Applications of Wireless Sensor Networks (WSN) in Buildings

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Sensor Network

- A sensor network is a set of small autonomous systems, called sensor nodes which cooperate to solve at least one common application. Their tasks include some kind of perception of physical parameters (Haenselmann 2006).

Crossbow WSN OEM Design Kit
(http://www.xbow.com/Industry_solutions/BuildingAutomation.aspx)

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Characteristics of a WSN

- Ability to withstand harsh environmental conditions
- Ability to cope with node failures
- Mobility of nodes
- Dynamic network topology
- Resilient to communication failures
- Heterogeneity of nodes
- Large scale of deployment
- Unattended operation
- Limited energy they can store or harvest

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Wireless

- Data transmission is wireless
- Sensing mechanism not necessarily wireless
- Power supply not necessarily wireless

WSN Applications

- The flexibility, fault tolerance, high sensing fidelity, low-cost and rapid deployment characteristics of sensor networks create many new and exciting applications (Akyildiz *et al.* 2002).

Experimental WSN Implementations in Buildings

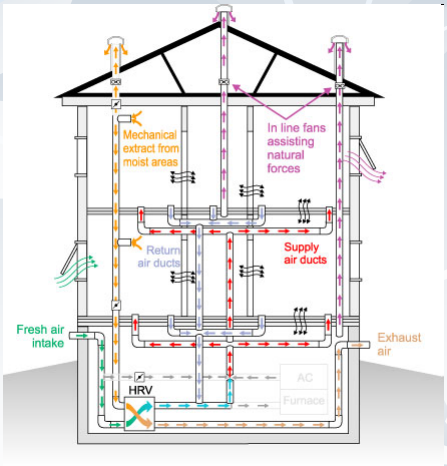
Application	Source
Energy consumption monitoring	Kappler & Riegel, 2004
Development and testing hybrid ventilation control strategies	Xu *et al*., 2007
VAV (HVAC system) control	Zheng *et al*., 2007
Lighting control	Park *et al*., 2007

Monitoring Energy Consumption in Office Buildings

- A WSN was successfully utilised to monitor energy consumption in large and dispersed office buildings (Kappler & Riegel, 2004).
- The main aim was to detect locations or devices that are consuming a lot of energy to provide indications for potential reductions in power consumption.
- Sensor nodes are connected to the power grid (at outlets or fuse boxes) to measure power consumption and for their own power supply.

Hybrid Ventilation Monitoring

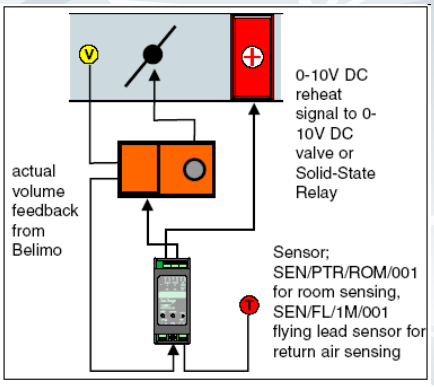
- To assist the development and testing of control strategies for hybrid ventilation systems in commercial buildings, an experimental WSN monitoring system was designed and implemented in an existing office building (Xu *et al*., 2007).



(http://irc.nrc-cnrc.gc.ca/pubs/ci/v11no4/v11no4_3_e.html)

Variable Air Volume Control

- Zheng *et al*. (2007) proposed a new control strategy combining with the WSN and the damper position based reset method for variable air volume air conditioning system, (i.e. cascade VAV optimal control strategy).



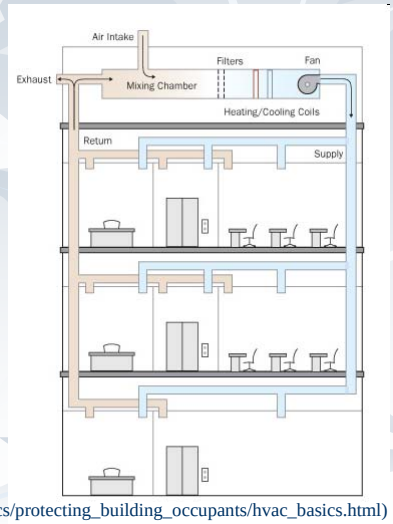
(http://www.sccontrols.co.uk/data/p/vav/vav_notes.htm)

Sensor Network-based Intelligent Light Control System

- Park *et al*. (2007) presented the design and implementation of the Illuminator, a preliminary sensor network-based intelligent light control system for entertainment and media production.
- Unlike most sensor network applications, which focus on sensing alone, a distinctive aspect of their work is that it closes the loop from light sensing to lighting control.

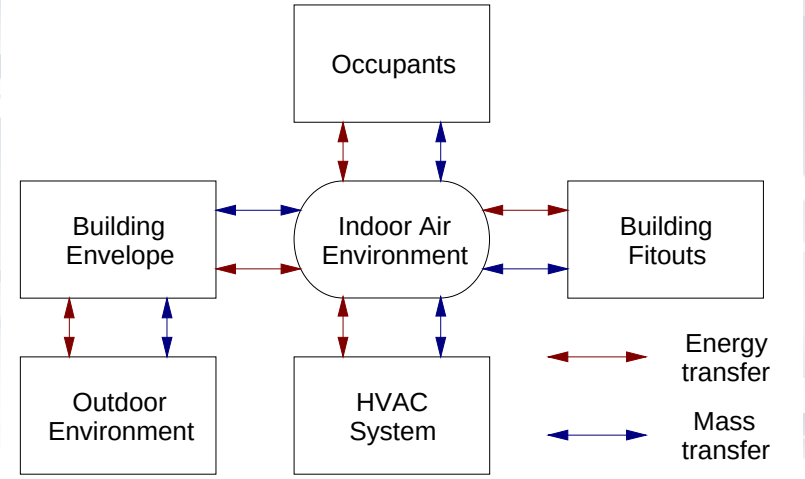
Benefits of Good Building Management and Control

- Improved work environments
- Enhanced living environments
- Reduced energy consumptions in
  - Heating
  - Cooling
  - Ventilation
  - Lighting
  - Equipment
  - Hot water



(http://www.upmc-biosecurity.org/website/special_topics/protecting_building_occupants/hvac_basics.html)

Dynamics of Indoor Environment



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BEMS

- Building Energy Management Systems aims to minimise the use of energy in buildings by maintaining at the same time the indoor environment under comfort conditions.
- BEMS have replaced hardwired controls, with control strategies implemented in software.
- Current established technology based on a wired network of sensors, actuators, controllers, and management systems.

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BEMS

BEMS control, manage and monitor the energy use in building
(http://www.learn.londonmet.ac.uk/packages/euleb/en/glossary/index17.html)

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Networking for BEMS

- Building Automation and Control Network (BACNet) uses existing computer networking standards as underlying transport (e.g. Ethernet, ARCnet, LonTalk, MS/TP (Token Passing), RS232 Serial, and also recently IP.
- It interconnects management, controller, sensor, and actuator nodes.

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BEMS Software

- Direct Digital Control (DDC) is the current major concept
  - The enthalpy program
  - The load reset program
  - The zero-energy band program
  - The time based lighting control program

BEMS Software Tools

- The enthalpy program monitors the temperature and relative humidity or dew-point of the outdoor and return air and then positions the outdoor air and return air dampers to use the air source with the lowest total heat or least enthalpy.
- The load reset program controls heating and/or cooling to maintain comfort conditions in the building while consuming a minimum amount of energy.

Contd. BEMS Software Tools

- The zero- energy band program saves energy by avoiding simultaneous heating and cooling of air delivered to spaces.
- The occupied-unoccupied lighting control is a time-based program that schedules the on/off time of lights for a building or zone to coincide with the occupancy schedules.

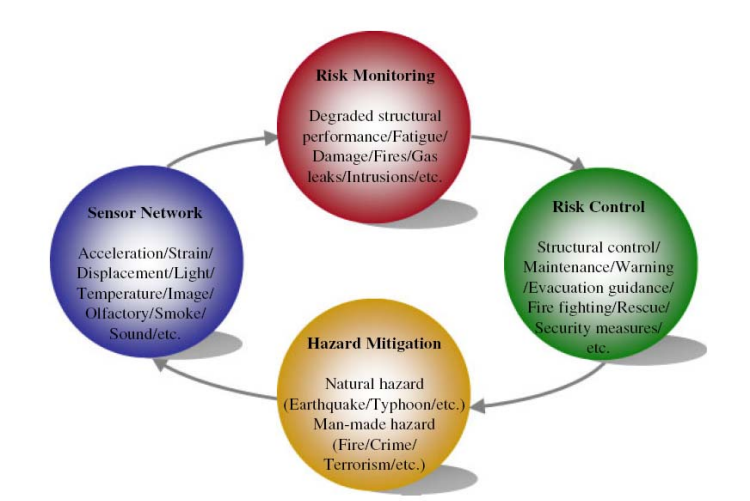
Sensor Measurements for Building Control

- Outdoor weather
  - Air temperature
  - Air relative humidity
  - Wind speed and direction
  - Solar radiation
  - Light intensity
- Indoor
  - Zone air temperatures
  - Mean radiant temperatures
  - Air relative humidities
  - Air velocities
  - Carbon dioxide level
  - Light (lux) level
- Building components
  - Windows/door (open/closed)
- Occupants
  - Occupancy meter and level
- Ventilation components
  - Extraction fan (on/off)
  - Bypass valve (open/closed)
  - Mixing valves (% mixture)
  - AHU temperatures
- Heating & cooling equip.
  - (on/off, power consumption, run hours, *etc.*)

Issues for Existing BEMS

- Largely based on wired controller, sensor and actuator nodes
- No simple retrofitting into existing buildings possible; 50% - 90% of retrofitting cost due to wiring (Pesch 2007)
- Often sensor locations cannot adapt to building reconfiguration
- WSN would be an appropriate solution

Risk Monitoring in Buildings (Source Kurata *et al*. 2005)



Possible applications relevant to hazard and the sensors in buildings

Hazard	Application	Sensor
Earth quake	Observation	Acceleration
wind	Structural control	Acceleration
	Health monitoring, damage detection	Acceleration, strain, displacement
Fire	Fire detection	Temperature, smoke, acoustic, acceleration, olfactory
Gas leak	Gas detection	Ofactory
	Alarm warning	Sound
	Evacuation control	Temperature, smoke, acoustic, olfactory, light
Crime	Surveillance	Acceleration, acoustic, light, camera
	Security alert	Sound

Source: Kurata *et al*. 2005

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