Research in Energy Sustainability at IIIT Delhi

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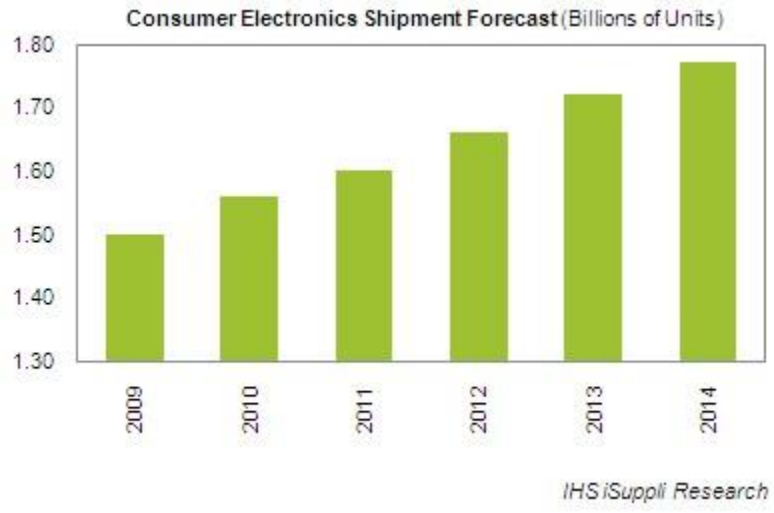
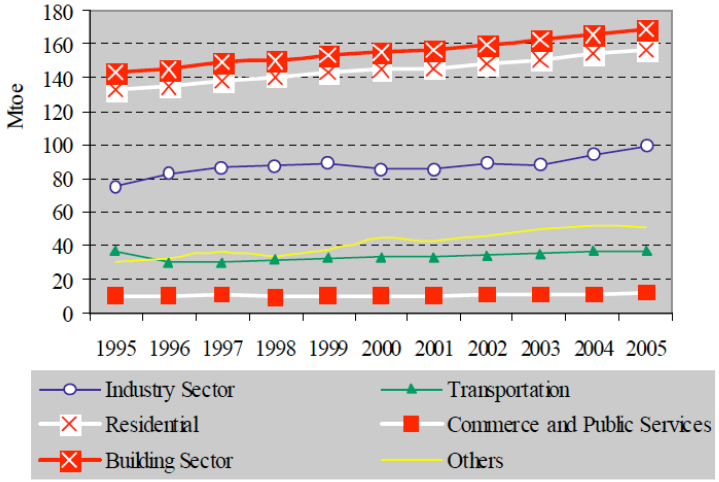
INDRAPRASTHA INSTITUTE *of*
INFORMATION TECHNOLOGY
DELHI

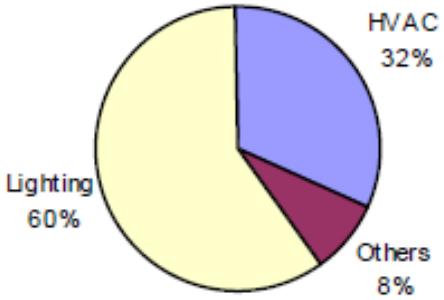
Motivation

- Growth in consumer electronics market comes with indirect demand in electricity



- Buildings (accounting for 40% in US and 47% in India) are the largest consumers of national energy use
  - Lighting and HVACs consume the most within the buildings





Annual Electricity Consumption in Indian Buildings - (CMIE 2001)

Motivation (contd.)

- Approximately 22 and 19 million m^2 are added for commercial and residential buildings respectively every year [Eva09]
- Modest savings will yield to significant aggregate impact at national scale
- Up to 5-15% saving just from using energy usage feedback systems [Dar08]
  - Increase in electricity tariffs implies corresponding saving for the end user
- Existing building infrastructure
  - Inadequate detail information about energy usage
  - No smart actuation

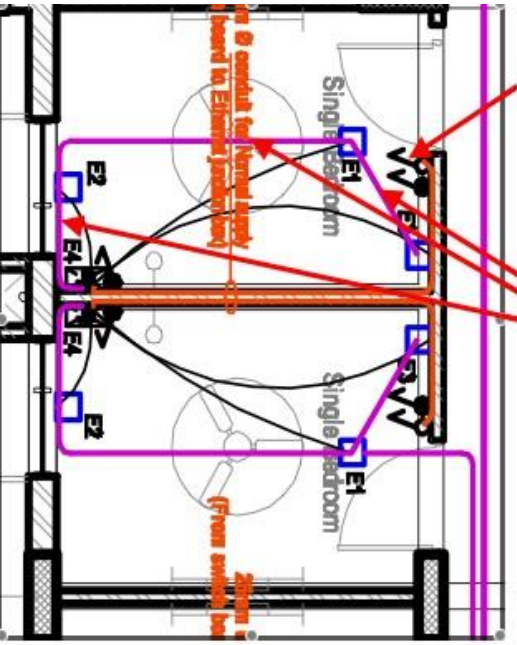
Energy Sustainability at IIITD - Overview

- Sensing Instrumentation
  - IIIT Delhi campus for energy, water and other physical parameters
  - Home for energy
- Server side system - SensorAct
  - Enabling privacy aware sharing of data
  - Allow users to submit automated tasks to the system
- Some preliminary analysis
  - Sensing interfaces
  - Indian scenario
- Project Ideas for the course

Sensing Infrastructure at IIIT Delhi

- New campus already instrumented with:
  - Smart Electricity (>50) and Water (>40 - planned) meters across the campus
    - High resolution monitoring feasible with such smart meters
  - Commercial BMS for HVAC and fire supporting BACnet
  - On campus Sewage Treatment Plant (Outputs: recycled water)
  - Separate lines in each building (6) for hot, cold, recycled and drinking water (each monitored for their consumption)
  - Solar based water heating with backup Gas based heating (all monitored for efficiency)
  - Conduits and Junction Boxes across more than 400 dorm rooms to support wired sensing infrastructure
  - All labs with centrally monitored access control system

Planned Infrastructure in Hostels



Switches in the room - Connected by conduit to E4

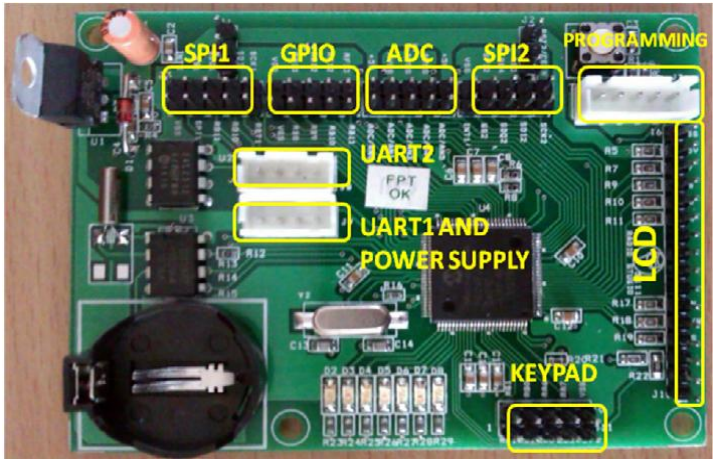
E1, E2, E3 junction boxes connected by conduit to E4

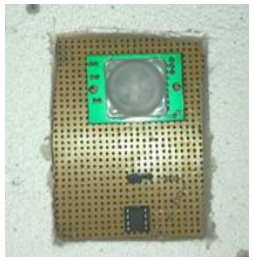
E4 and a power socket nearby connected by conduit as well

E4 has ethernet cable coming in from the switch situated on each floor

- Junction box E4 will contain the sensing system for data aggregation
  - Ability to internally access any other junction box in the room (used for both power as well as sensing)
- Built into construction in two buildings for more than 400 rooms

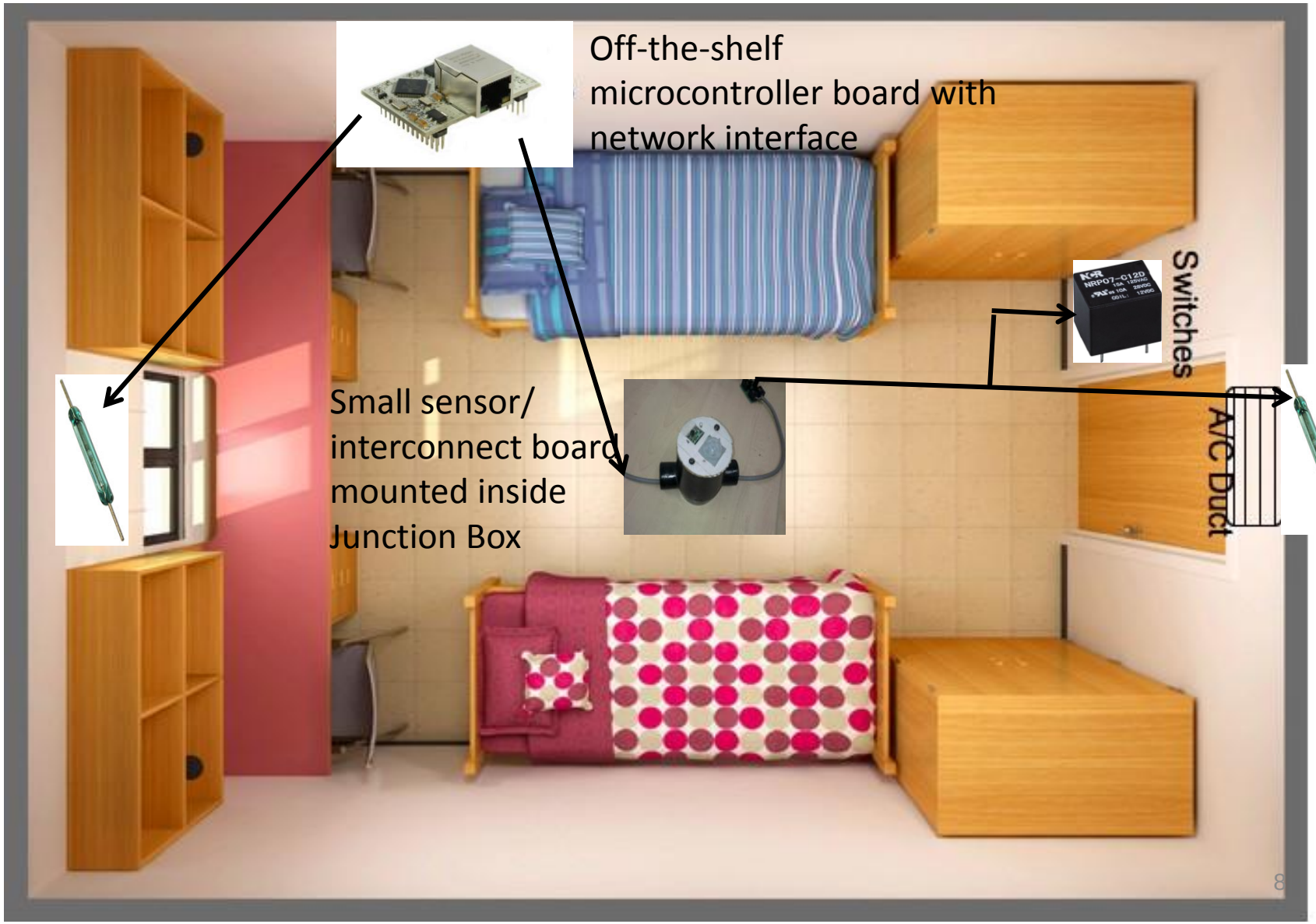
Systems for Pilot Deployment



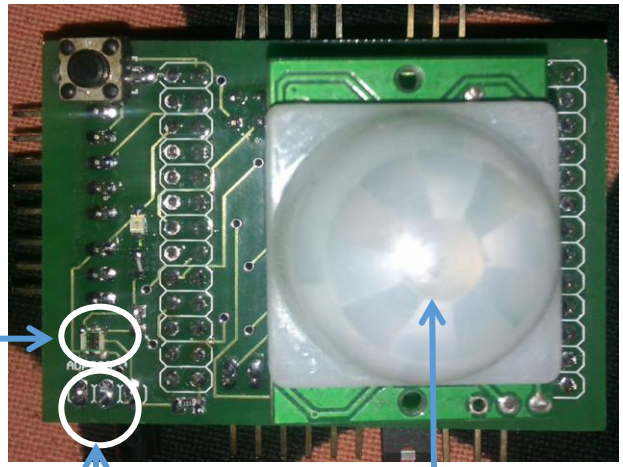


Developed in collaboration with
IBM-IRL and Radiostudio

IIIT Delhi Hostels: Actual Design View



Deployment in the mobile computing research wing



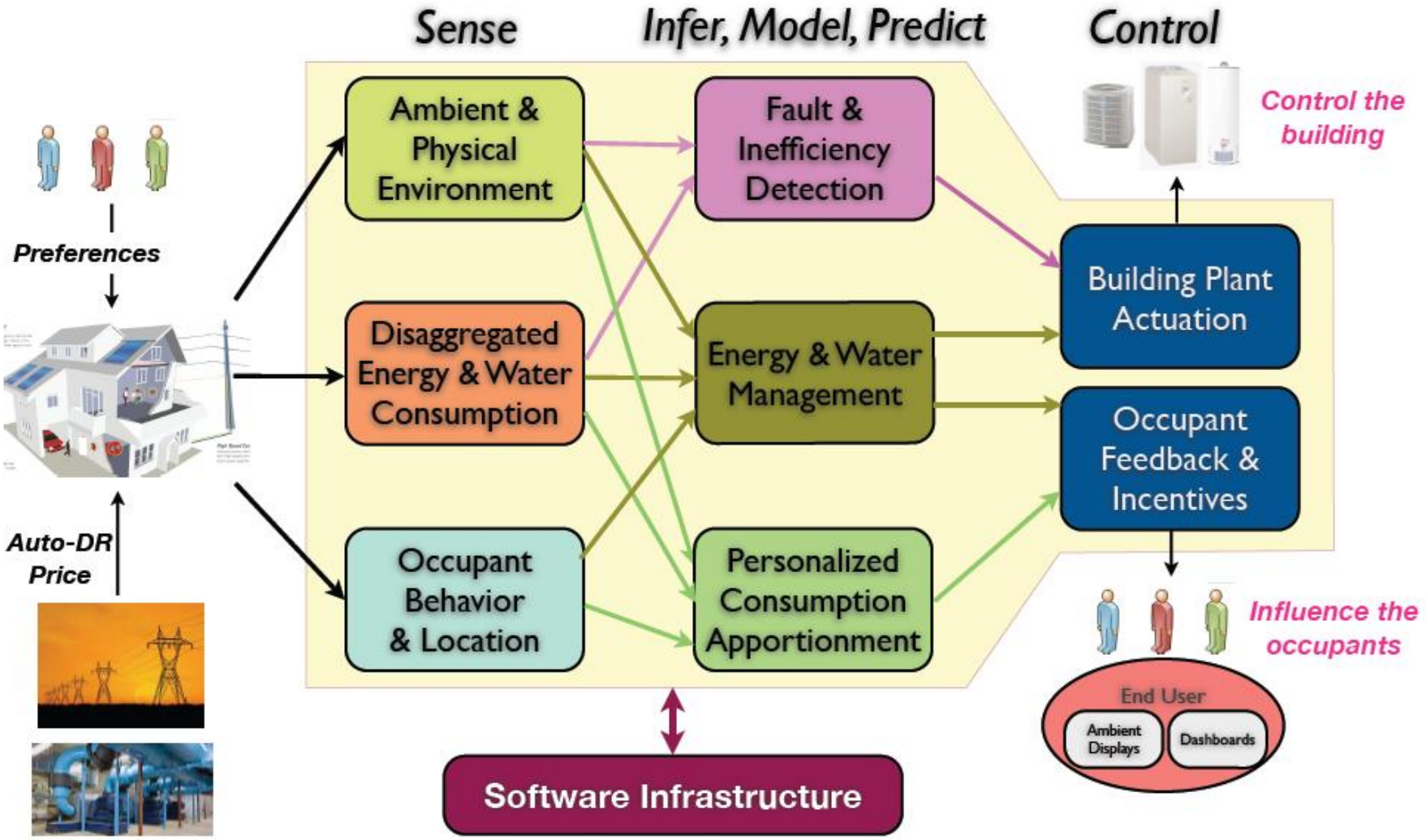
- Uses commercially available flyport modules
  - < Rs 4000
  - Compact (35*50mm)

Wi-Fi

Ethernet

- Total system cost < Rs 4500 (even for small quantity)
- Deployed these systems across 9 rooms – to monitor physical parameters
- Enhancing the system with control of appliances over IEEE 802.15.4

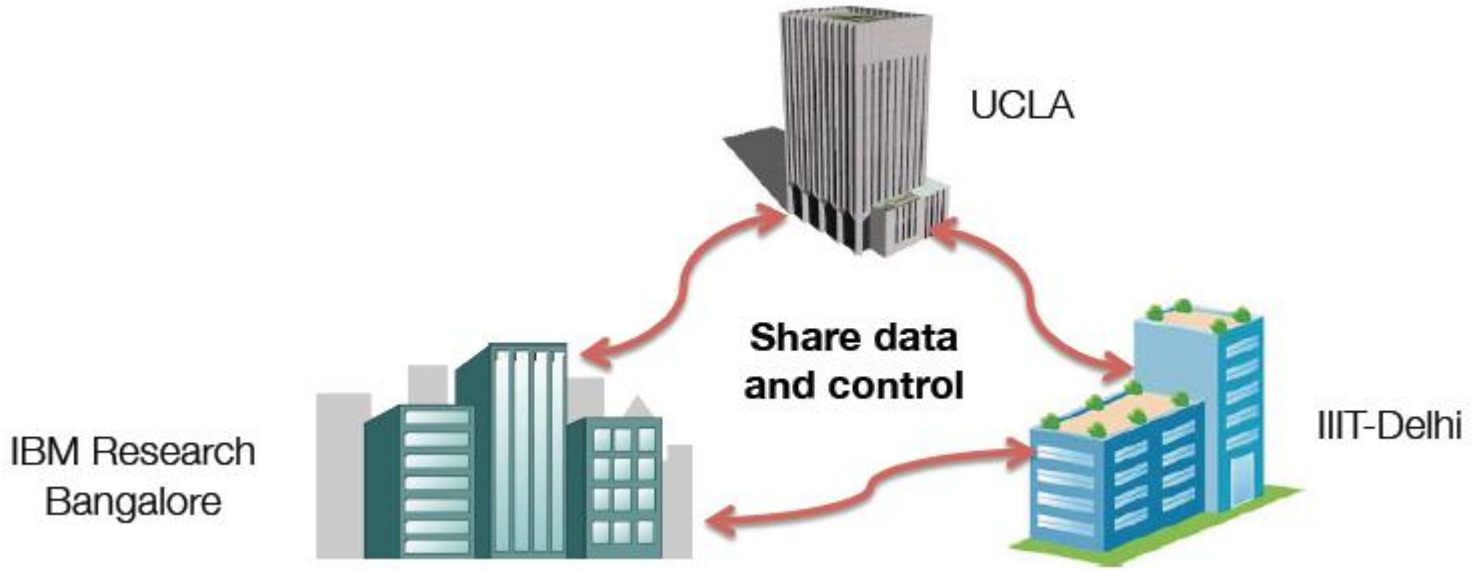
Occupant Aware Building Management



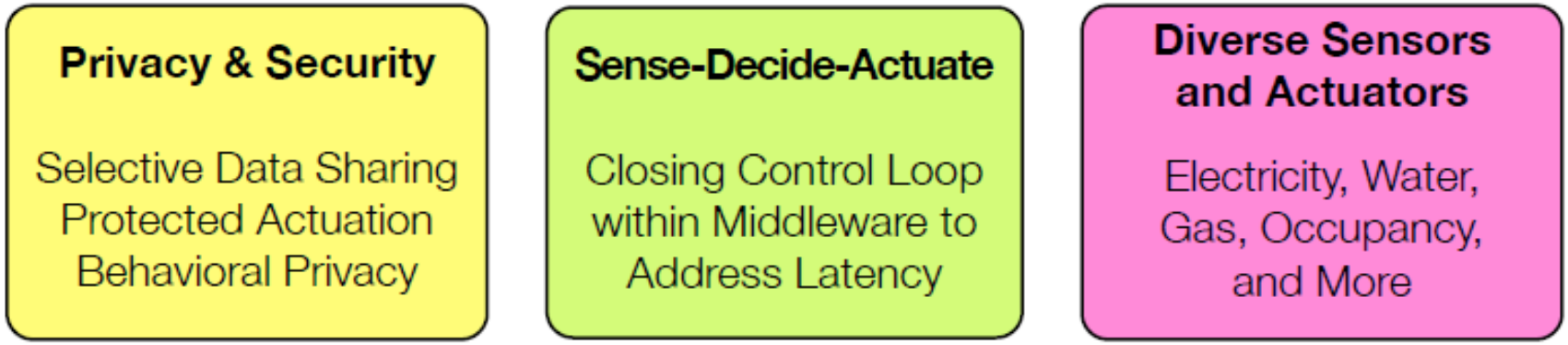
- Joint Research work with Prof. Mani Srivastava, UCLA (Funded by NSF and DIT), in collaboration with IBM IRL

Server Side System: Specific Challenges

- Richer ecosystem for sharing building resources (both sensing and actuation) across several collaborators
- Globally distributed Indo-US testbed raises challenges not encountered in a building and campus scale deployments.



Server Side System: Specific Challenges



- Existing systems
  - Building Scale: Trane, Johnsoncontrols, etc.
  - Home Scale: Micasaverde, etc.
  - Cloud-based: Cosm, Thingspeak, etc.

  - Provide some support in each one of these requirements.
  - Not scale to globally distributed testbed across organizations.

SensorAct in a Nutshell

- **Our Goals**
  - **Scalable**
    - Deployable from homes to across organizations
  - **User-Centric**
    - Participatory engagement of occupants
  - **Versatile**
    - Diverse sensing, actuation, and applications

A Tiered and Distributed Architecture

Powerful Sensor and Actuator Guard Rules

Lightweight Tasking Framework

Support Diverse Applications and Researches

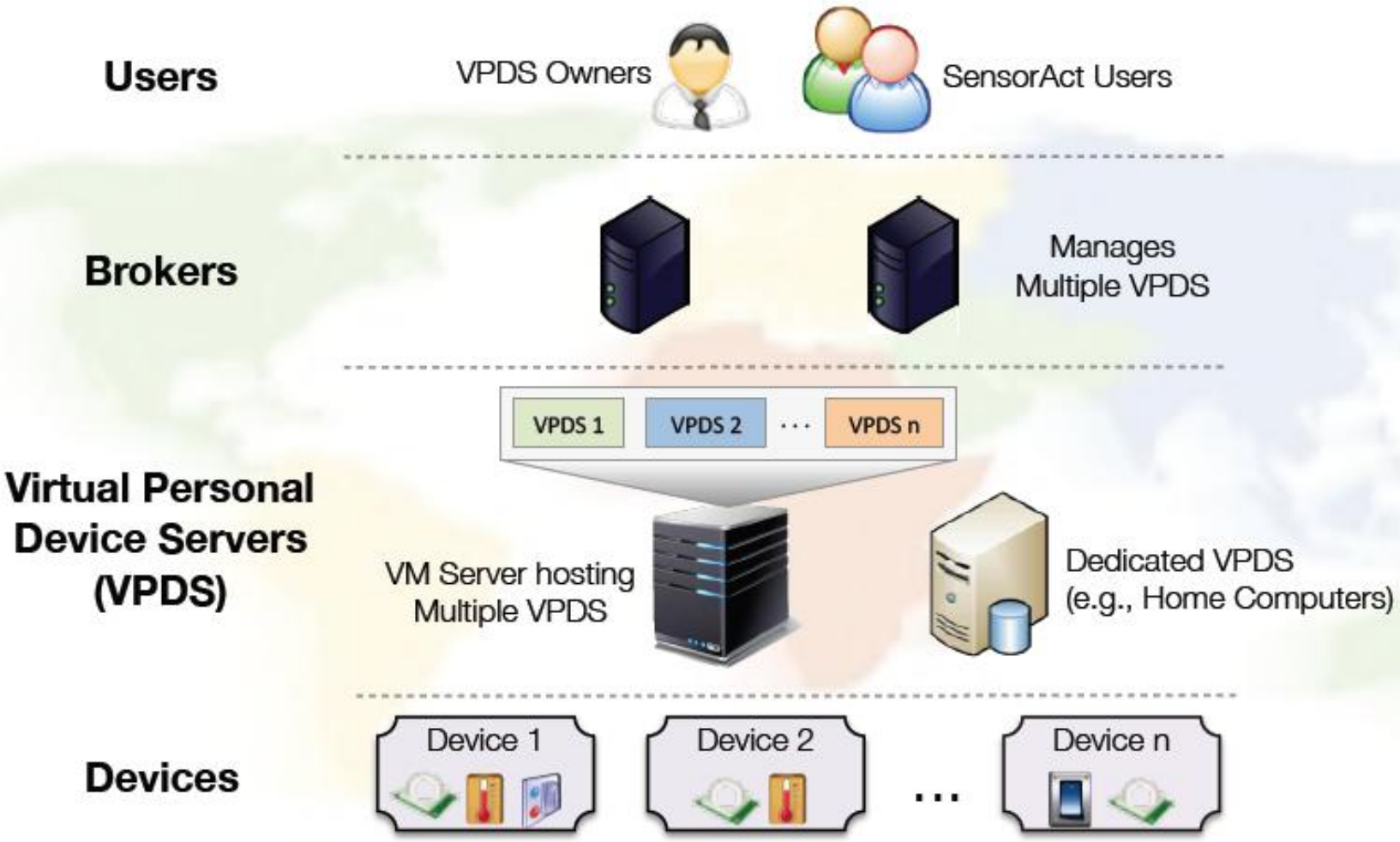
Energy (electricity, water, and gas) management

Sustainable buildings

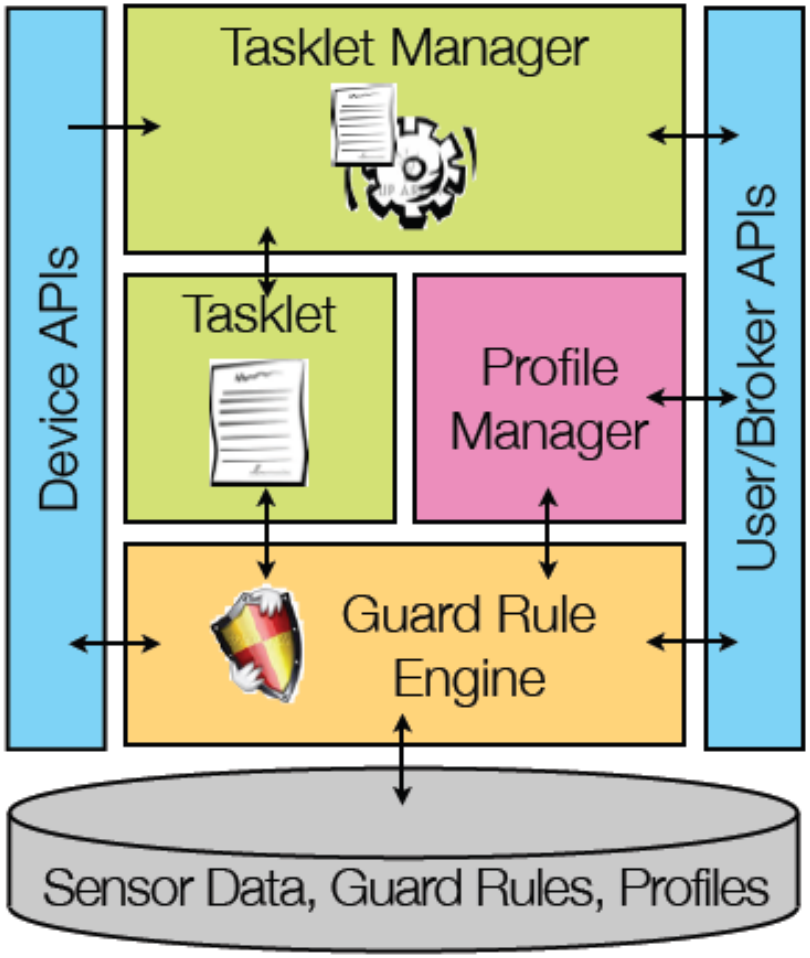
Resource management and utilization analysis

...

SensorAct Architecture



SensorAct VPDS



- Per user basis ensuring data ownership
- Guard Rule Engine
  - Protect privacy and security in accessing sensors and actuators
- Tasklet Manager
  - Manage and executes user written application logic
- Profile Manager
  - Manages user and device information
- Database
  - Stores sensor data, guard rules, device profiles.
- APIs
  - Device APIs, User/Broker APIs

SensorAct: Implementation

- RESTful APIs
- Java - Play Framework
- MongoDB
- Quartz
- Lua
- Web 2.0
- Open source

https://github.com/iiitd-ucla-pc3

Component	VPDS APIs
User	/user/{register|login|list}
Key	/key/{generate|delete|list|enable|disable}
Device	/device/{add|delete|get|list|search|share}
	/device/template/{add|delete|get|list}
Guardrule	/guardrule/{add|delete|get|list}
	/guardrule/association{add|delete|get|list}
Tasklet	/tasklet/{add|delete|get|list}
	/tasklet/{execute|cancel|status}
Data	/data/{upload/wavesegment|query}

Component	Broker APIs
User	/user/{register|login}
VPDS	/vpds/{register|remove}

A short demo ….

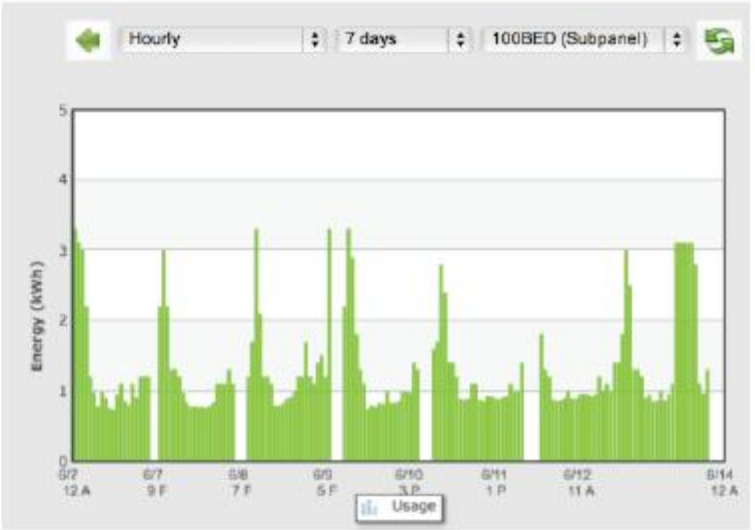
Deployments at other locations: UCLA

Interior Sensor Kit

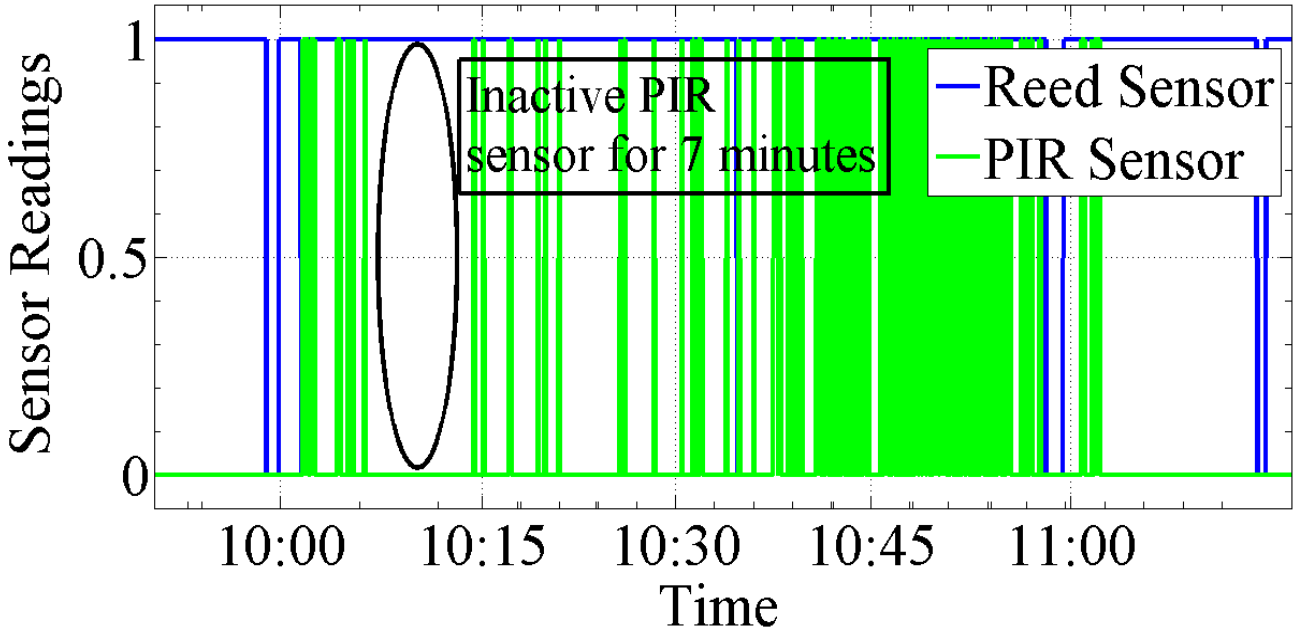
Circuit Panel Kit

Main Water Flow

- Wet & Dry Lab deployment
  - Main panel, circuit, outlet level electricity
  - Meter & outlet level water
  - Occupancy
  - Ambient (temperature, light, and pressure)
- Residential deployment
  - Main panel, circuits, outlets
  - Main water

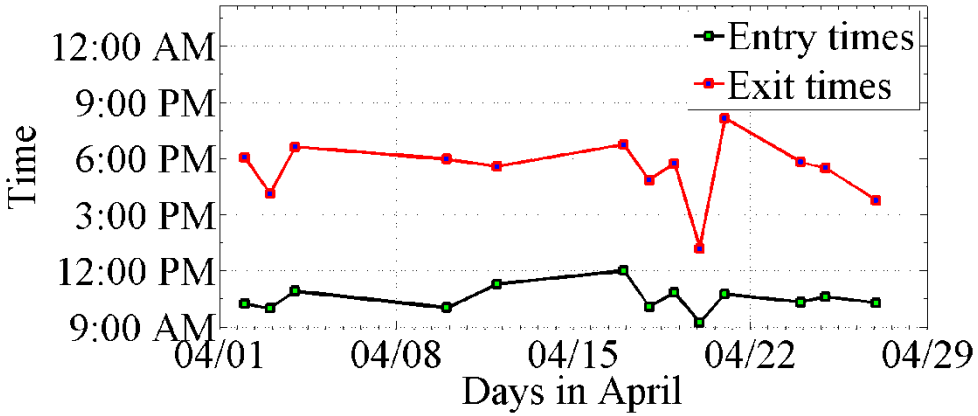


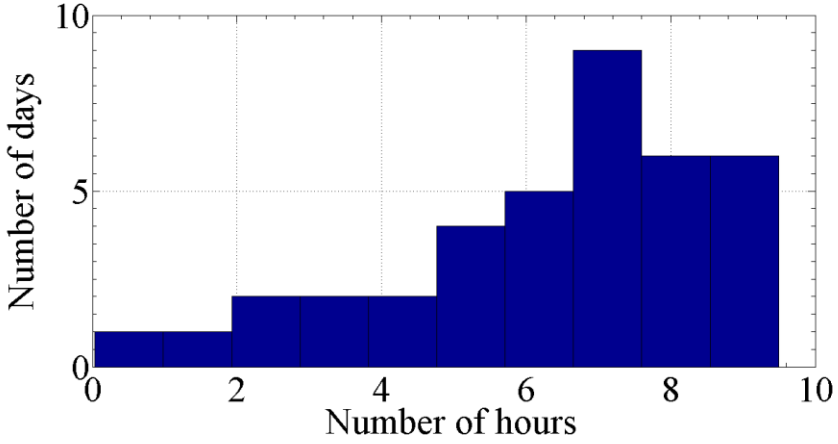
Preliminary Analysis of Collected Data - I



- PIR sensor has limitations while observing small movements
  - Combine PIR and door-status information to decide on occupancy

Preliminary Analysis of Collected Data - II

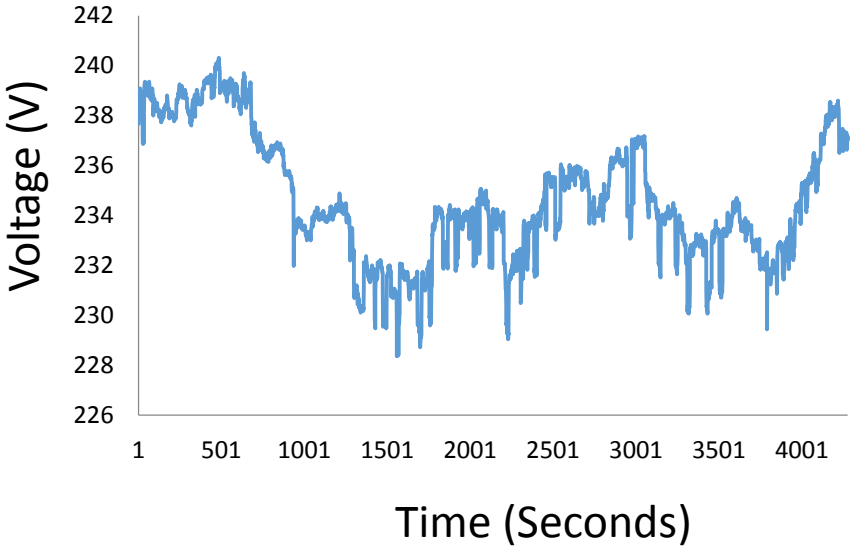


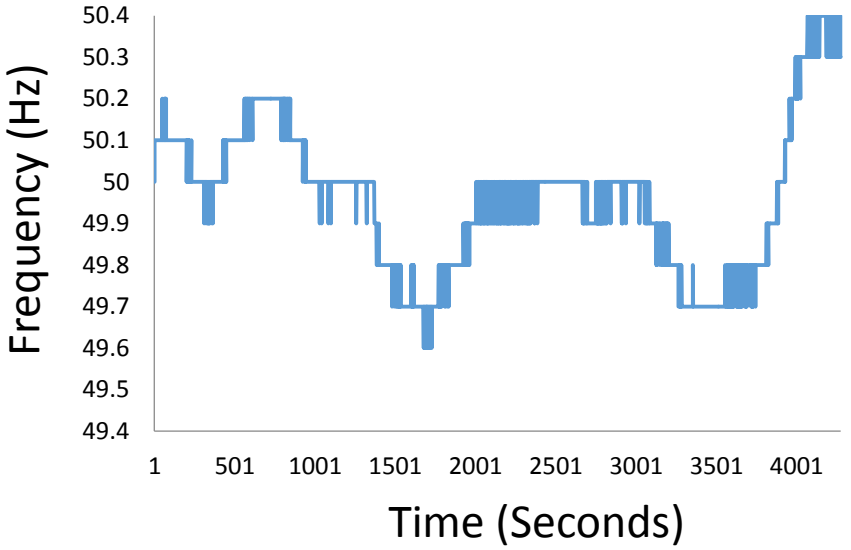


- Collected data has security and privacy implications
  - Develop systems that provide data ownership of the collected data and control to decide who can see the data and at what resolution

Preliminary Analysis of Collected Data - III

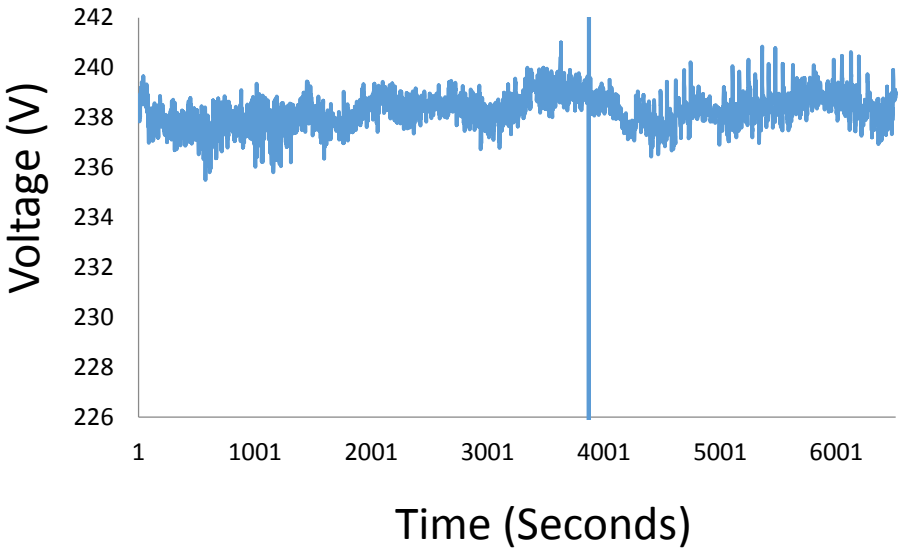
- Voltage and frequency fluctuations: At one of the homes in Delhi connected to regular grid infrastructure

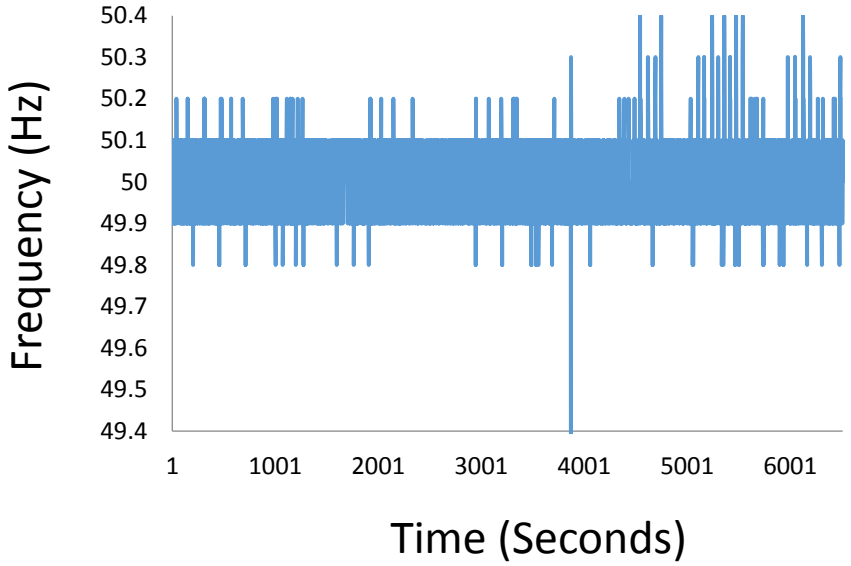




Preliminary Analysis of Collected Data - III

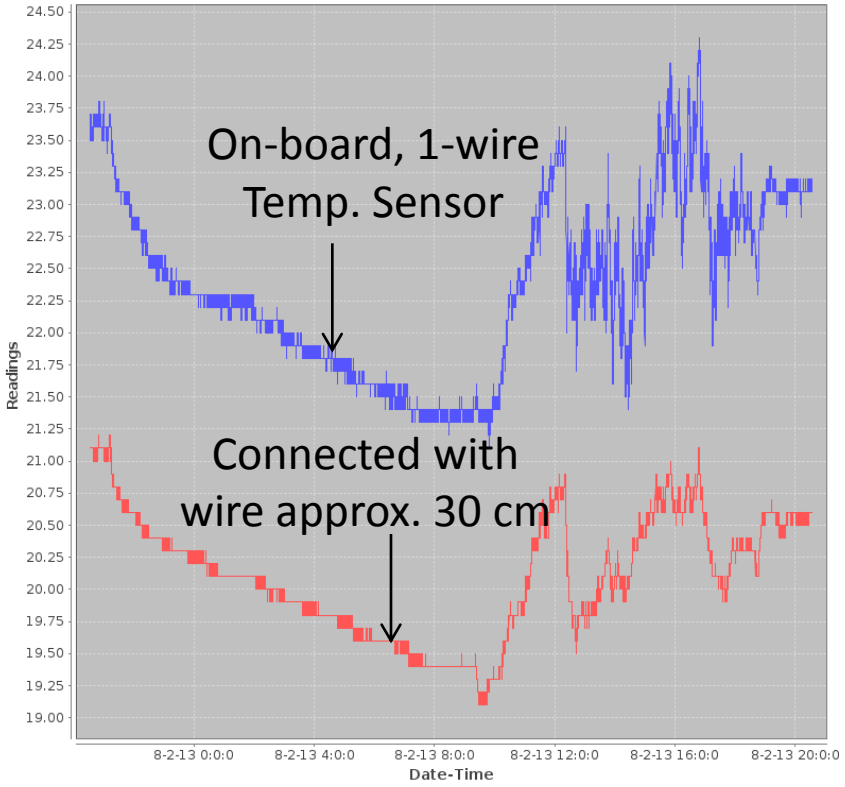
- Voltage and frequency fluctuations in one of the rooms in IIIT Delhi with newly built grid infrastructure

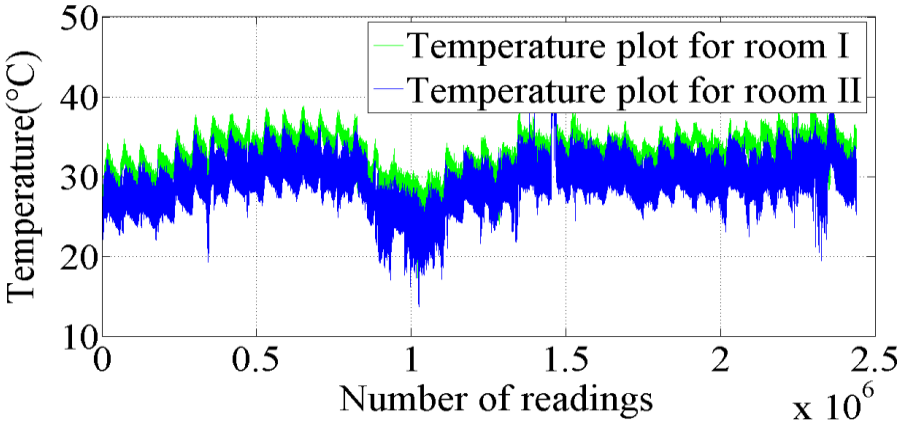




Preliminary Analysis of Collected Data - IV

- Appropriate choice of sensing interfaces
  - Analog signals need calibration for longer cable lengths
  - I2C is not suited for communication over long distances
  - 1-wire temperature is better instrumented off-board





Analog temperature sensors in adjacent rooms with different connection lengths

Collaboration and Acknowledgments

- IIIT Delhi:
  - Faculty – Dr. Pushpendra Singh, Dr. Vinayak Naik
  - PhD students – Nipun Batra (TCS PhD Fellowship), Pandarasamy Arjunan (IBM PhD Fellowship)
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- UCLA:
  - Faculty – Prof. Mani Srivastava
  - PhD students – Haksoo Choi
  - MS students – Jason Tsao, Kevin Ting
- IBM IRL – Smart Planet Group:
  - Deva Seetharam, Zainul Charbiwala, Sunil K. Ghai …
- RadioLabz, Chennai
  - Rajesh, Sathish

Some Project Ideas

- Setup IOT services (Nimbits/Cosm/SensorAct) and then write applications using the collected data:
  - Daily report generation and sending it to the users email address configured
- Create a daughter board for RaspberryPI platform to attach diverse sensors – light over I2C, temperature over 1-wire and some analog sensor
  - Use appropriate Linux libraries for collecting the data and sending it over WiFi to one of the IOT services (cosm is the easiest)
  - Same thing can be done using Flyport (easily available in both India and US)
- Test out multiple sensor interfaces: Example use light sensor with I2C, Analog and PWM outputs and compare their values
- Audio profiling to detect occupancy in a room:
  - Use RaspberryPI audio input and appropriate libraries to classify number of occupants in a room using audio profile

Some Project Ideas – Indian context

- Collect data from a smart meter using modbus interface (python libraries like pymodbus can be easily used) and then send it automatically to a dropbox folder

- Collect data from a pulse based water meter and send it to a IOT service (cosm/nimbits)