CHAPTER 3

INTELLIGENT BUILDINGS AND BUILDING AUTOMATION SYSTEMS

3.1 INTRODUCTION

With the development of times and advancement of technology, the intelligent buildings begin to appear in people's lives and work. Among them, building automation is an important part of the intelligent building and is also one of the main directions of the future development of architecture and technology.

An intelligent building is the integration of technology, building, and energy management systems . An intelligent or smart building takes a number of building systems and brings them together to reduce energy consumption and make the building as efficient as possible.

According to definition of intelligent building defined by the new revision of national standards of China “Intelligent building design standards" (GB/T50314-2006) the intelligent building is a building as a platform, containing the information facilities system, the application of information technology system, construction equipment’s management system, Public safety systems, etc. It includes a set of structure, system, service, management and their optimal combination providing safe, efficient, convenient, energy saving, environmental protection and healthy environment.

Characteristics of an intelligent building include:

- Integrating various building systems so they can be controlled by a centralized common user interface.
- Use of a shared network for all building-system communications.

- Are high-performance buildings that helps in providing significant benefits to building owners, property/facility management professionals, and end users
- Maximizing building performance and efficiency by integrating building systems such as lighting, HVAC, safety, power management, security (access control, video surveillance, and visitor management), etc.
- Use technology and strategies that add long-term, sustainable value to the property.

Defining an intelligent building can be grouped into three categories as listed below:

- Performance - based definitions
- Services - based definitions
- System - based definitions

3.1.1 PERFORMANCE – BASED DEFINITION

Performance- based definitions define intelligent building by stating what performances a building should have. A typical performance- based intelligent building definition may be that of the European Intelligent Building Group (EIBG) defines an intelligent building as a building created to give its users the most efficient environment; at the same time, the building utilizes and manages resources efficiently and minimizes the life costs of hardware and facilities.

Another example is given by the Intelligent Building Institute (IBI) in the United States, states that an intelligent building provides a highly efficient, comfortable and convenient environment by satisfying four fundamental demands: structure, system, service and management, and optimizing their interrelationship.

Performance- based IB definitions emphasize building performance and the demands of users rather than the technologies or systems provided. According to this category of definition, owners and developers of buildings need to understand correctly what kind of buildings they want and also how to satisfy continuously the increasing demands of users. Energy and environmental performances of buildings are certainly among the important issues of an intelligent building. An intelligent building should also adapt itself quickly in response to internal and external conditions, and to meet the changing demands of users.

3.1.2 SERVICE – BASED DEFINITIONS

Services- based definitions describe intelligent building from the viewpoint of services and quality of services provided by buildings. The key issues of intelligent building focus on the following four services aspects:

- serving as a locus for receiving and transmitting information and supporting efficient management;
- ensuring satisfaction and convenience of persons working inside;
- rationalization of building management to provide more attractive administrative services at lower cost;
- Fast, flexible and economical responses to the changing sociological environment, diverse and complex working demands and active business strategies.

3.1.3 SYSTEM – BASED DEFINITIONS

System- based intelligent building definitions describe intelligent building by directly addressing the technologies and technology systems that intelligent building should include. A typical system- based intelligent building definition is that in the Chinese intelligent building Design Standard (GB/T50314–2000), which states that intelligent building provide building automation, office automation and communication network systems, and an optimal composition integrates the structure, system, service and management, providing the building with high efficiency, comfort, convenience and safety to users.

3.2 EVOLUTION OF INTELLIGENT BUILDINGS

Intelligent buildings began from the automatic intelligent control of typical building services processes and communication devices. Along with the rapid evolution of electronic technology, computer technology and information technology, intelligent building systems are becoming more and more advanced, and the level of integration is being developed progressively from the subsystem level to total building integration and convergence of information systems.

Before 1980, the automation of building systems was achieved at the level of the individual apparatus or device. After 1980, intelligent building systems entered the integrated stages. There has been great progress on intelligent building system integration in terms of both technology and scale. Intelligent building systems after 1980 can be divided into five stages as follows:

- Integrated single function/dedicated systems (1980–5);
- Integrated multifunction systems (1985–90);
- Building level integrated systems (1990–5);
- Computer integrated building (1995–2002);
- Enterprise network integrated systems (2002–).

Integrated single function/dedicated systems (1980–5), all the building automation subsystems (including security control; access control; heating, ventilation and air-conditioning [HVAC] control; lighting control; lift control; other electrical systems; fire automation; etc.) and CA subsystems (including electronic data processing [EDP]) and data communication; telefax and text communication; voice communication; TV and image communication; etc.) were integrated at the level of a single or individual function subsystem. Integration and communication between the automation systems of different subsystems was impossible.

Integrated multifunction systems (1985–90), security and access control were integrated. The automation systems of building plants or services systems were integrated. There were unified networks for text and data communication, voice communication and image communication respectively. At this stage, the integration of systems with the same nature or similar functions was achieved.

Building level integrated systems (1990–5), both building automation and communication systems were integrated at building level as building automation system (BAS) and integrated communication system (ICS). At this stage, a building automation system could be accessed remotely via telephone network using a modem, while the cellular phone for voice and data communication was introduced to the market.

Computer integrated building (1995–2002), convergence networks became available and were used in practice progressively, with the popular use of Internet protocol (IP) network technologies and increased network capacity. At this stage, the integration was at the building level. Remote monitoring and control could be achieved via the Internet.

Enterprise network integrated system (2002–), the intelligent systems can be integrated and managed at enterprise level or city level. Intelligent building systems are not enclosed within buildings anymore; they are merged with intelligent building systems in other buildings as well as other information systems via the global Internet infrastructure.

Integration and management at this level become possible due to the applications of advanced IT technologies such as Web Services, XML, remote portfolio management and helpdesk management, among others. Communication, image communication via cellular phone has been brought into practical use. Modern Intelligent building systems have been becoming very large in terms of system scale and complex in terms of hardware and software system configurations, while their functions and capacities have been increasing progressively.

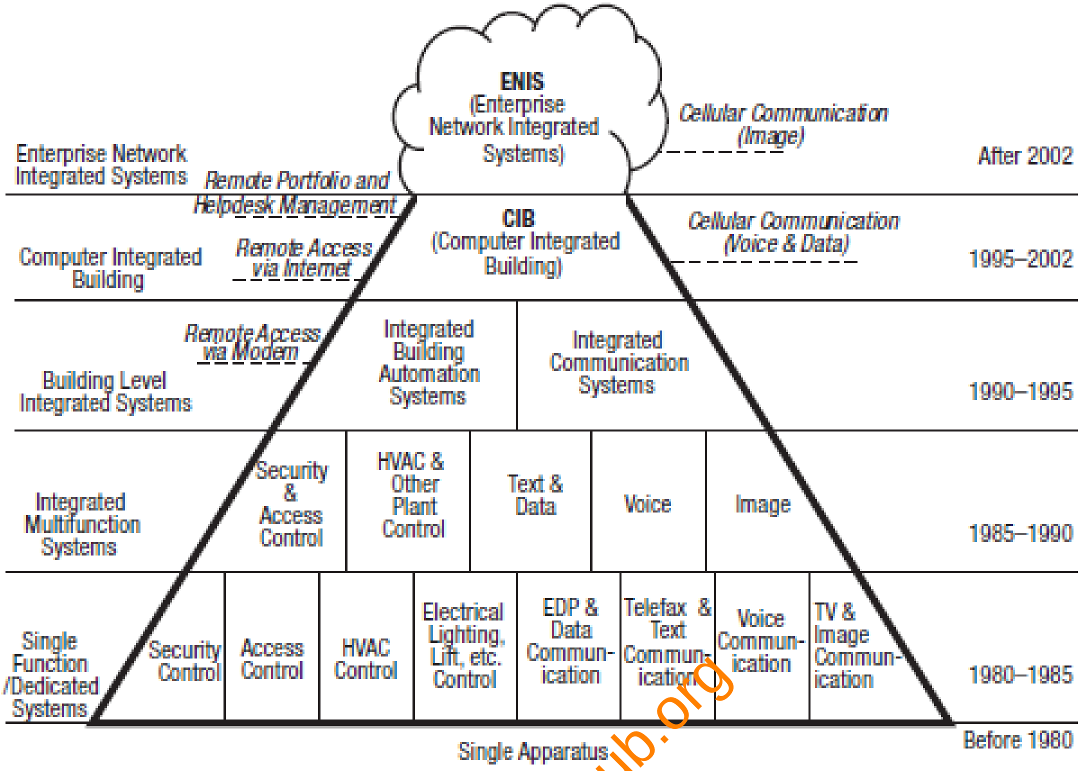

Figure 3: Evolution of intelligent buildings

3.3 HOW TO MAKE A BUILDING INTELLIGENT

In modern building environment, intelligent buildings cannot exist without advanced technology systems, especially information technology systems. But having those technology systems is not enough to make a building an intelligent one. Furthermore, the technology systems should be correctly configured and properly integrated with each other and with the building facilities. The system functions should be appropriately customized to meet user requirements and to provide the expected performance of intelligent buildings.

Finally, the technology systems, including their integration and interoperation, should be properly commissioned and maintained to ensure they function as expected. Besides the system hardware and software, the application software, including that for facility automation and control, optimization and management, should be customized and commissioned appropriately. A building may have technology systems, but if they are not working correctly it will not make the building intelligent in reality.

Even though the successful use of advanced technologies, including IT, is the main feature of intelligent buildings, the implementation of technologies should not be the sole objective of intelligent buildings. Performance is definitely a key objective of intelligent buildings. Intelligent buildings cannot be separated from the architecture design, building façades and materials, which are among the essential elements of intelligent buildings.

3.3.1 INTELLIGENT ARCHITECTURE

Intelligent architecture refers to built forms whose integrated systems are capable of anticipating and responding to phenomena, whether internal or external, that affect the performance of the building and its occupants.

Intelligent architecture relates to three distinct areas:

- Intelligent design;
- Appropriate use of intelligent technology;
- Intelligent use and maintenance of buildings.

3.3.1.1 INTELLIGENT DESIGN

It requires that the building design responds to humanistic, cultural and contextual issues; that it exhibits simultaneous concern for economic, political and global issues; and that it produces an artificial enclosure which exists in harmony with nature. Existing in harmony with nature includes responding to the physical laws of nature and the proper use of natural resources.

3.3.1.2 APPROPRIATE USE OF INTELLIGENT TECHNOLOGY

This is achieved by integrating intelligent technologies with an intelligent built form that responds to the inherent cultural preferences of the occupants is a central theme in intelligent architecture.

For example, in areas where people place a high premium on operable windows for conservation of electricity, the most appropriate and efficient air- conditioning strategy for a building may be the use of thermal mass and night- time free cooling instead of a high- tech air- conditioning system. In other cases, the use of carefully selected electric lighting and environmental control strategies may be more appropriate.

3.3.1.3 INTELLIGENT USE AND MAINTENANCE OF BUILDINGS.

Intelligent architecture incorporates intelligent facility management (FM) processes. For a design to be intelligent the life cycle of a building and its various systems and components must be taken into consideration. Although an intelligent building may be complex, it should be fundamentally simple to operate, be energy and resource efficient, and easy to maintain, upgrade, modify and recycle.

Materials and equipment that require complex maintenance and unhealthy cleaning agents, and building components that must be treated as hazardous waste in the recycling process like mercury in light- bulbs should not be used in an intelligent architecture.

3.3.2 INTELLIGENT AND RESPONSIVE BUILDING FAÇADES

Façades designed to integrate a host of emerging technologies will have an inherent 'intelligence' and be able to respond automatically, or through human intervention, to contextual conditions and individual needs. The development of the intelligent and responsive façade requires the redefinition of 'window' and 'wall'. With the introduction of new glazing and wall assemblies, what is 'transparent' can become 'opaque' with a switch.

Intelligent façades currently can be centrally controlled still providing the occupant with the ability to manually override the system, change their thermo physical properties such as thermal resistance, transmittance, absorptance and permeability, modify their interior and exterior colour and texture, function as communicating media façades with video and voice capabilities, change optical properties and allow the creation of patterned glazing, providing the opportunity for dynamic shading and remote light control.

Central controls for intelligent façades will respond to climatic conditions by transforming the building envelope to optimize heating and cooling loads, daylight utilization and natural ventilation Intelligent façades will transport daylight deep into a building's interior and allow the occupants to determine the degree of luminous, acoustical and thermal comfort required along with the degree of visual and acoustical privacy provided by the enclosure.

The benefits of an intelligent building potentially include energy savings, reducing the cost of changing occupancy and configuration (churn), maintaining a comfortable, safe and secure environment, and improving user productivity.

3.4 FACILITIES MANAGEMENT AND INTELLIGENT BUILDINGS

Facility management professionals often consider almost all BAS functions as part of facility management functions, and BASs are the systems used to achieve facility management functions. Intelligent buildings need facilities management to define requirements, justify investment and deliver benefits. At the same time, facilities managers need intelligent buildings to control building performance, manage distributed services, adapt rapidly to changing requirements and provide crucial management information.

The basis of facilities management is to ensure all the service equipment works properly. But for building services engineers, facility management functions mostly refer to the use of building spaces and facilities, including the economic effectiveness and financial aspects.

Intelligent buildings usually imply facilities management via building automation systems. Therefore, the facilities management of intelligent buildings requires the combination of an integrated BAS and the traditional information management system. Facility owners and managers require large amounts of data of various types for quality and efficient management. Typically, this information, such as management data of utilities, energy, maintenance, space, tenant and environmental compliance, is available and recorded on various computers or control stations.

Regarding the traditional information management systemin practice many facilities management systems (software tools) have been widely used in facilities management, such as Net Facilities, CAFM Tools and ARCHIBUS/FM. The tools in this category are usually integrated information management platforms, often web- based, providing computer- based space management, move management, work- order administration, vendor interaction management and other FM functions. They provide real- time collaboration platforms between facilities managers, maintenance staff, vendors, tenants and suppliers and others.

A facility management system (FMS) is an overarching system of an intelligent building that brings together some of the operational management functions of the facility and the building technology systems. The FMS is typically a server-based configuration coupled with operator workstations, which may be supplemented with wireless devices.

3.5 BUILDING AUTOMATION SYSTEMS

Building Automation system (BAS) is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. A BAS consists of software and hardware; the software program, usually configured in a hierarchical manner, can be proprietary, using such protocols as C-bus, Profibus.

Building Automation is also an energy management system which saves management companies and building owners by efficiently controlling air conditioning, lighting and heating comfort systems and thus staying "green".

BAS is where mechanical and electrical systems and equipment are joined with microprocessors that communicate with each other and to a computer. This computer and controllers in the building automation system can be networked to the internet or serve as a stand-alone system for the local peer to peer controller network only. Additionally, the BAS controllers themselves do not need a computer to operate efficiently as many of these controllers are designed to operate as stand-alone controllers and control the specific equipment they are assigned to control.

BAS is one of the major intelligent building systems. A BAS comprises several subsystems which are connected in various ways to form a complete system. The system has to be designed and engineered around the building itself to serve the services systems for which it is intended. Building services include HVAC systems, electrical systems, lighting systems, fire systems and security systems and lift systems.

A BAS may be used to monitor, control and manage all or just some of these services. There are good reasons and ultimate objectives in investing considerable sums of money in this way. These will vary, depending on the use of the building and the way the building is managed as well as the relationship between the value of the end product and the cost of operating the building. It may also depend on the level of sophistication of the building services and their capital cost.

3.6 BENEFITS OF BUILDING AUTOMATION SYSTEMS

Systems linked to a BAS typically represent 40% of a building's energy usage; if lighting is included, this number approaches 70%. BAS systems are a critical component to managing energy demand. As well as controlling the building's internal environment, BAS systems are sometimes linked to access control or other security systems such as closed-circuit television (CCTV) and motion detectors. The main benefits of BAS include:

3.6.1 INCREASED RELIABILITY OF PLANT AND SERVICES

The objectives of system operation and maintenance are to ensure the plant runs properly without breakdowns and to preserve efficient operation. Failure of a component almost always results in a more expensive repair or replacement than would have been necessary with timely periodic attention. Additionally, the breakdown of certain equipment interrupts the service provided by the environmental system with resultant inconvenience to occupants and extra cost to the owner.

A BAS can make a significant contribution towards guaranteeing the operation by monitoring the system continuously and providing preventative maintenance. Typical examples are equipment alerts when the predetermined operating time has been reached and in the case of equipment performance having been degraded to a certain level.

3.6.2 REDUCED OPERATING COSTS

The major expenses in operating a building is the cost of energy required for heating, air-conditioning and illuminating the space. A key function of the BAS is to reduce the energy costs as much as possible. Typical examples of this are programmed start/stop, duty cycling, set - point reset and chiller optimizations.

The personnel used to maintain a building and its services is a significant portion of the overall operating costs due to increased remuneration costs and the increased sophistication of modern building services systems. The contribution BAS provides to reducing manpower requirements have an effect on the annual cost of running a building.

3.6.3 ENHANCING STAFF PRODUCTIVITY

A BAS can also provide benefits which are less tangible and therefore difficult to measure. These include increased efficiency of personnel because of improved environmental conditions. Improved morale and job satisfaction of maintenance personnel, who are able to spend more time preventing things from going wrong and less time in 'fire fighting', can be another intangible benefit.

3.6.4 PROTECTION OF PEOPLE AND EQUIPMENT

BAS is a communication network that extends throughout the building or complex of buildings. This same communication system can be put to work sending alarms to an operator or security service in the event of smoke, fire, intrusion or situations that could possibly damage equipment.

In addition, the BAS can also assist in other security measures. It can control access to itself by providing the building manager with the capability of granting different levels of access to various staff members. The BAS can help guard against intrusion in the building by utilizing card access, by controlling and monitoring specified areas of the building, and by assuring that the rounds of security patrollers match a predetermined schedule.

3.6.5 BUILDING MANAGEMENT

BAS provides the most cost- effective means for staff to manage the building. This include monitoring the conditions and services and maintaining them at the required level at all times. It also means being able to respond quickly and efficiently to changes in function patterns and use of space.

3.7 FUNCTIONS OF BUILDING AUTOMATION SYSTEMS

A building automation system is the high- technology tool or platform that expands and enhances the capabilities of those responsible for operations of a building. To understand the potential impacts of a BAS, one need to look at the needs of the building operation and management which a BAS addresses. Typical functions provided by building automation systems include:

- Installation- management and control functions;
- Energy- management functions (supervisory control);
- Risk- management functions;
- Information- processing functions;
- Facility- management functions;
- Performance monitoring and diagnosis;
- Maintenance management.

3.7.1 INSTALLATION- MANAGEMENT AND CONTROL FUNCTIONS

The increasing acceptance of direct digital control changed the overall nature of building control systems used in practice from traditional analogue systems to digital systems. Standalone control stations with direct digital control capacities have played significant roles in, and are increasingly important for building automation.

Control functions of a BAS can be divided into two categories:

- local control (installation- management and control) functions
- Supervisory control (or energy- management) functions.

Local control functions are the basic control and automation that allow the building services systems to operate properly and provide adequate services. Local control functions can be further subdivided into two groups:

- sequencing control
- Process control.

Sequencing control defines the order and conditions associated with bringing equipment online or moving it offline. The typical sequencing control in building systems includes chiller-sequencing control, pump- sequencing control, fan- sequencing control and lighting on/off control, etc.

Process control is used to adjust the control variables to achieve well- defined process objectives in spite of disturbances, using measurements of state and disturbance variables. Examples of typical process control in buildings are temperature control, air and water flow rate control and static pressure control.

The most common feedback control function adopted for building processes is proportional-integral- derivative (PID) control. On/off control step control and modulating control are the effective control- actuation schemes of local process control loops in building practice.

3.7.2 ENERGY- MANAGEMENT FUNCTIONS: SUPERVISORY CONTROL

In BAS installations, savings by improved energy management provide the economic justification for the purchase of the systems. BAS makes energy savings can be broadly grouped into two categories.

- The first is the savings which result through starting and stopping plants according to correct or optimal timing.

- The second is the savings which result through running plants in energy- efficient conditions, typically by setting the set- points of the local process controls at correct or optimal levels.

There is no better means of saving energy than that of turning off the energy- using equipment. One cannot turn off equipment that is needed constantly; but has to be able to turn off equipment without compromising the quality of services or the indoor environment. There are two approaches for starting and stopping equipment in an energy- efficient manner. They are called ‘scheduled’ and ‘optimized’ start/stop.

In scheduled start/stop, the HVAC equipment, lights and so on are turned on or off according to a combination of the clock and calendar. With an optimized start/stop program, the BAS assesses the existing conditions, anticipates conditions for the next several hours and decides when to start and stop the systems so that environmental conditions are provided during the complete building occupancy period with minimum energy use.

The control settings of the local controllers might be optimal and energy efficient when certain subsystems or certain subsystem performance criteria are considered. Supervisory control or optimal control, seeks to minimize or maximize a real function by systematically choosing the values of variables within allowed ranges.

In the control of HVAC systems, supervisory control aims at seeking the minimum energy input or operating cost to provide satisfactory indoor comfort and a healthy environment, taking into account the ever- changing indoor and outdoor conditions as well as the characteristics of HVAC systems. Compared to local control, supervisory control allows overall consideration of the system- level characteristics and interactions among all components and their associated variables.

3.7.3 RISK- MANAGEMENT FUNCTIONS

BAS detects temperature and humidity conditions, it can also be used to detect fire or the presence of smoke. Fire safety integrated into BAS provides a greater degree of personnel safety than using two independent systems.

The BAS is able, automatically, to close fire doors, close some air dampers and open others, start some fans and stop others and pressurize some parts of building with respect to others. This can help prevent the spread of fire and perhaps, more importantly, reduce the spread of smoke.

With the security system incorporated into the BAS, it almost always provides greater security and therefore reduces risk. Detection of someone trying to gain unauthorized entry is commonly by sensors on doors and windows.

From the information reported to the central computer, the security officers can be made aware, not only that an intruder is present or is trying to gain entry, but also the intruder's location within the building. Access control differs from security monitoring since as it is actually controlling who has access to a building or certain parts of a building.

3.7.4 INFORMATION- PROCESSING FUNCTIONS

The basic data needed for the economic evaluation is the cost of the BAS and the economic benefits that can be derived from the BAS. The initial cost of the BAS can be estimated more accurately than the annual savings from energy conservation and other improvements. Although prediction of dollar savings attributable to energy conservation features and building management features is difficult, powerful systems provide energy monitoring and graph/table reporting, making estimation easier.

Engineers can directly access actual plant operating conditions through BAS to monitor energy use and energy cost, to carry out energy audits or to check performance using computer simulation techniques. With the support of BAS, a financial report can be produced with much less effort.

3.7.5 FAULT DETECTION AND DIAGNOSIS, MAINTENANCE MANAGEMENT, AUTOMATIC COMMISSIONING

Fault detection and diagnosis technologies, and smart maintenance schedule and automatic commissioning tools have followed in the wake of the development of information-processing functions. Effective maintenance is a very important task of modern automation systems.

It can extend equipment life, improve equipment availability and keep equipment in proper condition, maximize equipment efficiency, and consequently reduce the complete life cycle cost of the equipment.

Effective maintenance is particularly important for intelligent buildings as modern intelligent buildings have many complex facilities, most of which have a direct relationship with the services quality and play a very significant role in the life cycle of the buildings.

Smart maintenance is proposed based on the monitoring data, which provides information on the equipment conditions. Conventional maintenance has been carried out according to schedule, which may be not suitable for all cases. Information- guided maintenance provides the service when it is needed, therefore saving manpower and reducing risk.

Fault detection and diagnosis technologies can be applied online or offline. An offline process is carried out based on the recorded monitoring data. Online technology is more advanced, and is able to detect and analyse faults while the system is running and produce a report concurrently.

Automatic commissioning is a further development of Fault detection and diagnosis technology. Applying this technology helps in not only to detect faults online but also to reflect the analysis results to the system simultaneously for better control or even data recovery and fault- tolerant control.

BAS shall utilize 'open' communication protocols, such as BACnet per ASHRAE Standard 135, to minimize the costs of providing integration and to allow interoperability between building systems and control vendors. Other open protocol language systems, such as LonTalk, may also be used, provided there is compatibility with overall regional and central monitoring and central strategies.