

Fault Analysis Engine for HVAC systems in Commercial Buildings

Hidetoshi Teraoka, Bharathan Balaji, Rizhen Zhang, Yuvraj Agarwal
CSE Department, University of California, San Diego

HVAC Maintenance

HVAC systems contribute:

- 25%-40% of electricity
- 40%-55% of primary energy

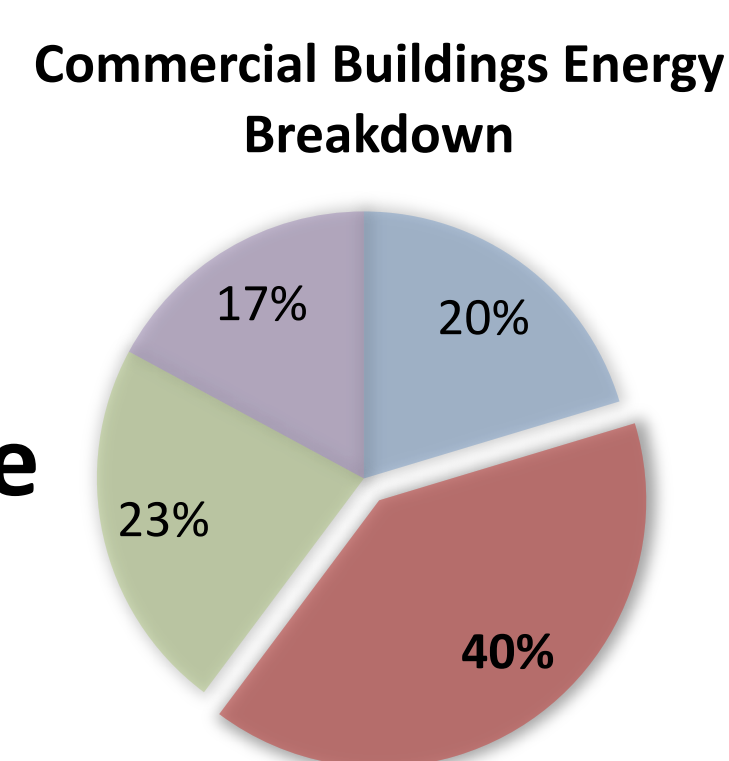
Faulty equipment and out of tune system leads to:

- Energy wastage
- Occupant discomfort

Proper maintenance saves 10%-25% of HVAC energy

Modern fault management systems:

- Are elementary, do not prioritize faults
- Require significant manual analysis
- Not intuitive nor accessible



BuildingSherlock: Faults Dashboard

Faults analysis:

- List of faults using data driven analysis
- Possibility score for a fault across different detection algorithms
- Energy wastage estimate for each fault
- Filter faults by category and prioritize faults
- Analyze each fault using historical data

Subsystem overview:

- Visualization of subsystems with detailed sensor data
- Single click shows equipment details
- Historical trends for each sensor point
- Faults for specific part of the subsystem highlighted



| Cooling System | Heating System | Machine Room |
|----------------------------|----------------------------|----------------------------|
| Faults(Major): 0 | Faults(Major): 0 | Alarm(Major): 0 |
| Faults(Minor): 0 | Faults(Minor): 0 | Alarm(Minor): 1 |
| Electrical Power: 34.1 kW | Electrical Power: 0 kW | Electrical Power: 21.3 kW |
| Cooling Power: 0.5 MBTU/hr | Heating Power: 0.2 MBTU/hr | Cooling Power: 0.4 MBTU/hr |

| Basement | 1st Floor | 2nd Floor |
|-----------------------------|----------------------------|-----------------------------|
| Faults(Major): 1 | Faults(Major): 0 | Faults(Major): 0 |
| Faults(Minor): 0 | Faults(Minor): 0 | Faults(Minor): 0 |
| Electrical Power: 24.9 kW | Electrical Power: 1.8 kW | Electrical Power: 2 kW |
| Cooling Power: 77.1 MBTU/hr | Cooling Power: 6.7 MBTU/hr | Cooling Power: 29.3 MBTU/hr |
| Heating Power: 0 MBTU/hr | Heating Power: 4.2 MBTU/hr | Heating Power: 5.6 MBTU/hr |

| 3th Floor | 4th Floor |
|-----------------------------|-----------------------------|
| Faults(Major): 0 | Faults(Major): 0 |
| Faults(Minor): 2 | Faults(Minor): 2 |
| Electrical Power: 2.3 kW | Electrical Power: 5 kW |
| Cooling Power: 38.2 MBTU/hr | Cooling Power: 24.6 MBTU/hr |
| Heating Power: 0.8 MBTU/hr | Heating Power: 1.7 MBTU/hr |

HVAC Faults Overview

Fault overview:

- Overview of major subsystems in the building
- Breakdown of power by end use
- Highlight major and minor faults
- Single click shows details of subsystem

UCSD-Main-EBU3B-F1r-2-Rm-2150-Zone Temperature:PresentValue



Historical Analysis of Sensor Data

Fault algorithms management:

- List of algorithms currently enabled with adjustable threshold
- Fault algorithms flag a group of possible faults based on failure symptom detected
- Detailed analysis of each fault by analyzing corresponding sensor data
- Algorithms which report false faults punished

Faults Analysis

Modern buildings centralized management system for HVAC operation and maintenance:

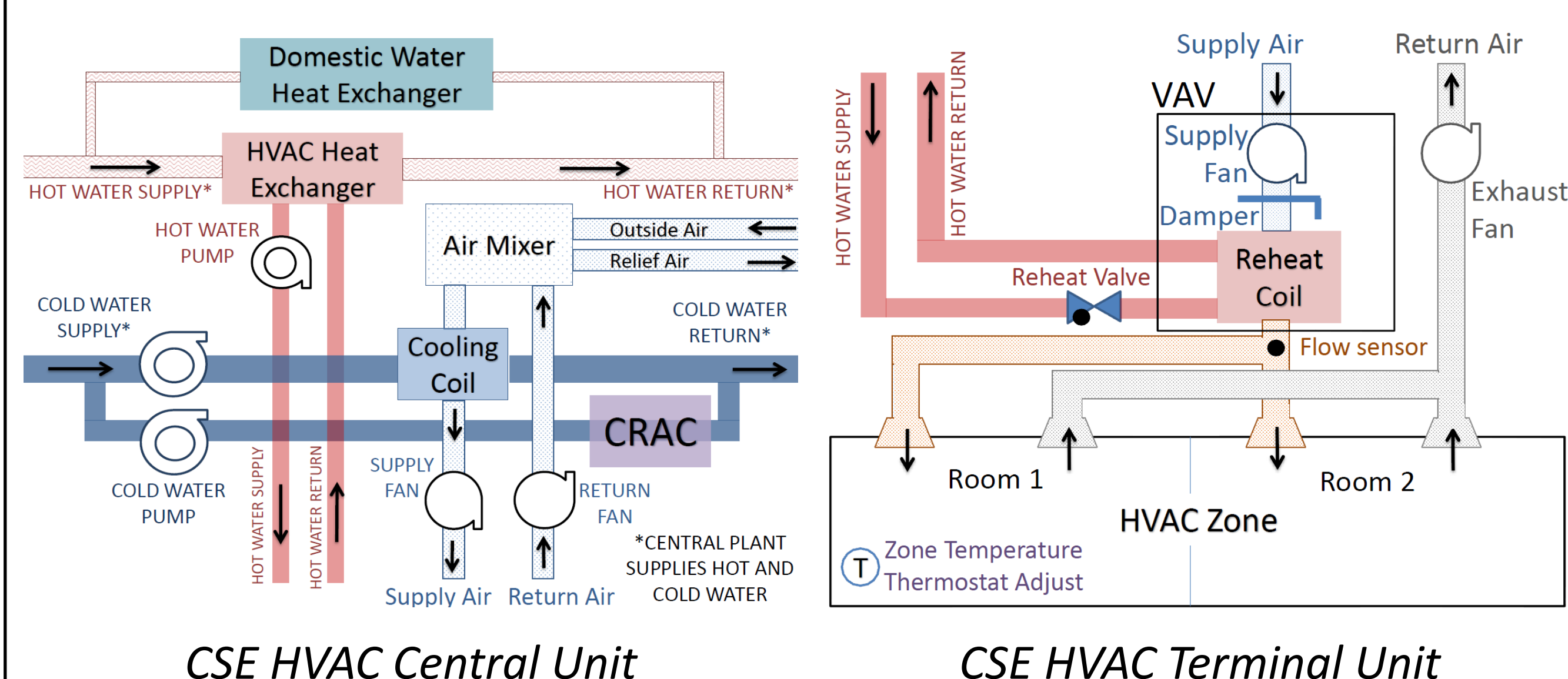
- Thousands of sensors for monitoring and control
- Standardized network protocol – BACnet
- Can be leveraged for data driven faults analysis

Fault detection algorithms already exist:

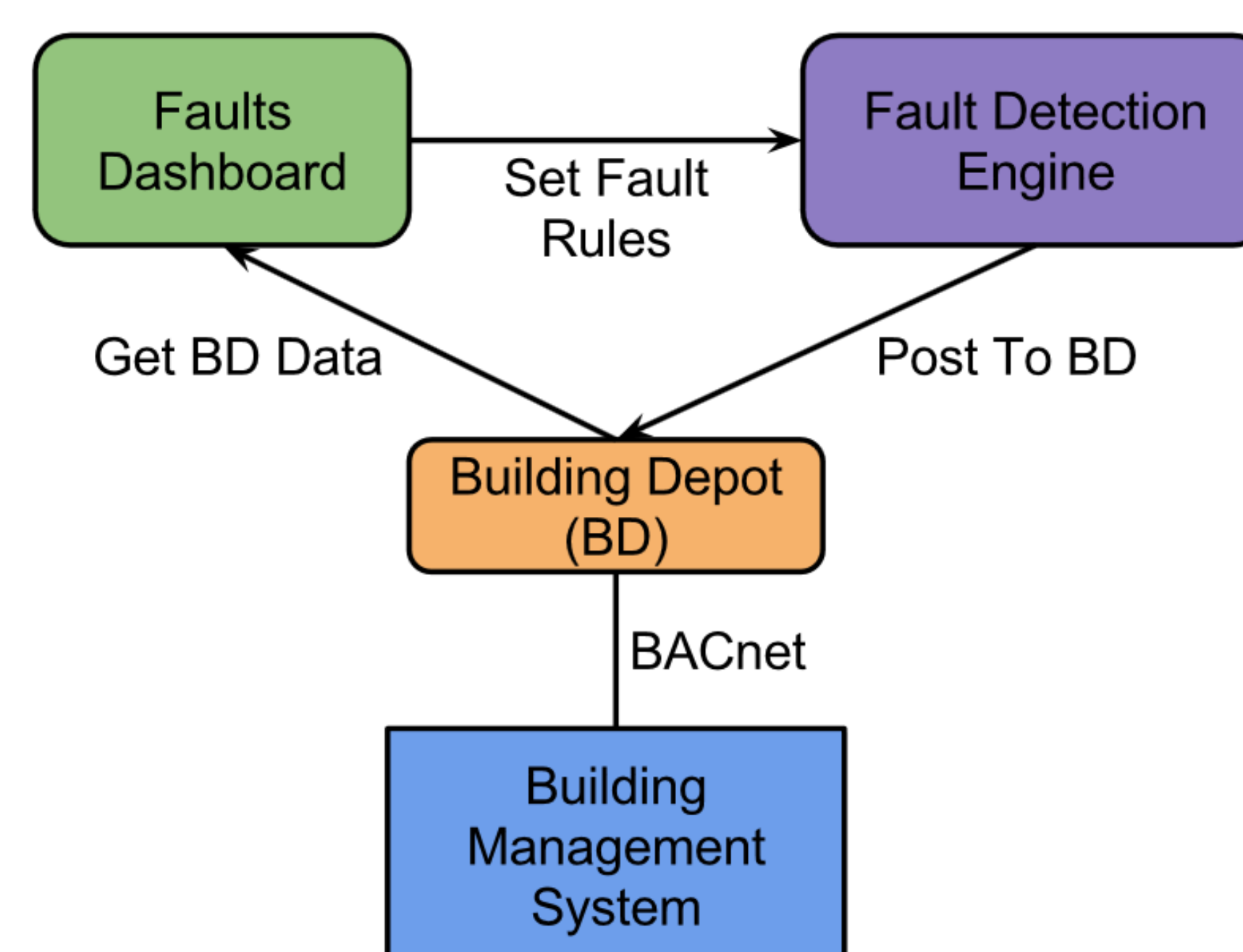
- Rule-based analysis based on HVAC configuration
- Machine learning based black box anomaly analysis

Requirements for assisting building manager:

- Faults dashboard for overview of HVAC condition
- Priority list of faults detected using algorithms
- Tools for manual analysis of faults detected



System Architecture



System Architecture of BuildingSherlock. The system is designed as a RESTful web service for ease of access, application development and scalability

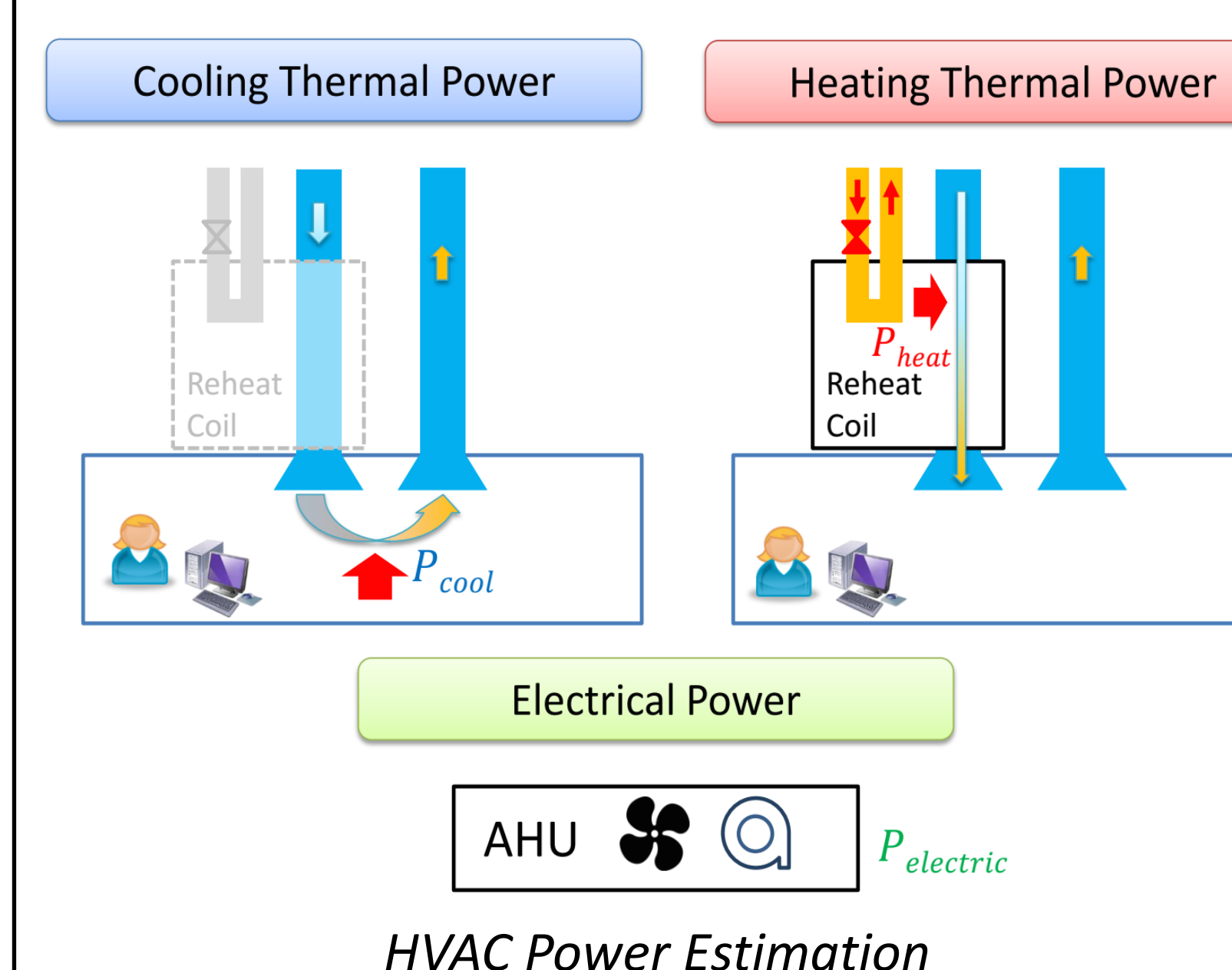
Building Depot (BD):

- Datastore for building sensors
- HTTP RESTful APIs
- Data and user management
- Access control and sensor groups
- Scalable to other buildings

Fault detection engine:

- Faults registration APIs
- Faults reporting with relevant sensor data
- Algorithms report faults with confidence score
- Weights allotted to algorithms as per success rate

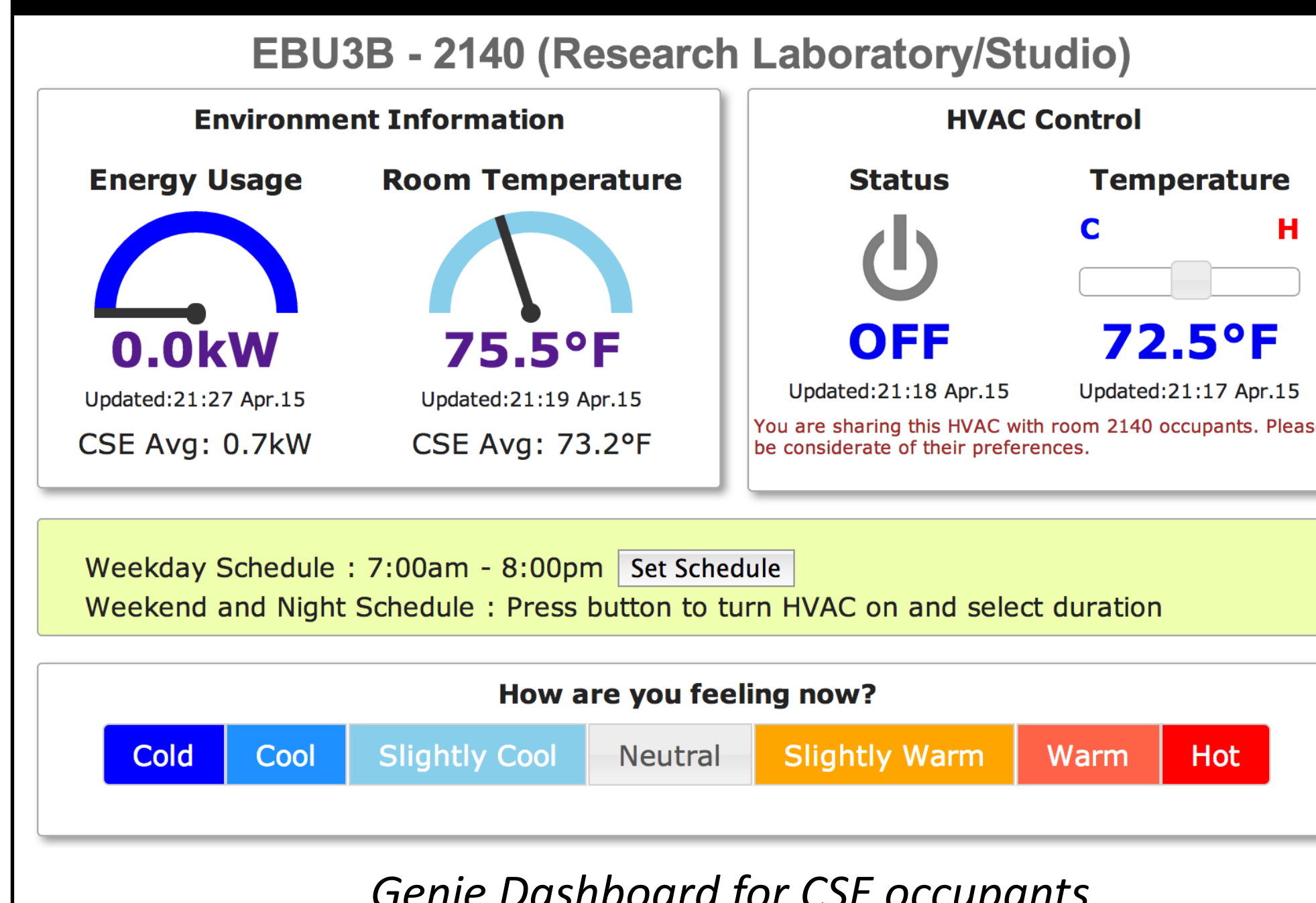
HVAC Zone Power Estimation



Zone power estimation benefits:

- Faults analysis based on end use energy breakdown
- Quantifies savings due to fault repair
- Energy feedback to both facilities and occupants
- ❖ **Cooling thermal power:**
 - Heat transfer equation – uses room temperature, outside temperature and airflow sensors
- ❖ **Heating power:**
 - Reheat valve analysis – uses valve control sensor
- ❖ **Electrical power:**
 - Proportional to cubic of fan speed. Uses airflow sensor
- ❖ **It will provide:**
 - Feedback on e energy savings and wastage
 - A single parameter to analyze faults
 - Feedback to building managers and occupants

Genie: Occupant Dashboard



Current HVAC status:

- Room temperature
- Estimated power usage, average CSE usage
- Current HVAC settings and schedule
- Historical trends of each sensor point
- Tips to view Genie and save energy

Control of HVAC:

- Turn On/Off the HVAC system at zone level
- Change temperature within 6F band
- Thermal feedback (too hot or too cold)
- Send complaint to building manager
- Set personalized schedule