BEARS | SinBerBEST

Architecture for Dense State Estimation of Buildings

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Motivation

- Buildings are not currently analyzed as a complete system.
- Dense sensing is needed to understand, model and optimize the building as a proper cyber-physical system.
- Monitoring of human activity is essential to understanding the 'demand' of operations.
- Potentially tremendous improvements in energy savings, efficiency and occupant comfort await.

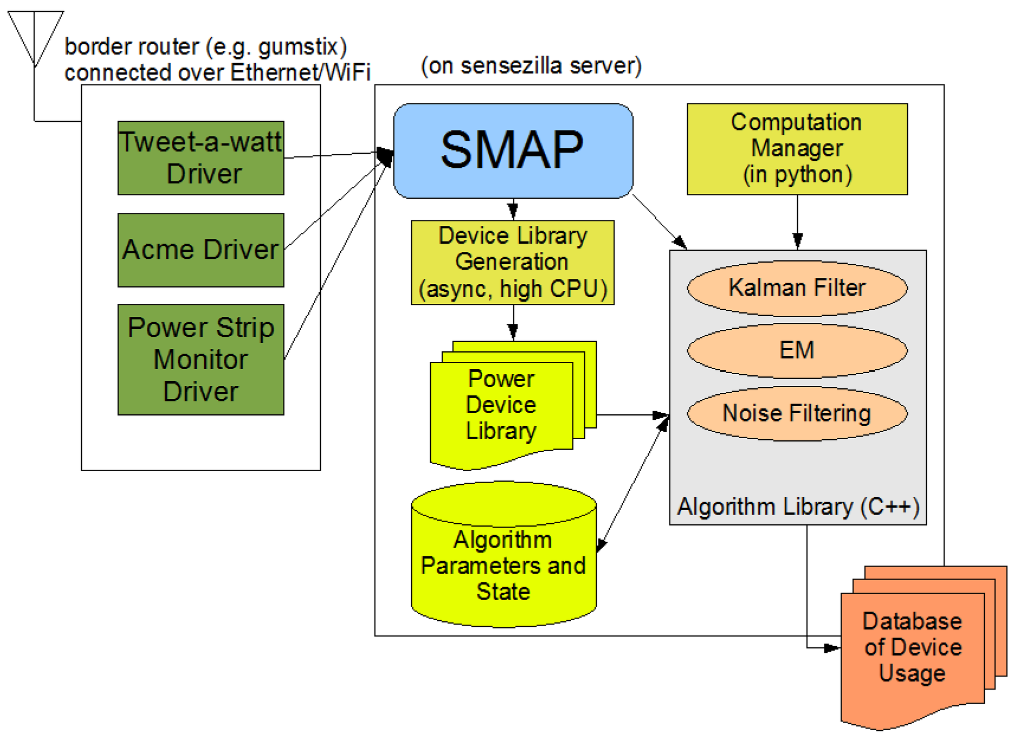
2012 Main Objectives

- Design a modular and high-reliability server to accept and process sensor data.
- Using power monitoring as a motivating example, demonstrate autonomous processing of the incoming data into a digestible form.
- Demonstrate novel visualization methods giving building managers the tools they need to check on the building.

The Problem

- Integration is fundamental to the project:
- Physical world ↔ Digital world
- Sensor hardware ↔ High-performance computers
- Real-time reliable software ↔ Cutting-edge theory
- Scientific advancement and quality engineering are both essential to success of the project.

System Design (Power Monitoring)



Key Technologies

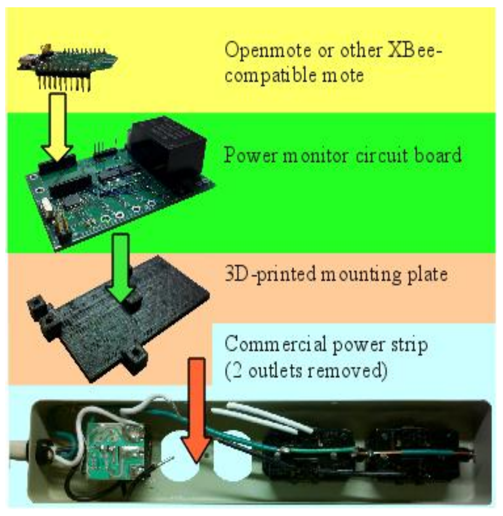
Sensing
Environmental and Participatory

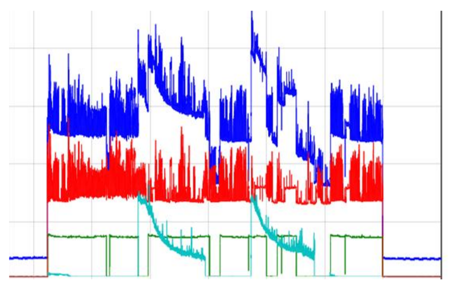
Communication
802.15.4, WiFi, RFID and Wired

Analysis
Inverse modeling and visualization

Sensing: Device-Level Power

- Find electrical energy that is being used unnecessarily.
- Device usage is a proxy for occupancy.

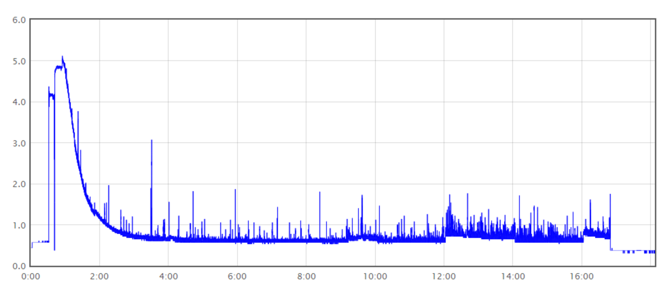


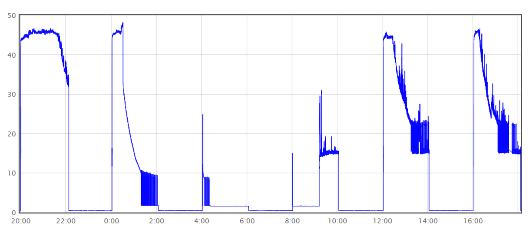


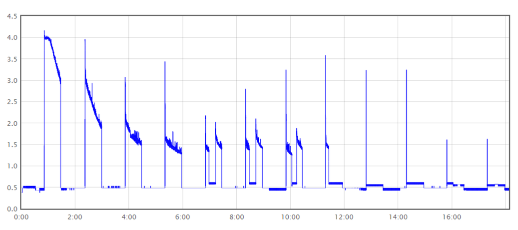
Blue: Total Power Use
Red: PC Power Use
Cyan: Laptop Power Use
Green: Monitor Power Use

Sensing: Power measurement results

- Automatically measure charging curves of devices using instrumented power strip and mechanical timers.



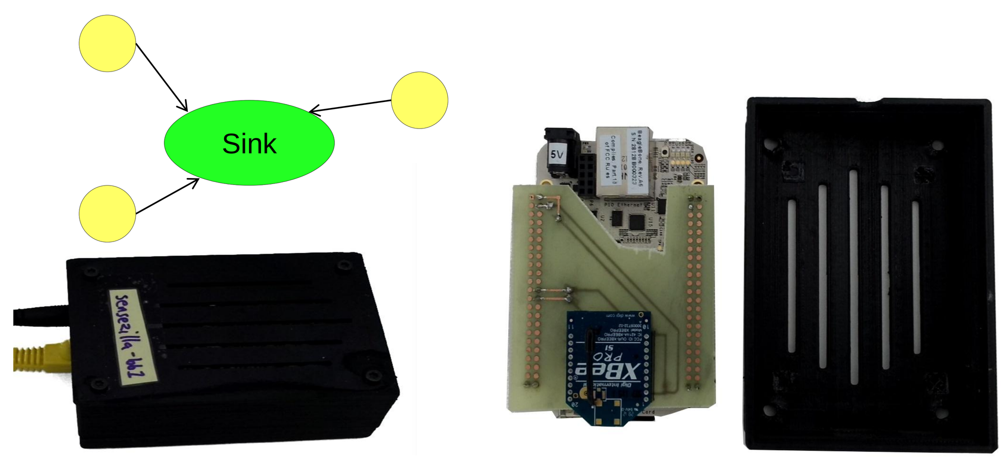




Top: Macbook charging. Bottom Left: IBM Thinkpad charging w/ 4hr cycle, 50% duty cycle. Bottom Right: Android phone charging w/ 1.5hr cycle, 33% duty cycle.

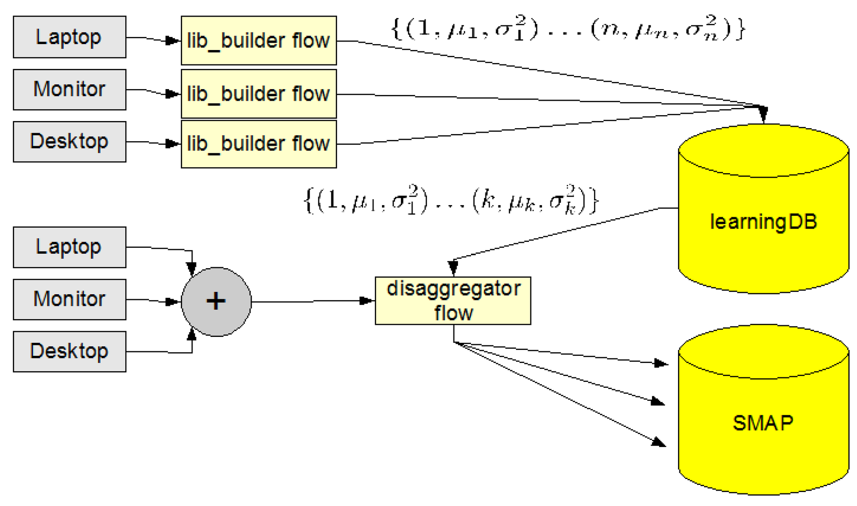
Communication: 802.15.4

- Low-power interoperable wireless backbone.
- Sink nodes collect data from neighboring sensor nodes and forward to internet server.
- XBee compatible sockets for other wireless hardware (e.g. ZigBee, TinyOS or WiFi)



Analysis: Real-time Device Disaggregation Design

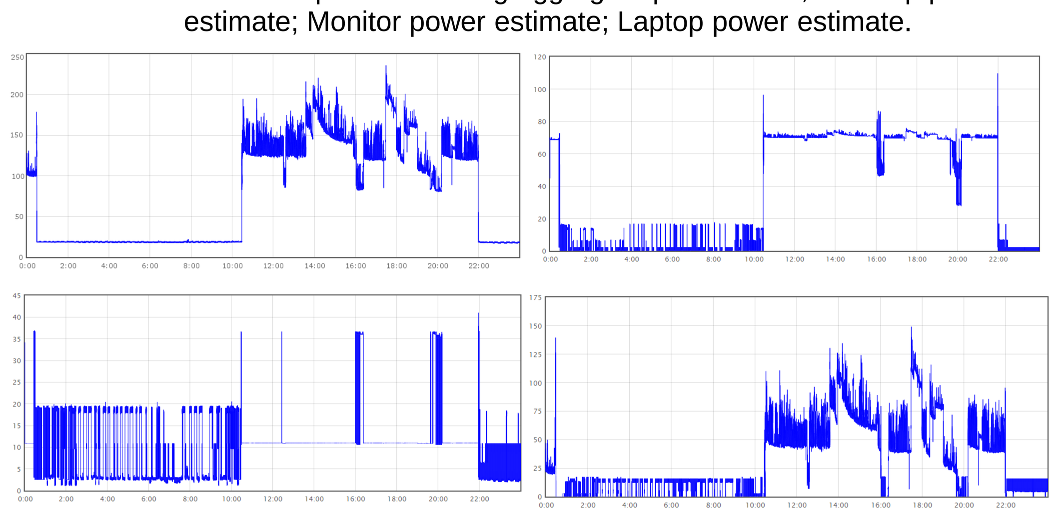
- Measure individual device parameters from learning nodes and store in database.
- Compute state and power use estimates from aggregate feeds.



Analysis: Device disaggregation results

- Using Hidden Markov Model with Gaussian Emissions to compute ML state estimate.
- Compute ML power use given state estimate.

Clockwise from top-left: Incoming aggregate power trace; Desktop power estimate; Monitor power estimate; Laptop power estimate.



Summary

- Developed preliminary implementation of key technologies: Sensing, Communication, and Analysis in the context of device power monitoring.
- Modular server architecture allows "plugging in" of algorithms as they become available.
- Ready to accept other types of time-series data, e.g. Temperature, Occupancy, light-level, etc..
- Efficient implementation runs at 79000 times real-time for a single stream.

Future Goals

- Accept non-time-series and structured data, such as keycard reader logs.
- Develop modular architecture for organizing and controlling of building actuators.
- Integrate system with other researchers' architectures and unify metadata strategy.