Infrastructure Aided Occupancy Detection for HVAC Control

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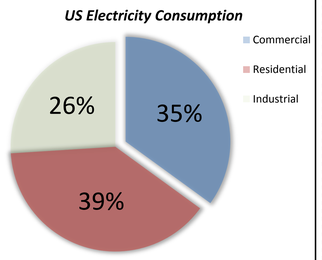
HVAC Energy Consumption

- Commercial buildings contribute:
  - 35% of electricity
  - 19% of primary energy
- HVAC systems contribute:
  - 25%-40% of electricity
  - 50% of primary energy
- Impact on:
  - Electricity bills
  - Peak load
  - Carbon emissions
  - Demand on Power Grid



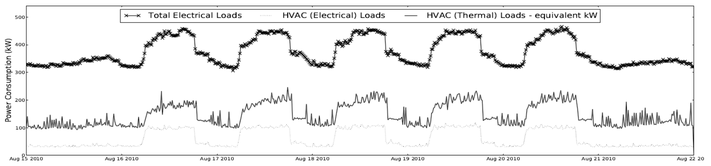
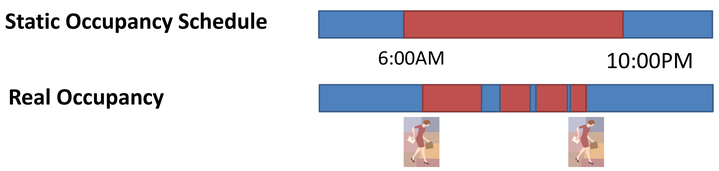


Figure 1: HVAC power consumption trends for a week at CSE building

Occupancy Based Actuation



- Modern HVAC systems provide independent control of offices
- Centralized management using BACnet protocol
- Occupancy information can be used to actuate HVAC
- Existing solution require expensive wireless sensors for occupancy detection
- Energy savings estimated to be 15% - 40%

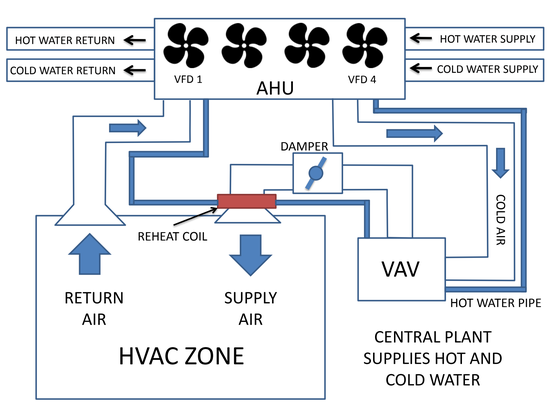


Figure 2: Overview of HVAC system working

WiFi Infrastructure Sensing

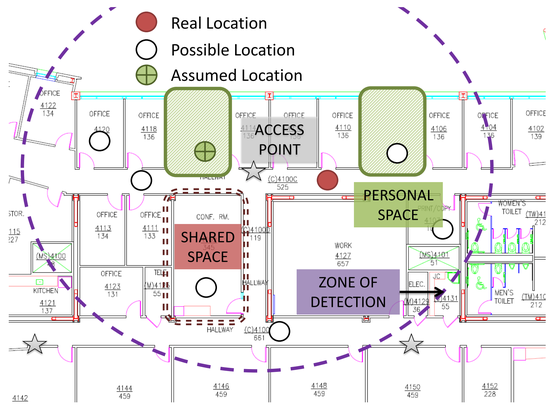


Figure 3: Occupancy inference using WiFi connectivity of employee smartphone

- Use WiFi connectivity for inference of occupancy
- Authentication, Authorization and Accounting (AAA) logs used for connectivity information
- Reduce inaccuracy in inference using known occupant information:
  - Username from AAA logs
  - MAC address from AAA logs
  - Office location from HR manager
  - AP location from network administrator
- Occupancy inference only for personal spaces

- **Occupant Requirements**:
  - Office space allocated within building
  - Continuous connectivity with WiFi network
  - Use of thermostat input as failsafe mechanism

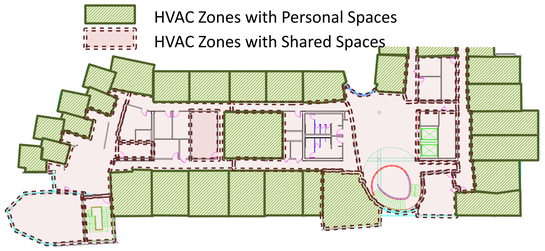


Figure 4: Partitioning of building into personal and shared spaces

- **Smartphone Requirements**:
  - Change Android and Windows Phone settings to be always connected to WiFi
  - iOS devices fetch emails every 15 mins to keep WiFi connection alive

System Architecture

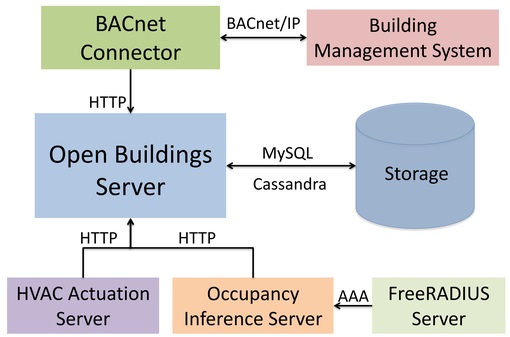


Figure 5: Overview of System Architecture

- **Open Building Server (OBS)**
  - RESTful web service
  - Data & User management
  - Access control of sensors
  - Scalable to other buildings
- **BACnet Connector**
  - Converts JSON to BACnet messages
  - Posts sensor data to OBS periodically
  - Controls HVAC on OBS input
- **Occupancy Inference Server (OIS)**
  - Processes AAA logs from FreeRADIUS Server
  - Infers occupancy of HVAC zone to OBS
- **HVAC Actuation Server (HAS)**
  - Sends HVAC control commands to OBS

Results

- 86% accuracy in occupancy inference
- 6.2% false negative errors
- Majority of errors caused due to iOS WiFi implementation
- Mitigation of errors using an app on the smartphones

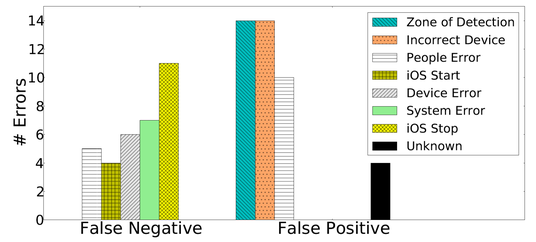


Figure 6: Distribution of errors in occupancy detection across 436 verified events

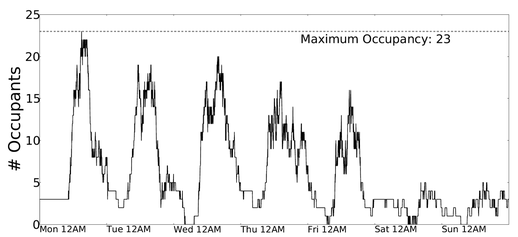


Figure 7: Occupancy trends across a week for 38 occupants who always use WiFi

- Occupancy trends indicate significant opportunities to save energy
- Maximum occupancy of 23 out of 38 users
- Comfort provided to occupants who stay late at work

- Control of HVAC based on occupancy information for one day
- 116 occupants, 55 HVAC zones controlled
- 17.8% electrical energy savings observed compared to static control
- Energy savings vary depending on actual occupancy of building

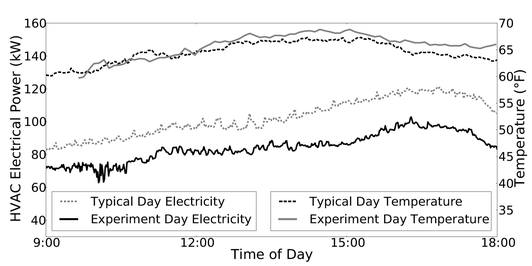


Figure 8: Comparison of electricity consumption of static and occupancy based control of HVAC system for a day