SMART BUILDINGS: THE USE OF SENSOR NETWORKS TO CONTROL INDOOR ENVIRONMENT

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SMART BUILDINGS

In order to make a significant difference in energy use, the average home or office space needs to be reinvented to incorporate efficiency in every aspect, yet in a sustainable, reproducible manner. This design integration is the core concept behind what are now classified as "smart buildings." Through the utilization of automated control processes on a common information technology (IT) network, previously separate aspects of a home are combined in order to provide peak efficiency, occupant comfort, and lessen environmental impact. In addition to the insides of smart buildings, their exteriors often utilize passive design methods to minimize the lighting and HVAC operation required in a home. Through proper orientation and careful design, occupants can take advantage of natural sources of light, heating, and cooling instead of relying solely on the grid. Through the implementation of smart building technologies, passive design and on-site renewable energy, engineers have created zero-energy buildings (ZEBs) that require no input from the grid. Instead, they fulfill the entirety of their needs through renewable methods.

SMART HVAC

Efficiency in ZEBs must be at its peak for the occupants' needs to be fulfilled. The largest sink, or source of energy usage, in almost any building type is the HVAC system; it is thus the least efficient component. In one study on the smart building environment analysis of temperature and humidity, it was found HVAC accounts for 26.1% of total energy consumption in residential buildings, and 53.4% in commercial applications. Heating, ventilation and air conditioning systems, more commonly known as HVAC systems, are a group of components that work collaboratively to deliver heat to, remove heat from, and ventilate a space. Current systems consists of separate units connected by a direct digital control system that operates based on central scheduling, and thus is unresponsive to any change in indoor or outdoor climate. This leads to the production unnecessary amounts of heat or cool air, and a subsequent waste of energy. To mitigate this problem, its necessary to design an "smart" HVAC system that is responsive to both the indoor and outdoor environments in the same manner as ZEBs: through the use of sensors networks

COMPONENTS OF A SMART BUILDING

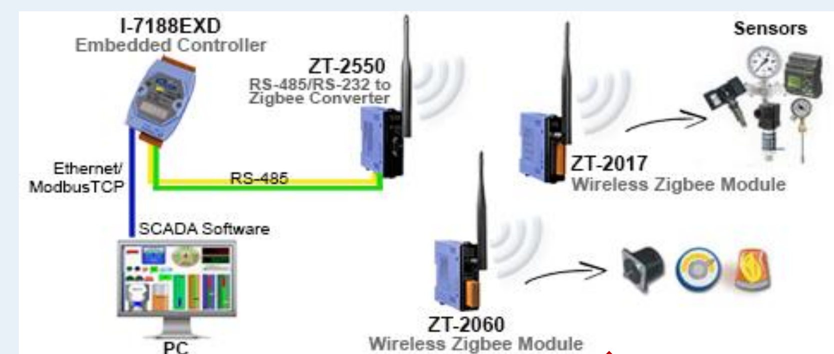
A smart system integrated in a building or home would consist of five parts that work together to generate the intelligent and efficient process that is aimed for. The first three include the sensors which gather raw data that the controllers pass to the actuators which are then responsible for carrying out the automated adjustments. The fourth part is the software involved in those adjustments that comprises the "brains" of the system, and the communication scheme that coordinates all of the separate processes makes up the fifth part.

MACHINE LEARNING

Another aspect to this intelligent network of sensors is the encoding of machine learning into the system itself. This is the process of the computers "learning" via recognizing patterns in the data they are taking in to predict outcomes through algorithms. Over time, these machines become better at this predictive ability, which in smart systems mean they will become more efficient and adapted to their setting

NETWORKS

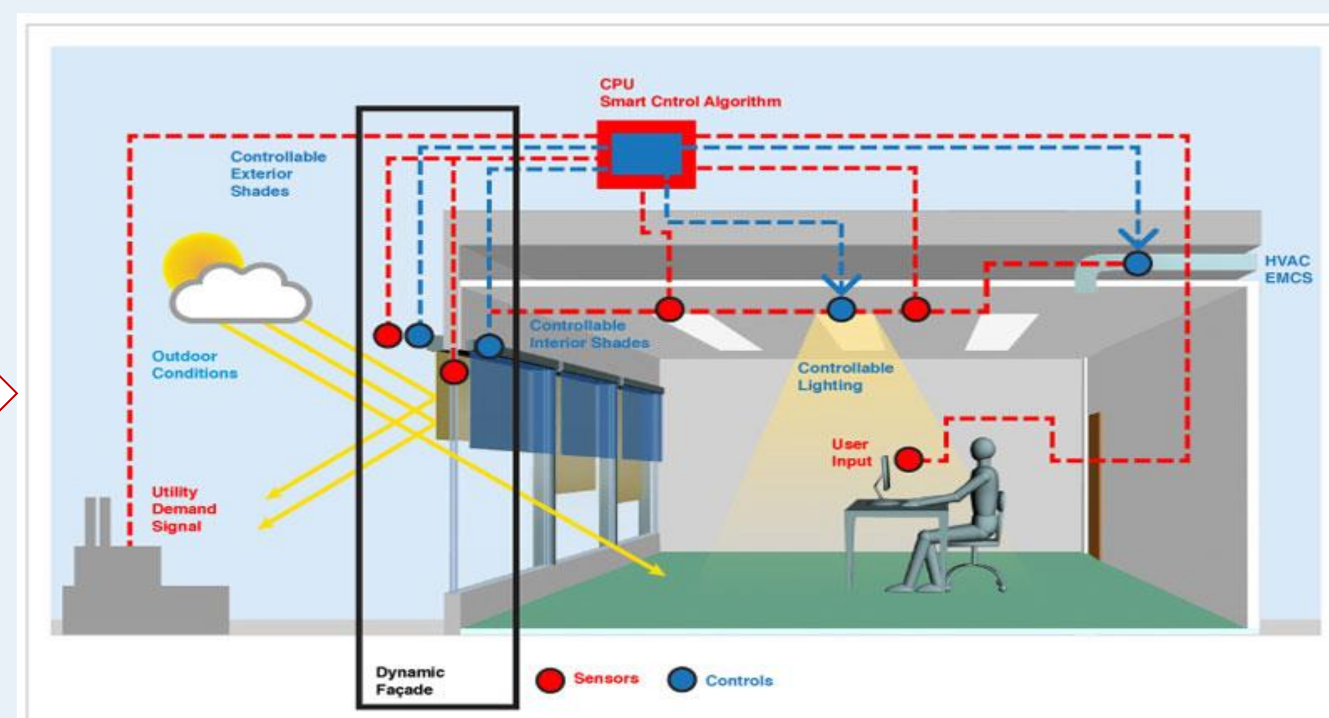
The types of networks that integrate the systems share the characteristics of being low-bandwidth, low-power, and short range. This minimizes energy use, and the data that is managed is relatively uncomplicated. ZigBee and Z-Wave networks show the most potential for applications in smart systems because of their fairly expansive range and node capabilities while also being one of the lowest in power usage. These characteristics are important for sensor technology in buildings as their effectiveness in improving efficiency can be maximized through varied and adequate sensor placement.



Simple ZigBee Model

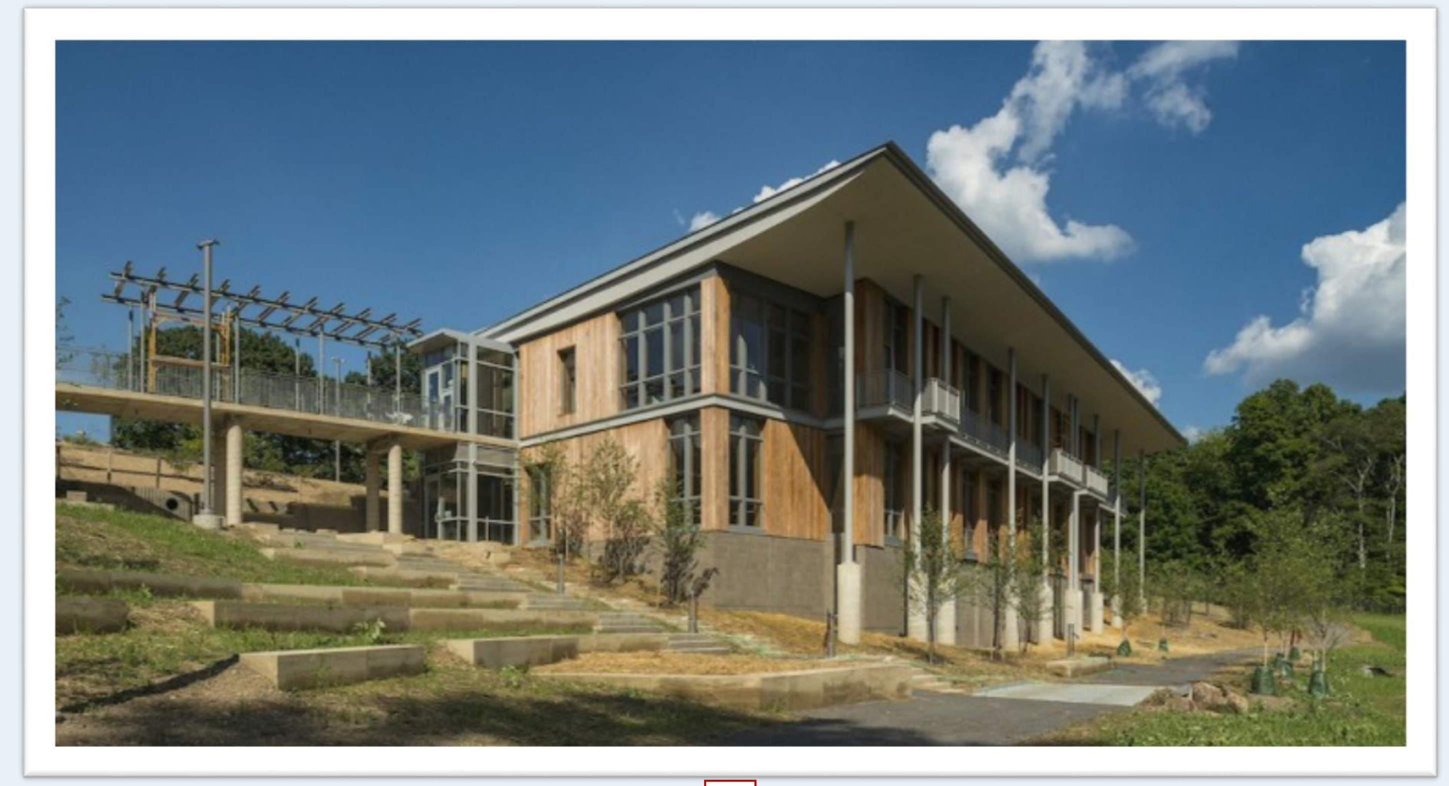
SENSORS

Sensors provide the abundance of data that can be used to increase the efficiency and comfort in a building or home, as shown in **the figure below.** Temperature, relative humidity, air quality and occupancy are among the most important measurements to be taken by sensors in a smart building. While infrared sensors are typically used for occupancy detection, Micro-Electro-Mechanical Systems (MEMS) Based Sensors are the most versatile (due to their small size, and unique integration of both mechanical and electronic components), and cost-effective sensors that can be used to make the other measurements, for use in a smart building and more specifically, its HVAC systems.



SMART BUILDINGS AROUND THE WORLD

The Edge is a smart office building in Amsterdam that was presented with the 2016 BREEAM Award for Offices New Construction. According to BREEAM, The Edge's Ethernet-powered lighting system utilizes over 30,000 sensors to continuously measure occupancy, lighting levels, humidity and temperature that permit continuous adjustment of the indoor environment. One smart building in Pittsburgh that stands out is the Frick Environmental Center (FEC). It was engineered to meet the Living Building Challenge, and is also LEED Platinum certified, the highest certification possible. The FEC is a ZEB that runs entirely off power from the sun, and utilizes geothermal wells to heat and cool the building. Along with zero-energy, it is also net zero-water building, meaning all water is collected, treated and reused or released on-site.



Comparison of energy cost between conventional building and smart building

Components	Conventional Building (C) Power (kWh)	Conventional Building (C) Energy Cost (Rp. million)	Smart Building (S) Power (kWh)	Smart Building (S) Energy Cost (Rp. million)	Energy Saving (C-S) Power (kWh)	Energy Saving (C-S) Energy Cost (Rp. million)
HVAC	736,968.96	996.38	479,520.77	648.31	257,448.19	348.07
Elevator	6,480.00	630.79	4406.40	428.94	2,073.60	201.85
Lighting	288.00	1,168.13	96.00	389.38	192.00	778.75
Security System	3,470.63	4.69	2,429.44	3.28	1,041.19	1.41
Fire Alarm System	18,020.57	24.36	12,614.40	17.05	5,406.17	7.31
Total	765,228.16	2,824.35	499,067.01	1,486.96	266,161.15	1,337.39

Note: 1 US$ = 13,400 rupiah

SUSTAINABILITY

The Benefit Cost Ratio (BcR) for the smart building was determined to be 1.99, while the traditional building was only 0.88. These ratios were determined through a comparison of the power consumption for main building components (HVAC and lighting) and their subsequent cost. It was found that the smart building required a 25% higher initial cost, but generated operational and maintenance costs about 38% lower than a conventional building over a thirty-year period as shown in the table above. Because less energy is required for operation, smart buildings contribute less to the pollution created in the energy production process. Lowering air pollution production directly improves the quality of life for everyone, since living in a cleaner world lowers the chances of developing or contracting a disease as a result of poor environmental health.