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Smart buildings: A primer

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Abstract
Transforming exciting cities into smart one begins with making buildings smart. Smart buildings are structures in which automated processes and devices are used to control and monitor building operations. A smart building combines a number of different technologies to automate building management. The smart building technology, which optimizes the energy usage between a building and the smart power grid, has become an important way to improve energy efficiency. This paper provides a primer on smart building.

Keywords: smart building, intelligent building

Introduction

Electricity, a form of energy, is a key resource for the current and future development of society. Demand for electricity continues to increase worldwide. The growth can be offset in two ways: (1) making the power grid "smart", (2) making buildings "smart." The building sector in the United States accounts for more 70% of electricity energy consumption. Residential and commercial buildings consume a big portion of energy all over the world, due to heating, ventilation, and air conditioning (HVAC) systems. They play an important active role in the smart grid, which is an electricity network that accommodates two-way power flows. Smart grid and smart buildings that can communicate with each other have more benefits for building management and power operation. The era of "dump," conventional buildings is rapidly coming to an end because they have no connectivity, no integration, no communication, and are less energy efficient. Smart building is making manual control of a building's heating and cooling a thing of the past.

Buildings include homes, schools, offices, hotels, banks, hospitals, restaurant, retail store, apartments, factoryies, etc. Since buildings represent a major capital expense for businesses, second only to salaries paid to employees, business owners are constantly looking for ways to make buildings more efficient, safer, and comfortable. Smart buildings are the fundamental blocks of smart cities. A building is smart only when it effectively contributes to the society at large. New buildings or old structures are being converted to smart buildings.

Smart Building Concept

The concept of smart or intelligent buildings started in the early 1980s in the United States . Today, it has become a household term worldwide. A smart or intelligent building is any structure that uses automated processes to control the building's operations including heating, ventilation, air conditioning, lighting, security, etc. It has the property to dynamically manage its personal energy demand and the energy generation. It uses information and communication technologies (ICT) to enable automated building operations and control. The elements of smart buildings include lighting control systems, audio-visual systems, fire alarms, and computer networks.

The main features of smart buildings include [1]

- *Systems are connected*: This is what makes a building "smart" – the ability of the systems within it to communicate with one another. To make a building smart requires connecting all the core electrical elements of the building - lighting, power meters, water meters, pumps, heating, security, fire alarms, cameras, elevators, access systems, control systems, security systems, office equipment, HVAC (Heating, Ventilation and Air Conditioning) systems, etc. Like the Internet, smart building connects individual computer networks into one larger super network. Some of the components of a smart building are shown in Figure 1 [2].
- *Networked Sensors*: Sensors (for sensing presence, light, temperature, humidity, etc.) are an integral part of smart buildings and play an important role in collecting data to inform decisions about where to allocate resources. Modern buildings are being integrated with numerous networked sensors to improve convenience, occupant comfort accessibility, and energy-efficient operations. Most sensors are categorized as [3]: (1) Thermometer. (2) Humidometer. (3) Ambient light sensor. (4) Door & Window sensor (detecting whether the door/window is open or not). (5) motion detection sensors(detecting movement in a particular area). (6) Energy meter.
- *Automation Systems*: For greater energy efficiency in smart buildings, automated systems are necessary to monitor and control the capabilities offered by the sensor network. In smart buildings, automation systems take inputs from the sensors installed in corridors and rooms and use these data to control certain subsystems such as heating, ventilation and air conditioning (HVAC), lighting, or security [4]. Information is gathered and analyzed by the systems that have been

put in place in a smart building. For complete control of the building, a proper SCADA (Supervisory Control and Data Acquisition) systems must be implemented.

- *Data*: Smart buildings generate a large volume of valuable data about their own use, which is something that regular buildings simply do not do. They can capture massive quantities of information about the building itself, the people that use it, and its wider environment. In today's connected world, data is the new oil and convenience is king. Smart buildings also collect data about how buildings are being used and provide a real-time picture of the status of the buildings. They also can count the number of occupants in each building at any given time [5].
- *Building Management System (BMS)*: The BMS refers to the central management system responsible for management, oversight, visualization, configuration, and performance monitoring of the building subsystem. This is a software interface to supply data to human manager. It is installed in a building to maintain and control the electrical equipment, fire alarms, and security system. It is required for energy consumption monitoring and management. Its mains purpose is to control, monitor, and optimize building services such as lighting, heating, security, TV, and alarm systems. The BMS is shown in Figure 2 [6]. IoT-ready products, such as sensors, actuators, and controllers are connected to the BMS.
- *Human Operation*: Even the most advanced smart building analytics and technologies can be rendered useless without effective human operators. Operators can interface with a smart building through user-friendly interactive displays. They interpret data displayed through smart building interfaces. They determine which types of alerts and reports will be the most useful to receive from analytics software [7].

Other enabling technologies include Internet of things, meters, advanced building automation, and data analytics software. Energy efficiency of smart buildings is important as they are an important component of the smart grid. Smart buildings are occupant-based, incorporating feedback both to and from occupants about their building use.

Applications of smart buildings

Smart office buildings, hotels, hospitals, educational facilities, stadiums, libraries, and many other types of smart buildings exist all over the world.

- *Smart Homes*: There is a growing interest in the idea of smart homes. Smart homes are supposed to enhance living experience and support independent living, especially for the elderly. The smart home network connects home appliances, e.g. Internet refrigerator, air conditioner, microwave, washer, cooker [8].
- *Smart Living*: Smart buildings provide happy living, amusing (entertaining) living, convenient living, smart working, and easy living.
- *Smart Library*: Many smart building technologies are well-suited to library spaces and have great potential to help libraries better serve their patrons.

Examples of smart buildings

The first ever intelligent building in the world was built in Hartford in the United States in 1984. Here we consider the most intelligent/smart buildings in the world. Due to space limitation, we will consider only three examples of smart buildings [9]:

- Figure 3 shows the Edge building in Holland. The Edge is regarded the greenest, most intelligent building in the world.
- Figure 4 shows Glumac in Shanghai, China. The Glumac was the first in Asia to pursue the Net-Zero Energy principle.
- Figure 5 depicts the crystal building in London, England. The building is one of the most sustainable buildings in the world.

Bene Afits

Creating or transforming a building into a smart building provides endless opportunities and benefits. The benefits vary range from energy savings to productivity gains to sustainability. A smart building is optimized for energy efficiency, comfort, and safety. It helps owners, operators, and facility managers improve asset reliability and performance. It enhances the health, utility, and value of all their resources, both human and capital. It makes the occupants more productive with lighting, thermal comfort; air quality, physical security, and sanitation. Smart buildings are accelerating business productivity, being energy efficient, providing positive occupant experiences, learning over time, and ensuring the safety and security of the buildings. Other benefits of smart buildings include [1]:

- They make the occupants more productive
- They create a better workplace
- They reduce energy consumption
- They provide stimulating living and working environments
- They are greener, more energy efficient and more cost effective.
- Significant operational savings
- Data protection

Challenges

Building smart in US is hard for the following reasons [10]: less-proven market, higher cost of building, inflexible mortgage lending requirements, and rigid building codes. Not-in-my-back yard activism is a bane to the builder's effort. Smart buildings are characterized by the use of wholly integrated systems that share vital information. Interoperability with other smart building elements is essential. The increased use of smart buildings is adding layers of complexity in the commercial real estate business and changing owner-tenant dynamics. Smart buildings, both residential and commercial, are the target of cyber-attacks with successful breaches. A lack of clarity in terminology on smart building technology is a challenge to designers, clients or researchers. Most proponents of smart building consider the crucial role of the technology without adequate consideration of social, cultural, and user interactions.

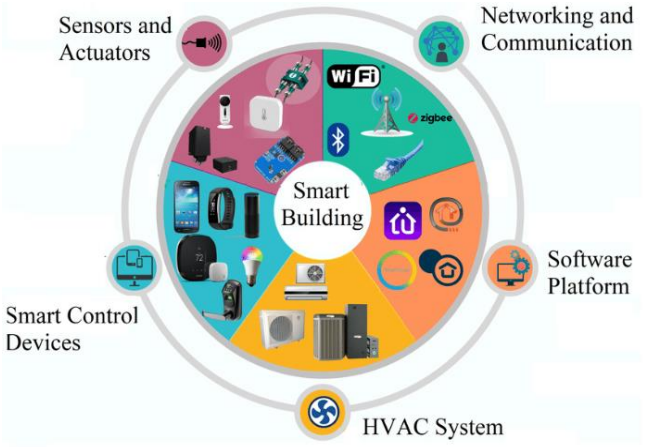

Fig 1: Some components of a smart building [2].

Fig 2: Building management system [6].

Fig 3: The Edge building in Holland [9].

Fig 4: Glumac in China [9].

Fig 5: The crystal building in England [9].

Conclusion

Advances in building technologies are combining energy efficiency, networked sensors, and data collection in exciting ways. Smart building is a solution optimizing energy consumption at buildings by integrating all main appliances. Smart buildings are ready for a future where IT and human innovation can be combined to make them smart enough for the 21st century. They produce smart communities of the future.

The next generation smart buildings are reaching further to attain Net Zero Energy. These also referred to as Zero Energy Buildings. These buildings are, by definition, designed to produce at least as much energy—if not more—than they consume. Wireless sensor networks (WSNs) and artificial intelligence (AI) will play a fundamental role in future smart buildings. Smart buildings are getting smarter and will be building of the future.

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