was the daily flooding of engineers' inboxes with tonnes of automated notifications, ranging in importance from the most insignificant notifications such as the start of a self-test, all the way to the most major issues such as a power outage. In this situation the most critical problem can be missed due to the overwhelming number of notifications and alarms, causing a greater delay to an already urgent problem. This reduces the engineer's effectiveness significantly. However, with the intelligent building solution, both patterns and correlations can be identified effectively.

Microsoft also has an advanced irrigation system in their Redmond campus that ensures about 11 million gallons of water are saved annually. Recycling is very prominent in this campus, where an average of 141 tonnes of material is recycled every month. This includes glass, aluminium, plastic, paper, organic waste, wood pallets and copper wires. This campus also started to compost their food waste from cafes, kitchens and conference rooms in an effort for waste reduction [b-MSsheet]. Therefore, this building shows how technology can be incorporated into buildings, to increase the efficiencies and save a huge amount of money as a result. This headquarters campus is generally focused on energy management, reducing operating costs and reducing carbon footprint.

I.7 Infosys building, Pocharam campus in Hyderabad

This software development block (SDB) of the Pocharam campus in Hyderabad by Infosys, as shown in Figure I.5, comprises a total built-up area of 24 000 sqm. The building consists of an east and west wing, where 85% of the total building area is air-conditioned office space and the total building occupancy is 2 500. The most unique feature is that the building is split into 2 identical symmetric halves (exterior and interior), where one half is cooled by conventional but efficient air-conditioning and the other half by radiant cooling.

Figure I.5 – Infosys building

Photo credit: Sekhar Kondepudi

This building was designed with a highly efficient day lighting systems (volumetric lighting), which allows for over 90% of the office space to obtain natural sunlight, reducing the need for artificial lighting during the day time [b-Kurmanath]. This was achieved through the use of light shelves, narrow floor places, and a reduced window-to-wall ratio. Passive solar design was also implemented by aligning the buildings along an east-west axis for minimum heat exposure, and terracing their buildings to minimize the impact from the summer sun [b-Joneslanglasalle]. The Pocharam campus installed a 400 kW solar plant that generates about 700 000 kWh per annum, resulting in the reduction in reliance on the power grid.

An efficient radiant cooling technology was also derived. This technology has the potential of changing and drastically optimizing the cooling processes used for air conditioning in buildings. Within the first couple of months, the side using the radiant cooling had energy savings of about 40% compared to the other side, which was measured through extensive metering. Radiant cooling is achieved by cooling the slab which then absorbs the heat (radiation) generated by people, devices, lighting and equipment that are exposed to the slab.

The building also featured a state of the art BAS to monitor and control the operation of the various building systems accurately with over 3 000 sensors placed throughout the building to monitor the building condition ranging from the chiller plant to indoor air conditions.

Infosys aims to enable processes for improving their systems for monitoring water recycling, with the aim to achieve long-term water sustainability. Fresh water was only to be used for human sustenance.

Rainwater harvesting was incorporated through surface-water catchment areas with storage in a man-made lake within the campus. Grey water is used for landscaping, flushing purposes and cooling towers. Efficient plumbing fixtures and the use of recycled wastewater resulted in about 50% less water consumption versus similar buildings.

Other water consumption initiatives include the installation of pressure reducing valves in pipelines and the installation of sensor taps in high-density locations, calibrating for a decreased flow.

From a technological perspective, electronic water meters were installed at all outlets of underground reservoirs to improve the monitoring accuracy and to detect leaks [b-Infosys]. The water meters can be used to further analyse which systems are not functioning efficiently.

Carbon dioxide (CO2) levels undergo continuous monitoring to ensure good indoor air quality (IAQ) for the occupants [b-Kurmanath]. The radiant cooling system technology inherently provides a healthier IAQ because the air is not re-circulated in the system. An abundance of treated fresh air is provided to the occupants. This accurate control of temperature, relative humidity and CO2 levels was possible due to the BAS. The Pocharam campus is seen to be strongly advocating green living, as well as incorporating new technologies into the buildings to achieve a well-rounded green and smart building. Efforts are made to improve water, waste and well-being management, rather than only focusing on energy management. The aims of the Pocharam campus lie in not only reducing operating costs, but also in reducing the carbon footprint.

I.8 San Francisco Public Utilities Commission (SFPUC) Building

The San Francisco Public Utilities Commission SFPUC headquarters building shown in Figure I.6, is located in San Francisco, CA. This is a thirteen storey Class A office building of approximately 277 500 square feet. It was called 'the greenest office building in North America', when it opened in July 2012, being known for its sustainability and energy savings. This building is a LEED Platinum (a certification for leadership in energy and environmental design) building, where it houses approximately 950 employees.

The SFPUC building uses a highly efficient exterior building enclosure with exterior sunshades for daylighting, glare management and to minimize heat gain. Daylight is also harvested for the use in the building, as facilitated by the light shelves integrated into the window walls for increased efficiency. The installation of workstation task lighting reduced the power needed for additional lighting.

Figure I.6 – SFPUC Building

Energy is also generated through the wind turbines that are installed along the façade of the SFPUC building and three roof top solar platforms that collect solar energy. Both of these systems have metering devices attached for data collection and analysis to allow for changes that can be made in meeting the building's energy demand.

The building uses IBMS to integrate data from various building systems to allow for the read or write capability of 13 500 data points. This integration allows for increased functionality and operability between different systems (software applications and operational tools) for monitoring and managing the building's performance in real time [b-Sinopoli]. This building serves as a demonstration of how the implementation of technology can reduce the impact of a building. The IBMS monitors and manages the data with analysis and control and in terms of energy management, it monitors and manages various systems including elevators, lighting, HVAC, power monitoring, solar energy collector metering, wind energy power generator metering and interior and exterior shade control.

A rainwater harvesting system is in place in the SFPUC in the form of a 25 000 gallon cistern used to capture rainwater from the roof and the childrens' day care centre play area. This water is treated and distributed to irrigation areas around the building. The use of water-efficient landscaping allows the captured rainwater to meet all of the irrigation needs.

SFPUC also incorporated an integrated living machine system that treats 100% of the building's grey and black water for reuse to flush the toilets in the building. The system treats about 5 000 gallons of wastewater per day, and allows for a reduction in consumption from 12 gallons per person, down to 5 gallons [b-sustainable]. The system uses a series of diverse ecologically engineered wetlands, located in the sidewalks surrounding the headquarters and in the lobby of the building, to treat the wastewater.

The IBMS also monitors and manages data from the wastewater treatment system and the water reclamation in the building, so that this data can be further analysed and the system optimized.

Natural ventilation is obtained with the use of operable windows and raised floors also facilitate the concept of natural ventilation, enhancing the overall IAQ [b-Kmdarchitects].

The usage of IBMS in this building has had huge positive impacts on the building. The IBMS also controls additional areas such as demand response, building performance analytics, alarm management and public information and education. The data in the IBMS is transformed onto dashboards. Visualization of the data is paramount and there are over 450 dashboards being developed to provide the facilities team, building operators and even the public, with information that is specifically tailored to their needs. Users of this information are then informed and prepared to make sound changes to the building's optimization, performance and efficiency [b-Sinopoli].

Appendix II

Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AHJ	Authorities Having Jurisdiction
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS	Building Automation Systems
BIQ	Building Intelligence Quotient
CABA	Continental Automated Building Association
CFS Alert	Canadian Forces Station Alert
CMOS	Complementary Metal Oxide Semiconductor
DDC	Direct Digital Control
FDD	Fault Detection and Diagnostic
FM	Facility Management
HVAC	Heating, Ventilating and Air Conditioning
IAQ	Indoor Air Quality
IBMS	Integrated Building Management Systems
IBT	Integrated Building Technology
ICT	Information and Communication Technology
IP	Internet Protocol
ISP	Internet Service Provider
LAN	Local Area Network
LEED	Leadership in Energy and Environmental Design
MRU	Multiple Rental Unit
OSI	Open System Interconnection
PSIM	Physical Security Information Management
PWGSC	Public Works and Government Services
QoS	Quality of Service
SDB	Software Development Block
UI	User Interface
UPS	Uninterruptable Power Supplies
VAV	Variable Air Volume
WTC	World Trade Centre

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