USN-based Energy Management in Building/Home Lighting Control System

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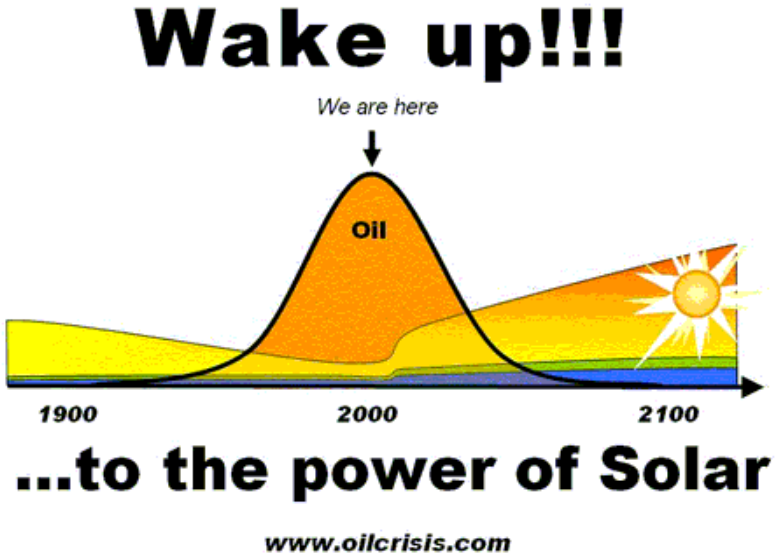
Research Motivation

- Global energy crisis.



- Two-third of electricity generated in the US is for commercial buildings; lighting consumes 40% of this .
- 45% of energy savings are possible through the use of occupant and light sensors (Yozell-Epstein, 2003).

Research Goals

- Energy management in building/home lighting control systems
  - Provide right amount of energy to the right lighting devices in the right place: demand-responsive decision-making
  - Real-time monitoring and control of energy consumption in each and every lighting devices: personalized decision-making
  - Increase energy saving by eliminating unnecessarily consumed energy loss: energy-saving decision making
- Develop a USN-based lighting control system
  - Develop USN-based sensor/controller/actuator nodes
  - Propose USN architecture and protocols for building/home lighting control systems
  - Examine the validity of USN-based lighting control system using demonstration facilities.

Key Directions of Approach

- Wireless communications
  - Ease of installation – increased sensing density
  - Maintainability – simpler retrofitting and commissioning
  - Expandability/Scalability – increased number of control points
  - Mobility – increased flexibility in operation

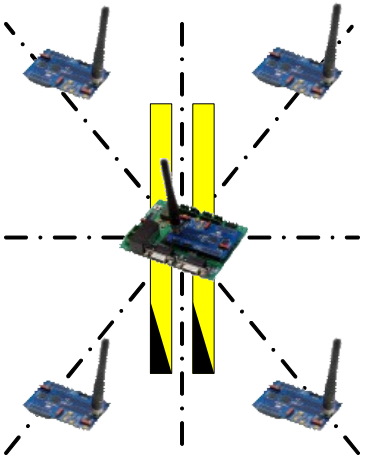
- Open/standard protocols
  - Vendor independent
  - Interoperability among different vendors
  - Flexibility and expandability in integrating building/home facilities (e.g. HVAC, lighting, fire and life safety, security, vertical transportation)

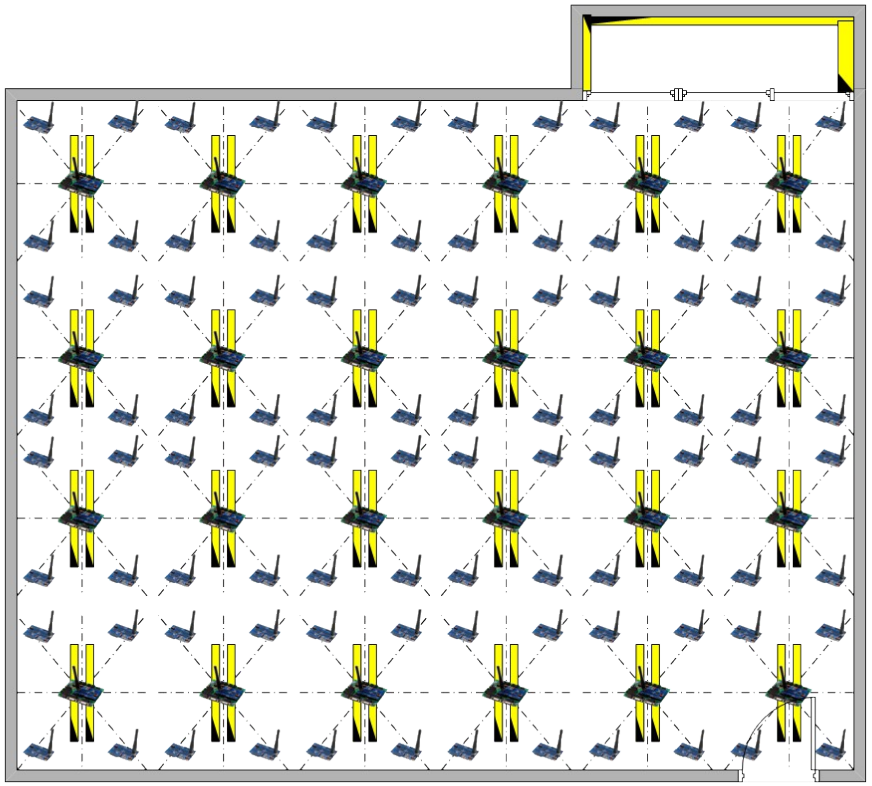
Light Control Systems in **Buildings**

- **Characteristics of building light systems**
  - Scheduled operation time with a few exceptions
  - Standardized illuminance intensities for each workspaces
- **Objectives of light control in buildings**
  - Increased user satisfaction with the system
    - Maintain target illuminance at the workspace
    - Personalized/demand-response lighting
  - Increased energy-saving
    - Maximize the utilization of daylight
    - Real-time monitoring of energy consumption at each and every lighting devices

Demonstration facility of building light control system

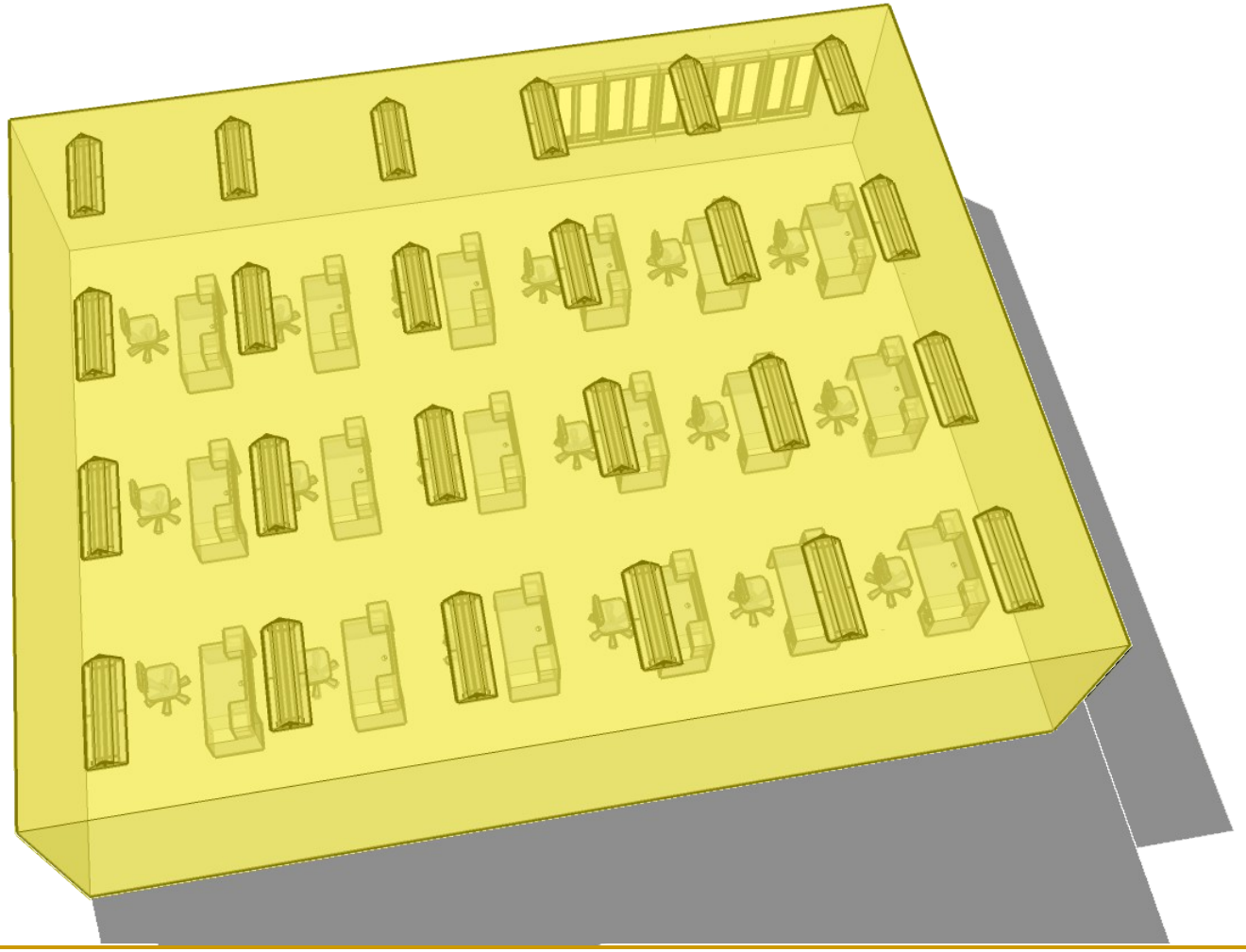
- **Location and size of demonstration space**
  - Basement of engineering building III
  - 16 m (W) x 8 m (L) x 2.55 m (H)





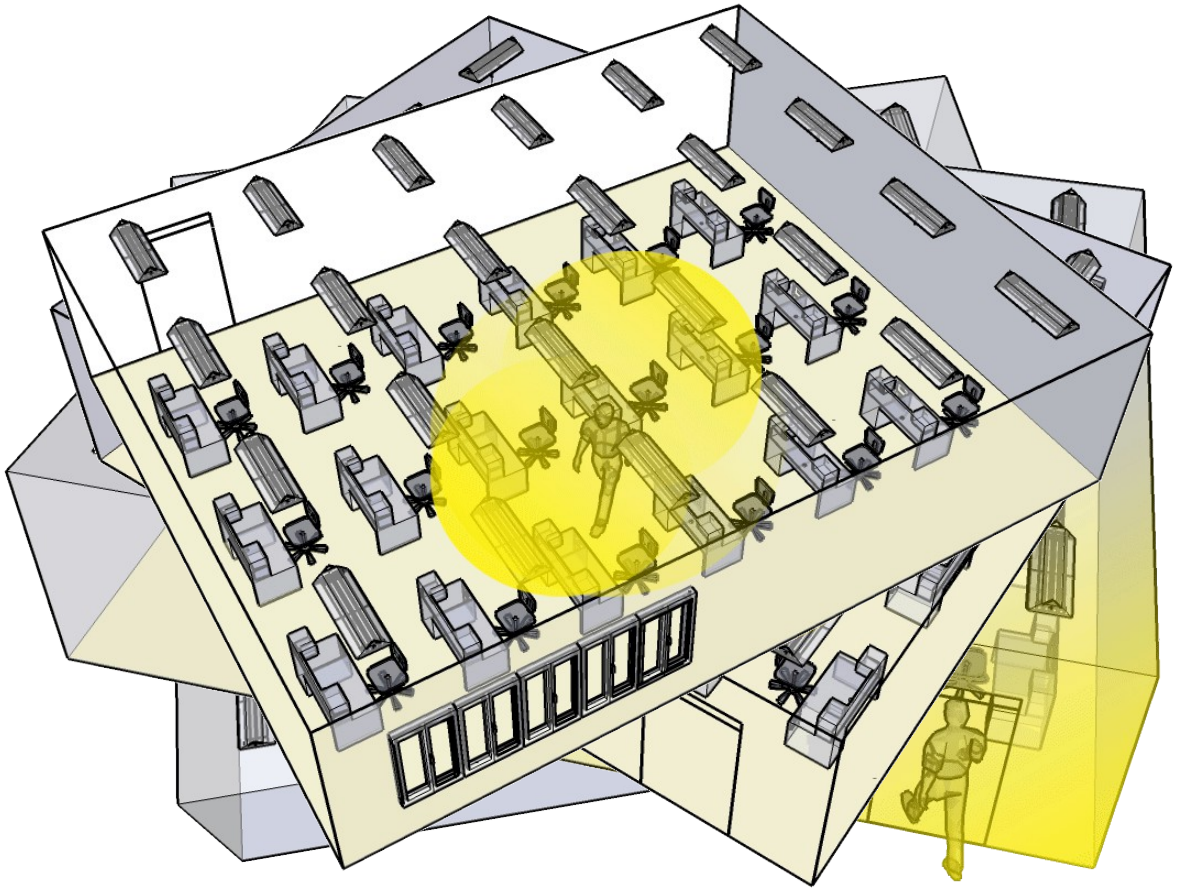
Demonstration scenario I

- Hybrid daylighting and artificial lighting system



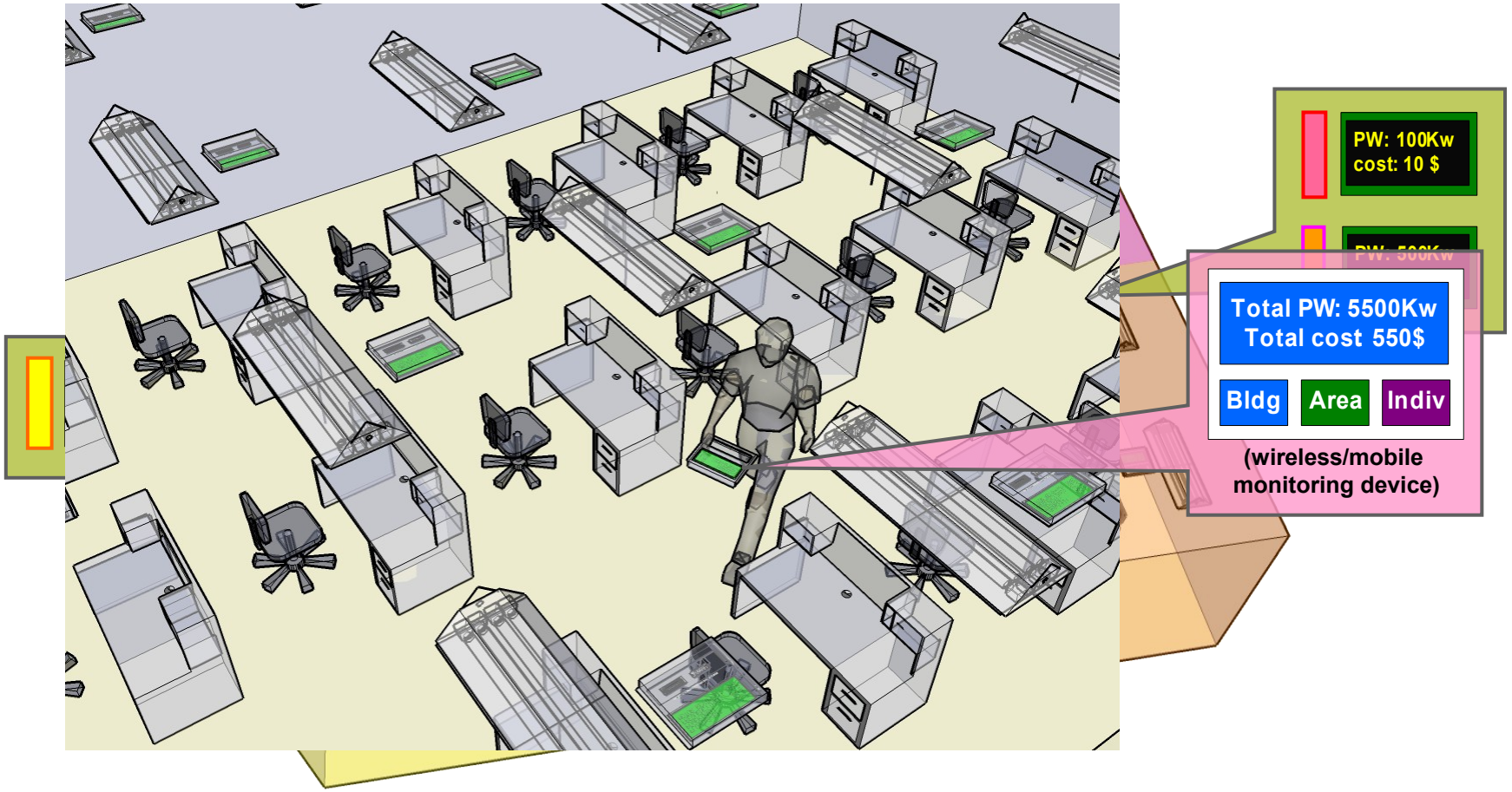
Demonstration scenario II

- Personalized/demand-responsive lighting



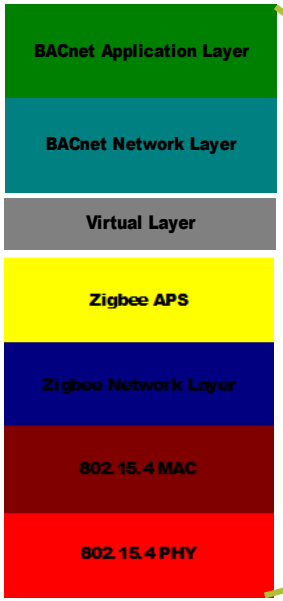
Demonstration scenario III

- Real-time measurement of energy consumption/cost at each lighting devices



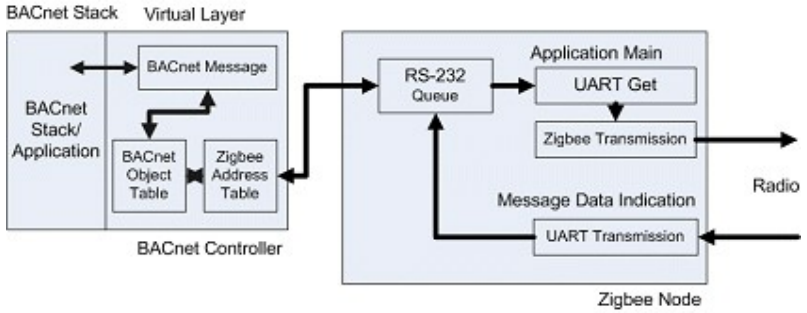
USN-based building lighting control nodes

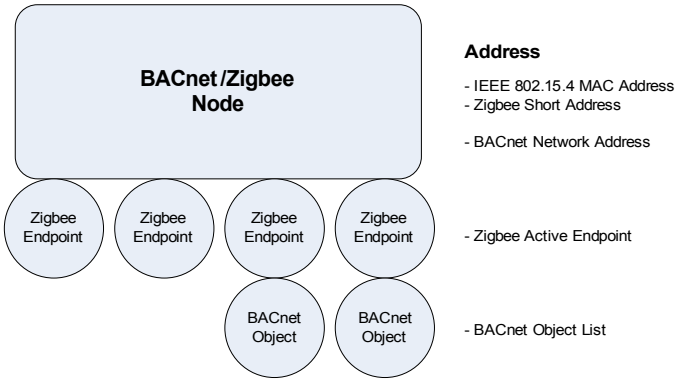
- Integrated BACnet/ZigBee system
  - Upper layer: BACnet (EN ISO 16484-5, KS X 6909)
  - Lower layer: ZigBee (IEEE 802.15.4, ZigBee alliance)
- Virtual Layer: address binding



Integrated BACnet/Zigbee Protocol stack

Integrated BACnet/ZigBee Board





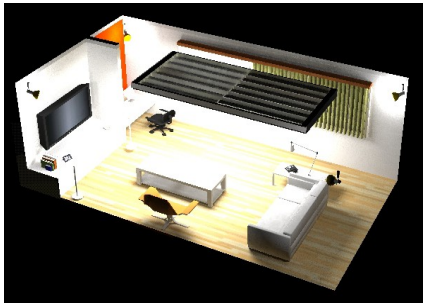
USN architecture for building lighting control

- In-network processing
  - Sensor fusion – integration of illuminance sensor, solar position trace sensor, occupatnt sensor, etc.
  - Data aggregation
- USN routing algorithm
  - Analyze routing algorithms for USN
  - Optimal routing algorithm for building lighting system
  - Simulation analysis: NS2
- Decision Making algorithm
  - FVF (Fuzzy Validation and Fusion) algorithm: UC Berkeley
  - Influence diagram modeling: UC Berkeley
  - Multi-agent system: UC Berkeley
  - Optimization theory: CMU

Light Control Systems in Homes

- **Requirements of lighting control system in home**
  - Scene control
  - Emotional light control
  - Energy efficiency

Example of scene control



Residential mode

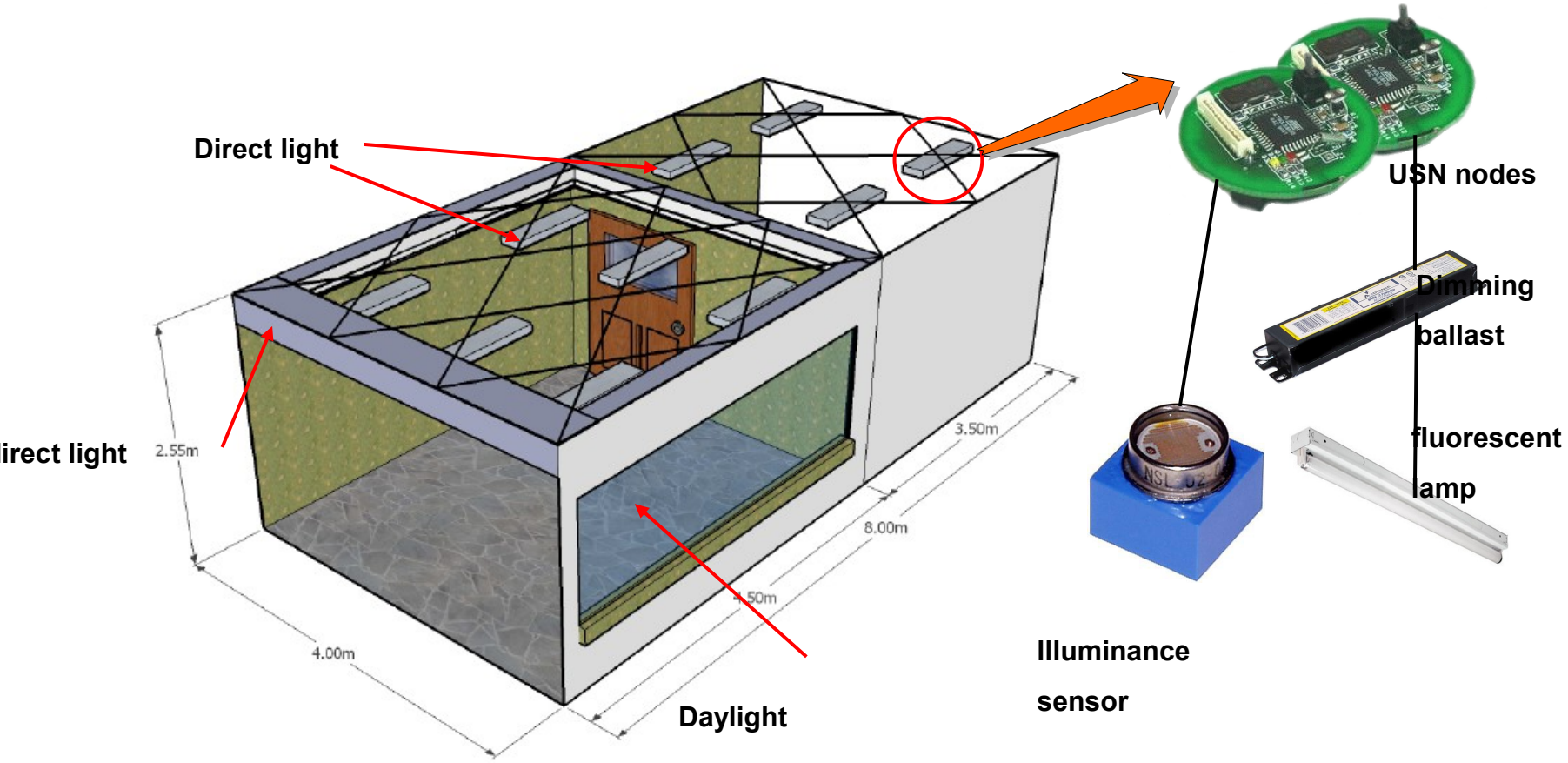
TV watching mode

mood mode

Example of emotional light control

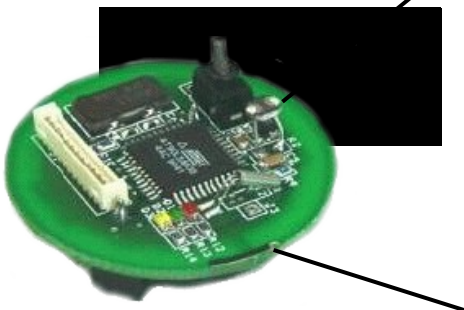
Demonstration facility of home light control system

- direct, indirect lights + daylight
- USN-based sensor, controller and actuator nodes

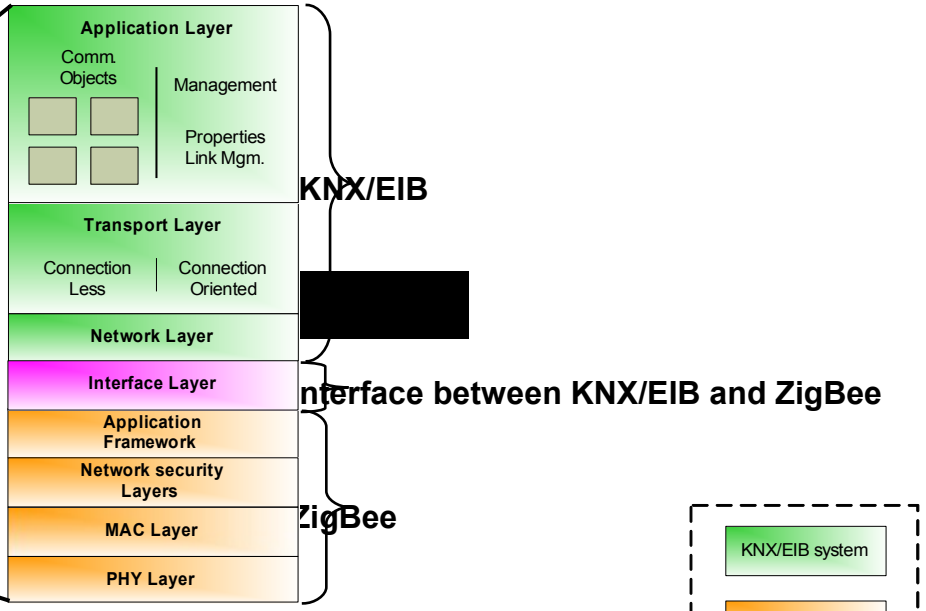


USN-based home lighting control nodes

- Integrated KNX/EIB and ZigBee system
  - Upper layer: KNX/EIB (IEC/ISO 14543)
  - Lower layer: ZigBee (IEEE 802.15.4, ZigBee alliance)
- Investigate more efficient USN protocols for home automation
- Investigate USN architecture for home lighting control: In-network processing, optimal routing algorithm, decision making algorithms



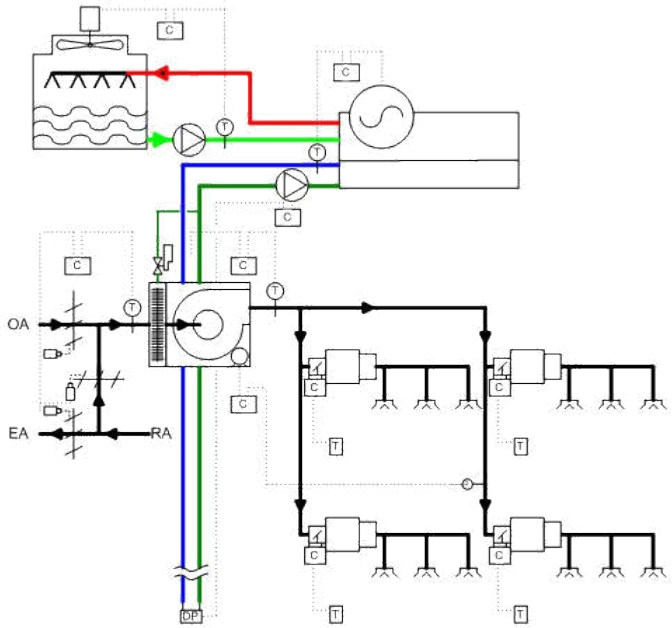
Integrated EIB/KNX and ZigBee Board



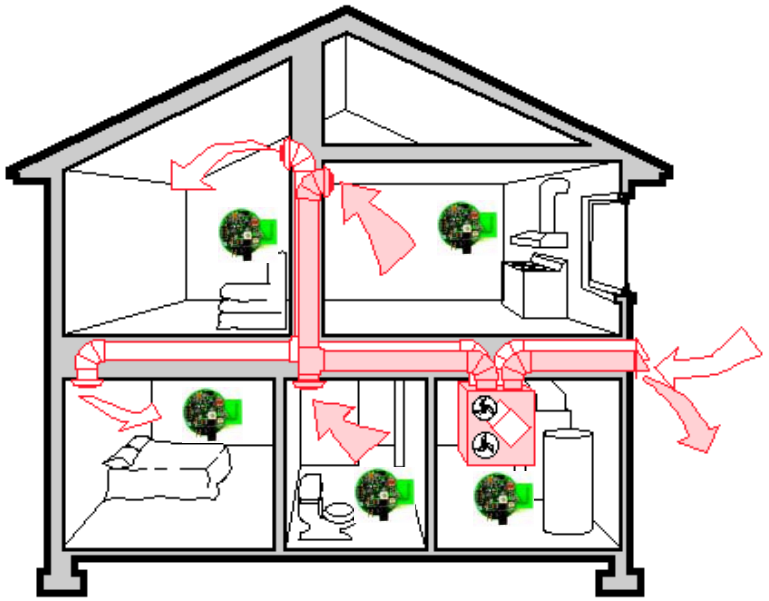
Integrated EIB/KNX and ZigBee Protocol stack

Future Works in Stage II (2009-2012)

- Expand the application scope
  - Building automation: HVAC, fire alarm, transportation etc.
  - Home automation: HVCA, security, etc.



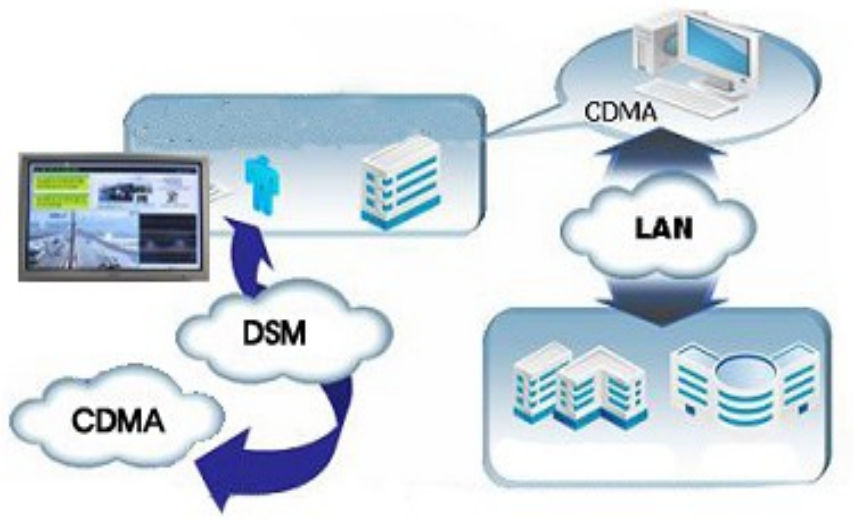
Building HVAC



Home HVAC

Future Works in Stage II (2009-2012)

- Integrate USN into wide area networks
  - Internet
  - WLAN
  - Wireless WANs: cellular and Satellite



Future Works in Stage III (2012-2015)

- Transfer the USN technologies developed during stages I & II to local/global industries
- Drive a project to develop demonstration models of USN-based building/home automations with a cooperation of industries.
- Develop new services and technologies related to USN-based building/home automations

Thank you very much for your attention !!!