



Achieving Energy Efficiency & Demand Response in Homes with Wireless Sensor Networks

Nathan Ota

Presentation to DRETD TAC

On behalf of DRETD Team

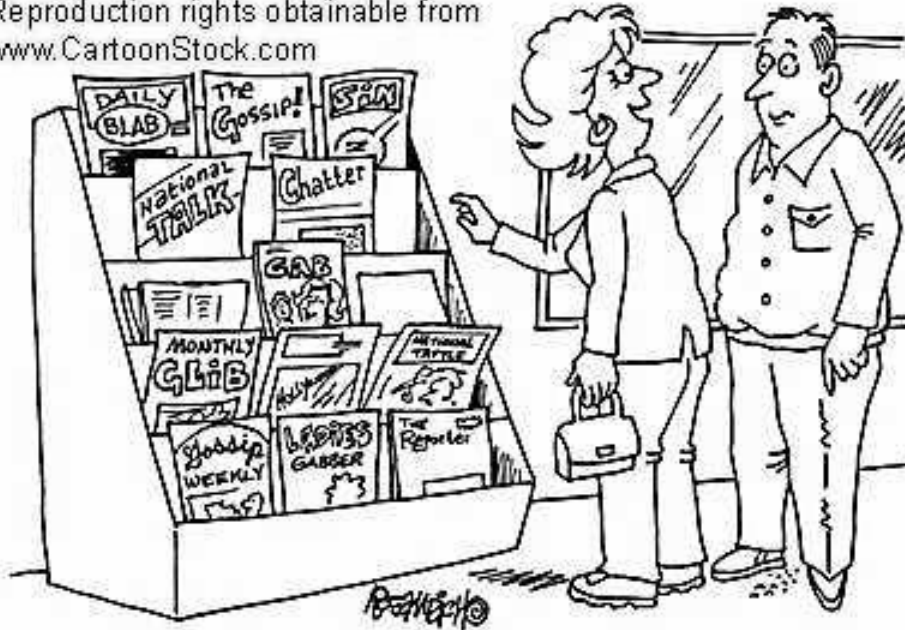
2/19/08



Motivation



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"I love the tabloids. One surmise fits all."

Temperature differences of up to three degrees from room to room are not uncommon, *EnergyStar*





Application Achievements

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

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Thermostat UI

Peffer



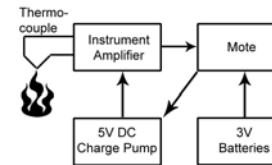
Layered Model

Peffer, Chen, Jiang

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

Optimal Control

Chen



Thermal Modeling

Jiang

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

System Architecture

Ota

Multi-Sensor Thermostat

Ota

Modular Monitoring

Ahrens, Hsu, Ota

RF Performance

Ota

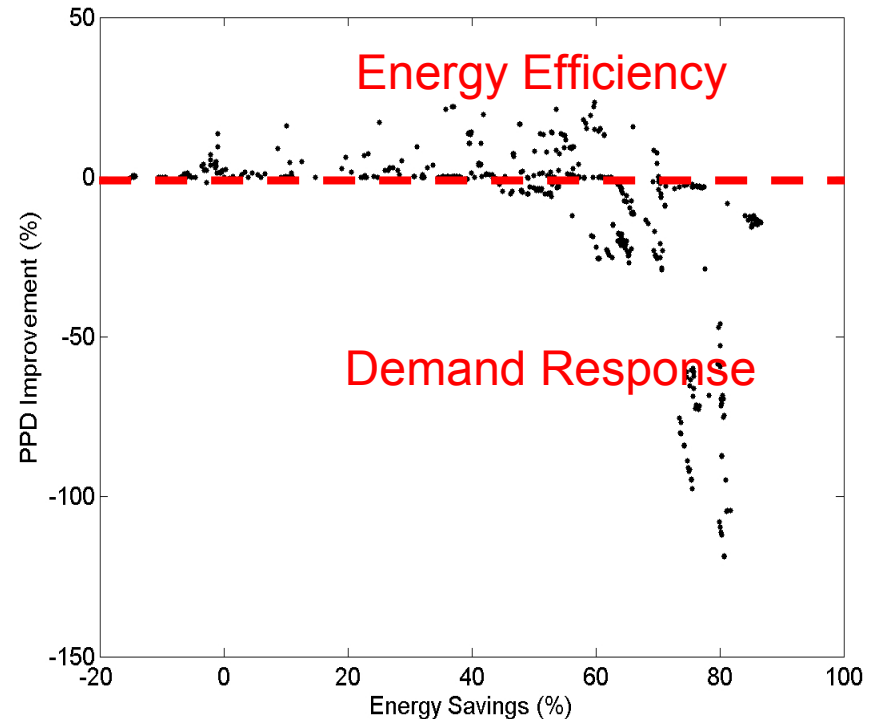
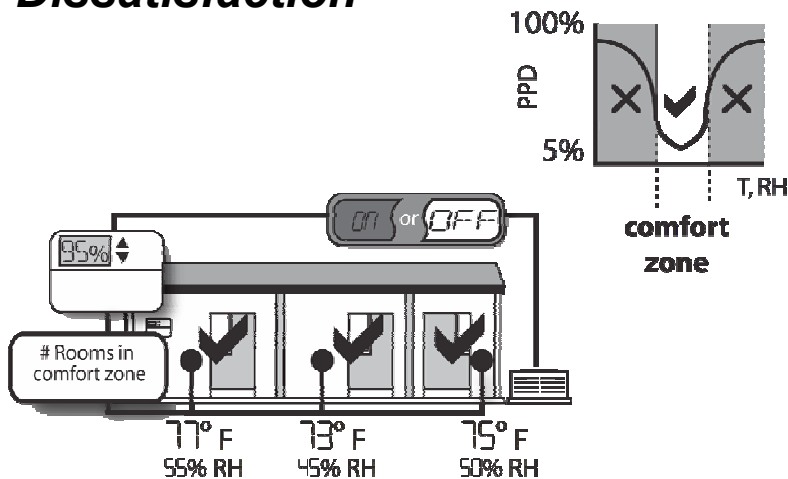


Multi-Sensor Thermostat



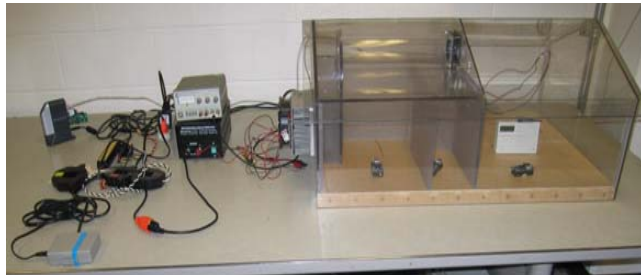
- ★ Measure environment conditions in every room.
- ★ 7 strategies, design for retrofit, no new actuators.
- ★ Comfort control rather than temperature control.
- ★ Energy efficient and DR opportunities.

Example Strategy:
Maximize the Number of Rooms
Below a Threshold Comfort
Dissatisfaction

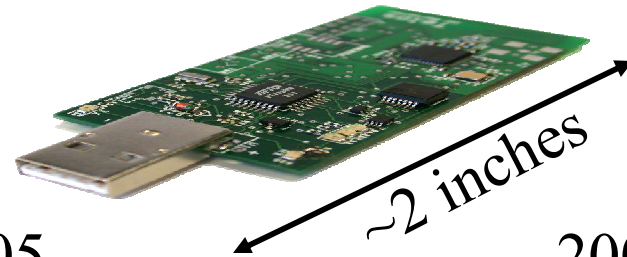




Hands-on Experience from Deployments of Wireless Sensors

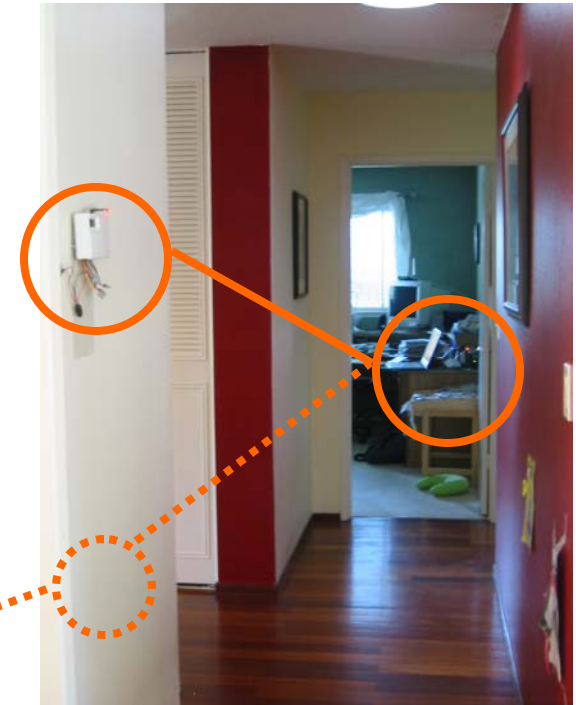


2003



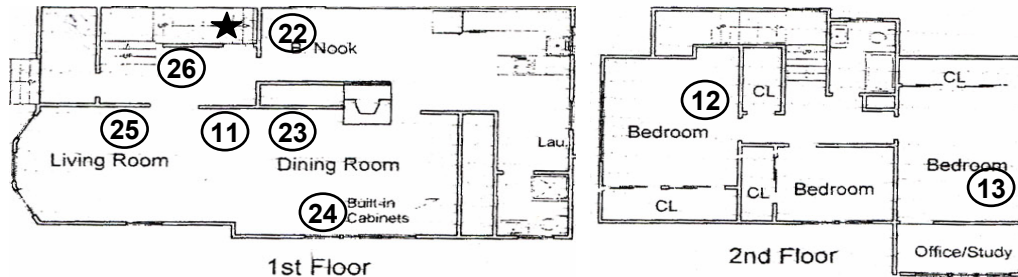
2004/2005

2006

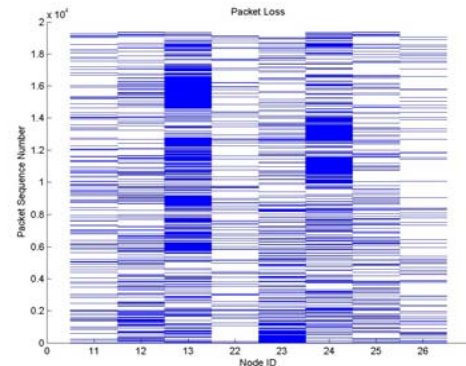
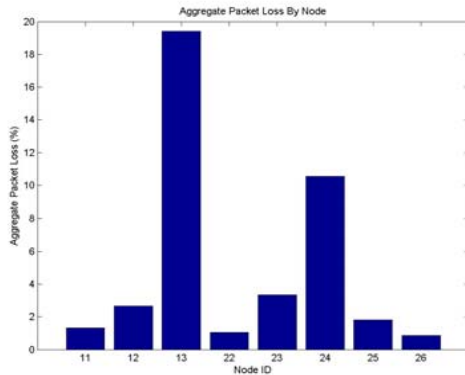


2.4 GHz RF Performance

- ★ Empirical testing in homes throughout Northern California.
- ★ Conclusion: multi-hop networking necessary.
- ★ Conclusion: control must handle data uncertainty.



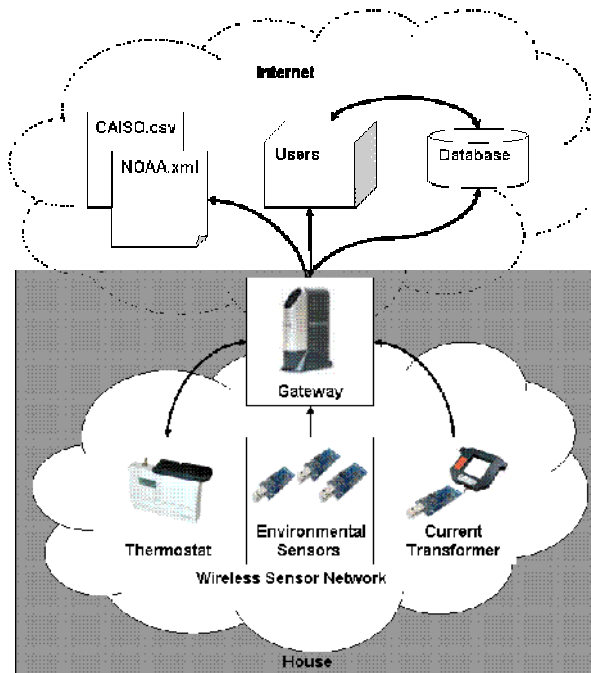
★ = base station ○ = node



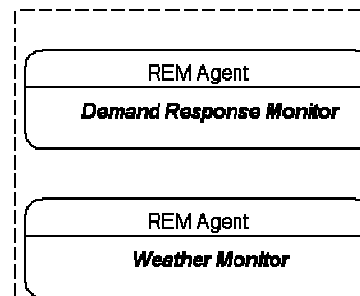


Systems Engineering

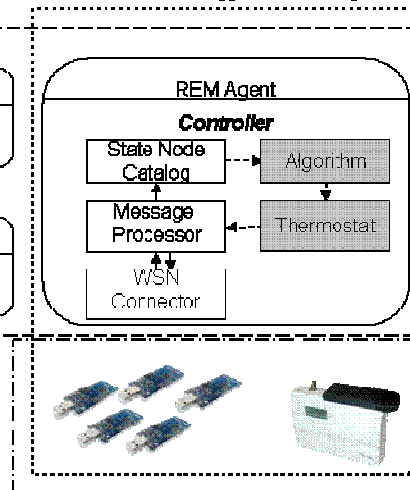
- ★ Perception, actuation, communication, decision making.
- ★ Agent-based architecture is scalable and extensible.
- ★ Agent-based architecture leverages layered architecture.



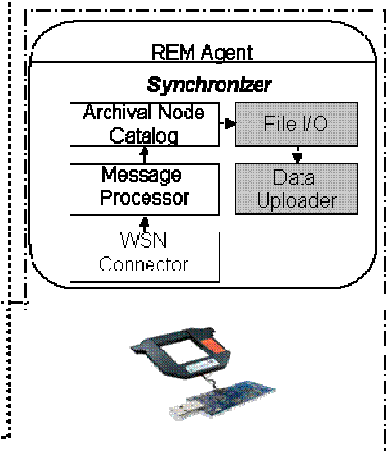
Task 1: Demand Response



Task 2: Energy Efficiency



Task 3: User Feedback

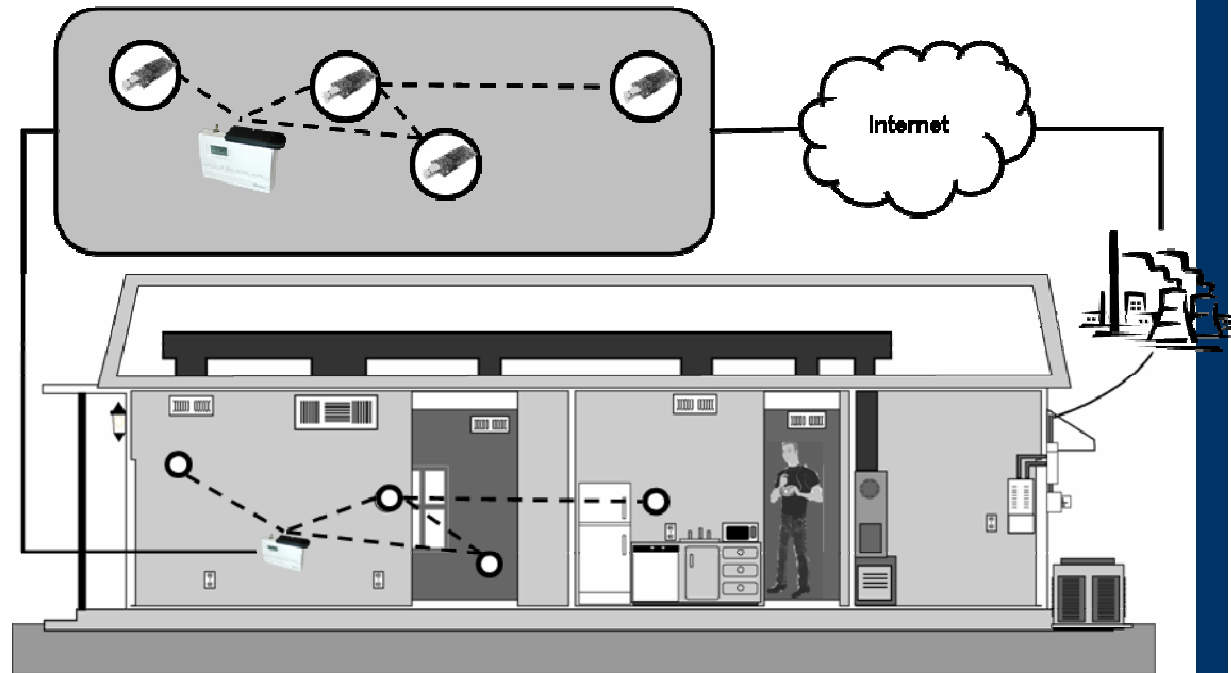




The “Disaggregated” Thermostat

- ★ **Communication-based functional separation.**
- ★ **Spatial-temporal sensing with WSN’s.**
- ★ **Grid-aware to support Demand Response.**

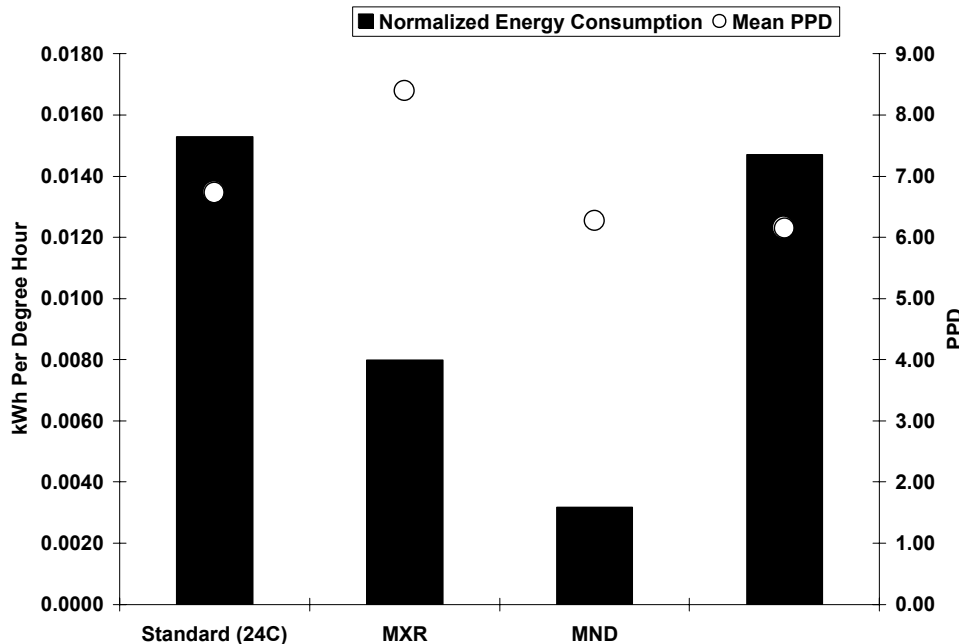
	<i>Old Way</i>	<i>New Way</i>
Actuates	On/Off	On/Off
Uses	Single sensor	Multiple sensors
Measures	°F	°F, RH
Controls	°F	Comfort, cost
Aware	n/a	energy prices, weather





Energy Efficiency with Disaggregated Thermostat

- ★ Field testing multi-sensor control strategies.
- ★ 7 sensors, 1 meter, 1 thermostat, 1 router.
- ★ Energy savings in “live” deployments.

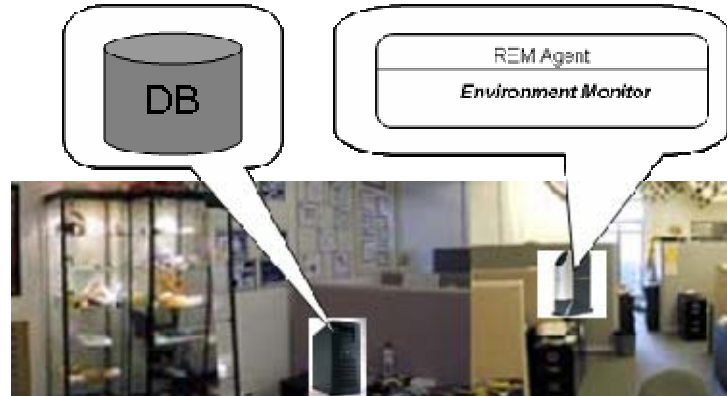




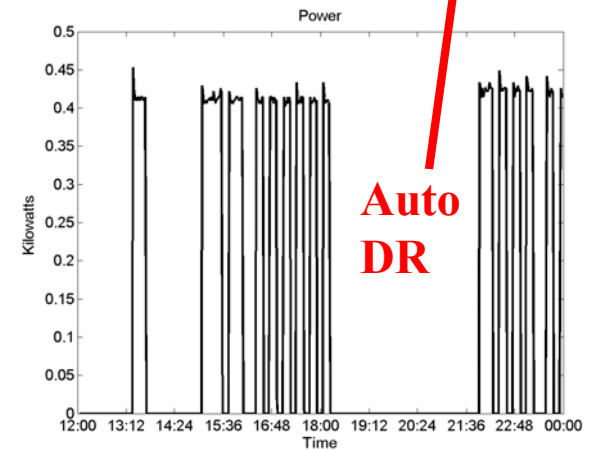
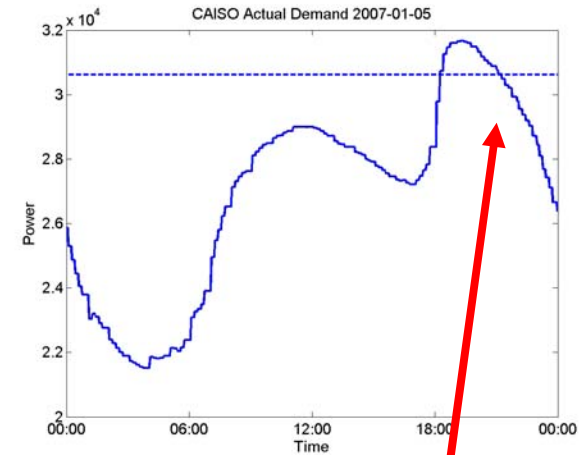
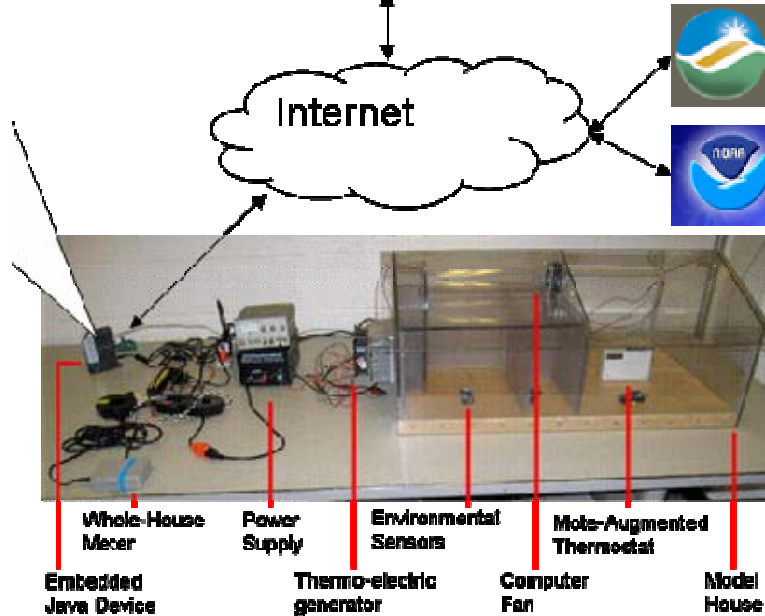
Auto Demand Response with Disaggregated Thermostat



Remote Data Storage & Supervisory Control



Disaggregated Thermostat

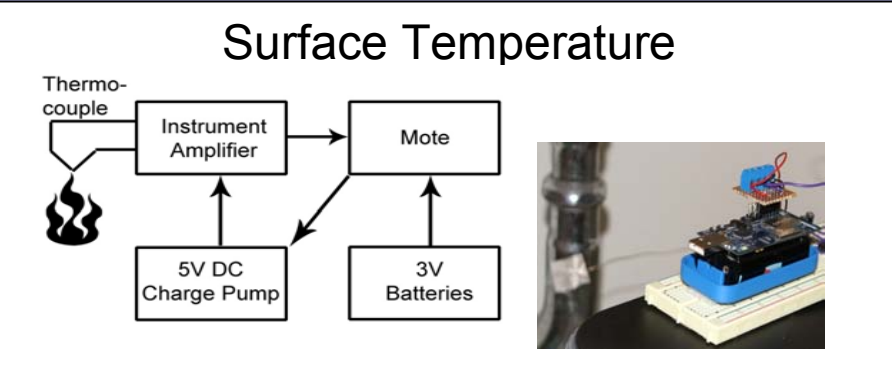
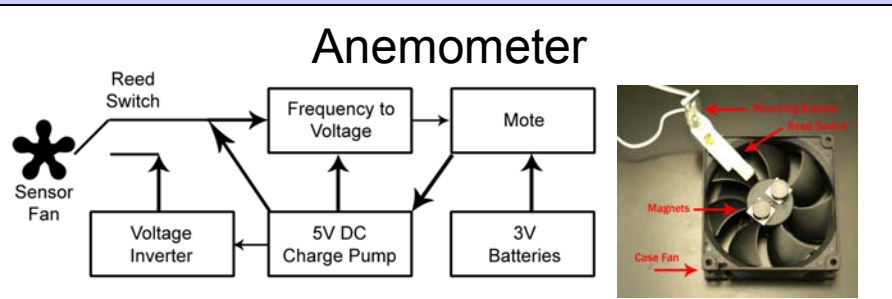




“Plug-able” Designs with Disaggregated Thermostat

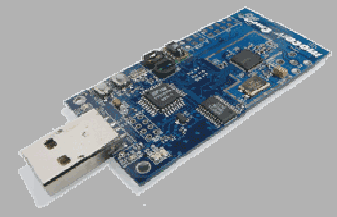


Predictive Maintenance Monitoring

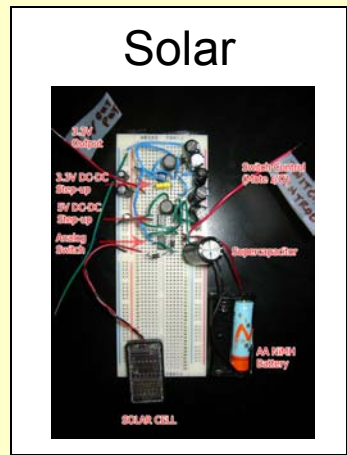


Mote Platform

- Temperature
- Humidity
- Solar

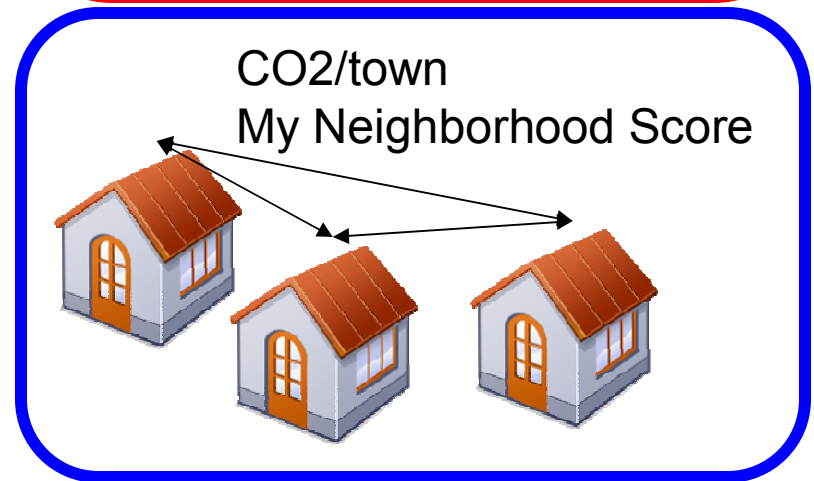
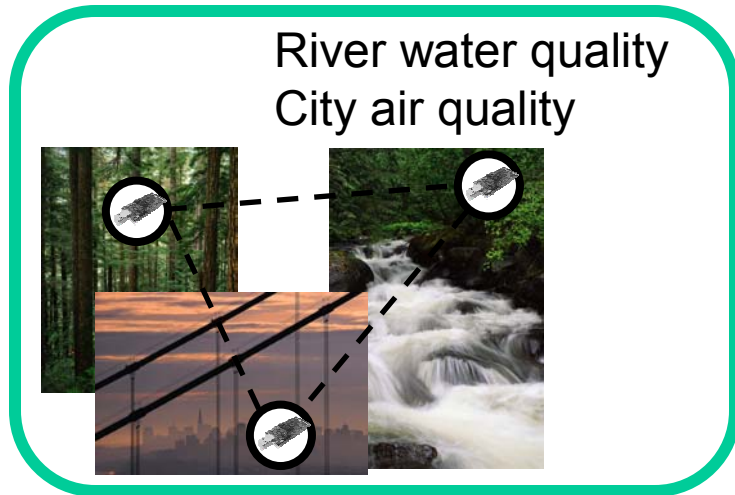
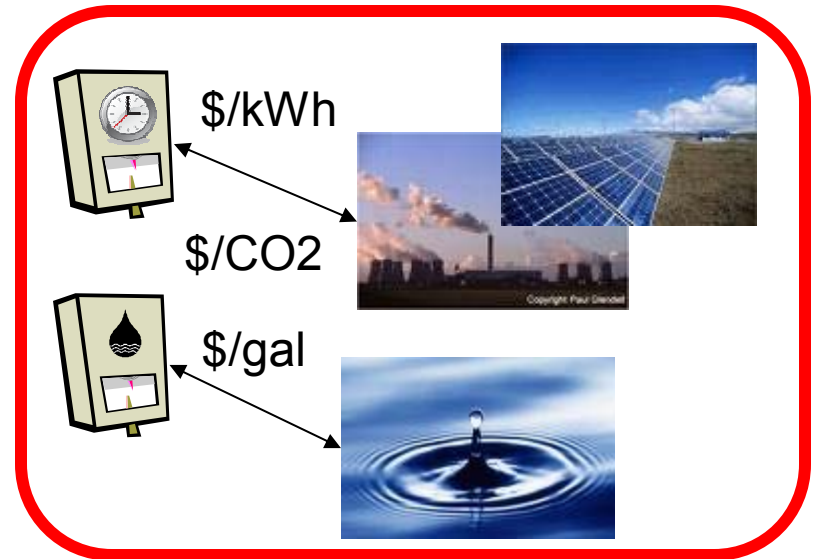
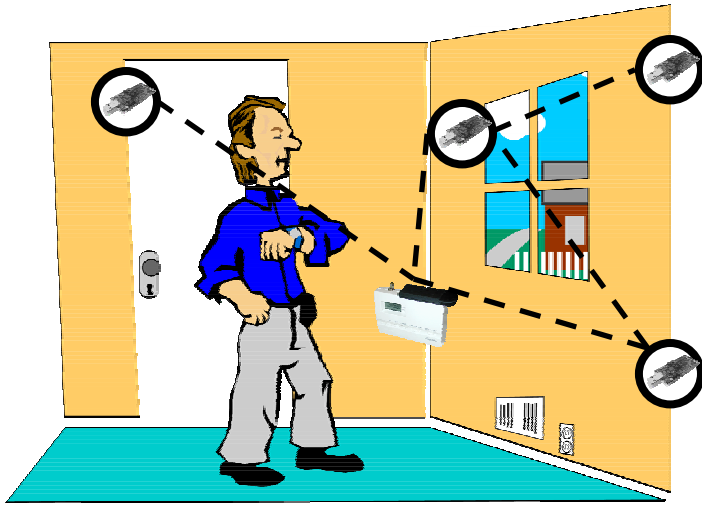


Energy Scavenger



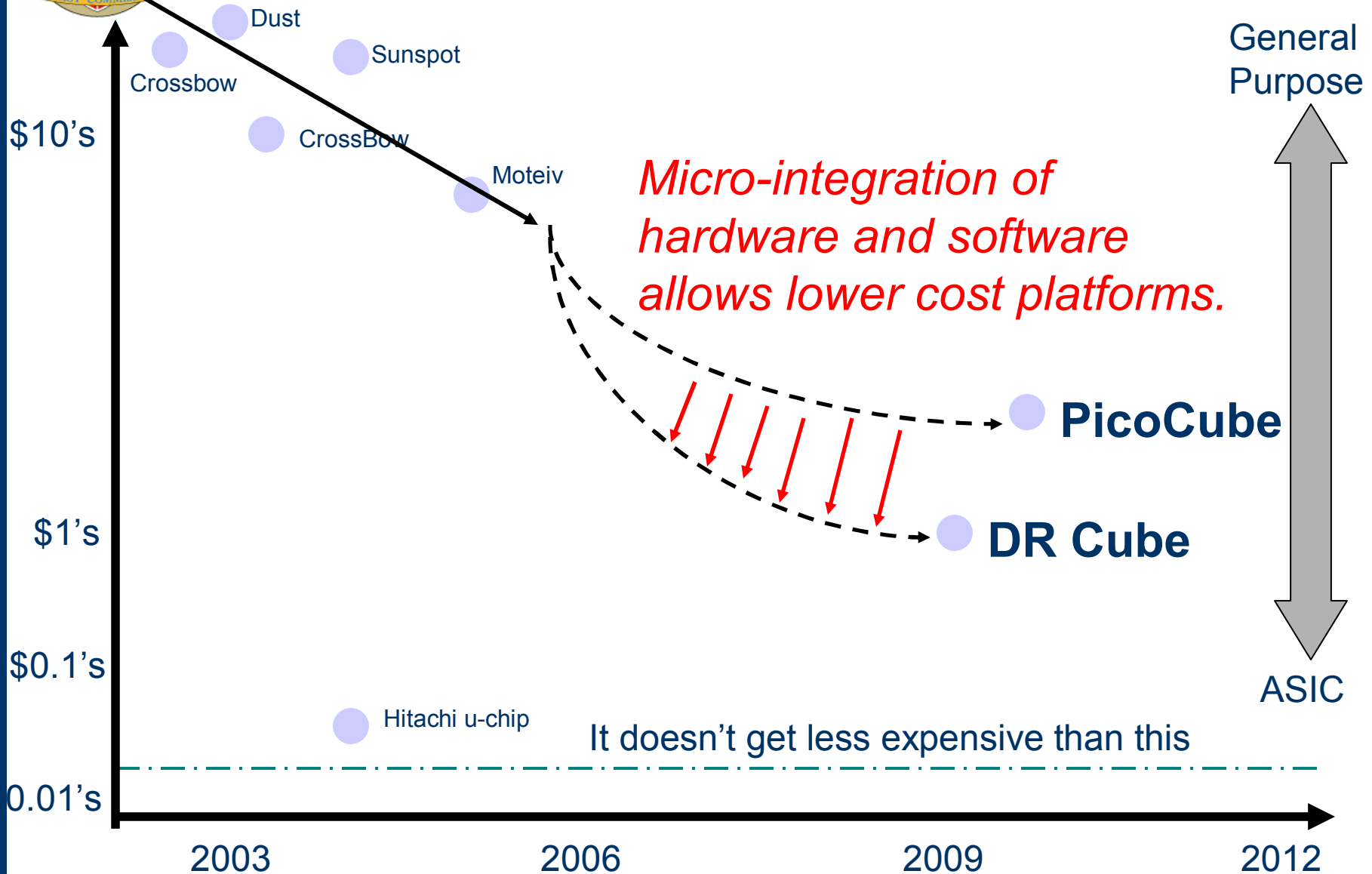


Vision: From Demand Response to Sustainable Choice





Towards the "DR cube" in 2009





Micro-integration by the millions

Software applications

run on the

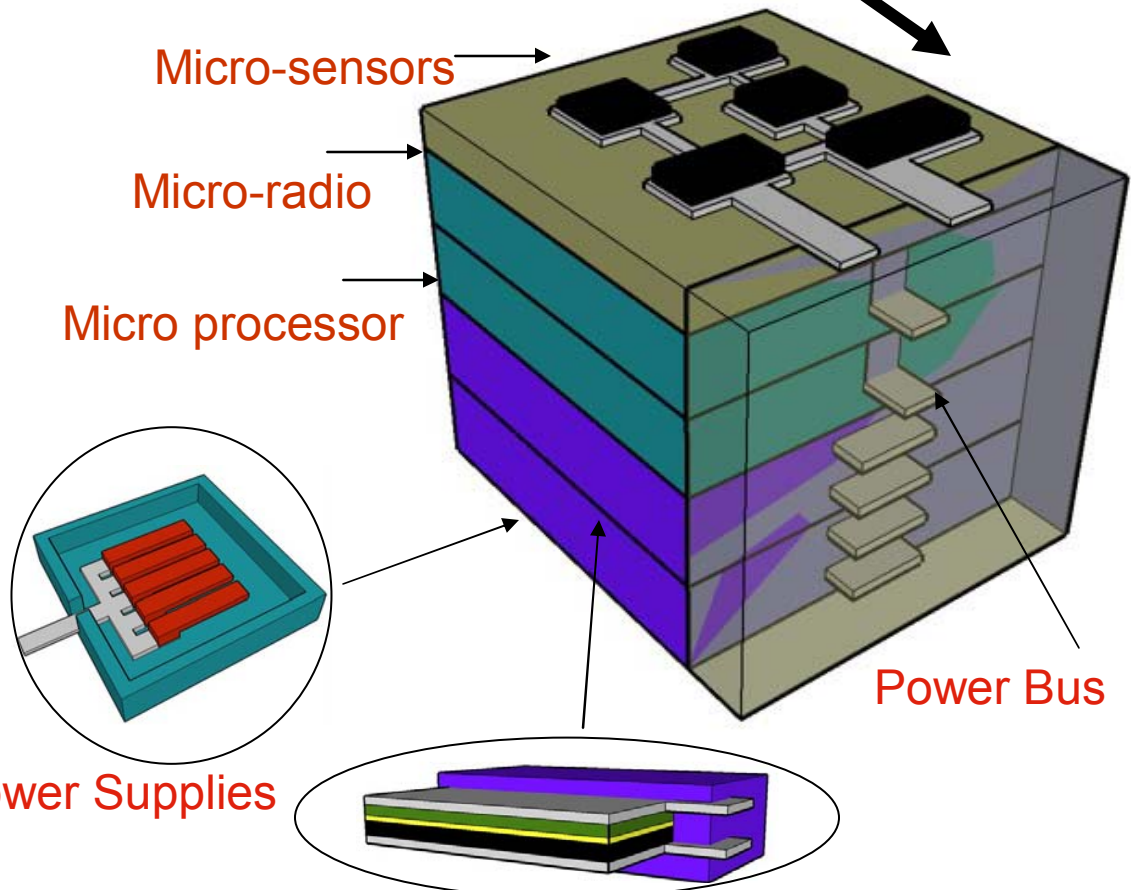
Hardware platforms

Control logic

Learning algorithms

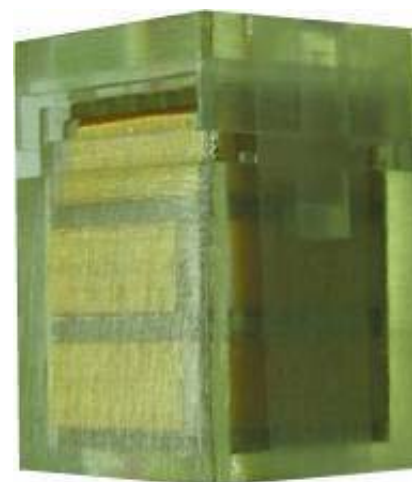
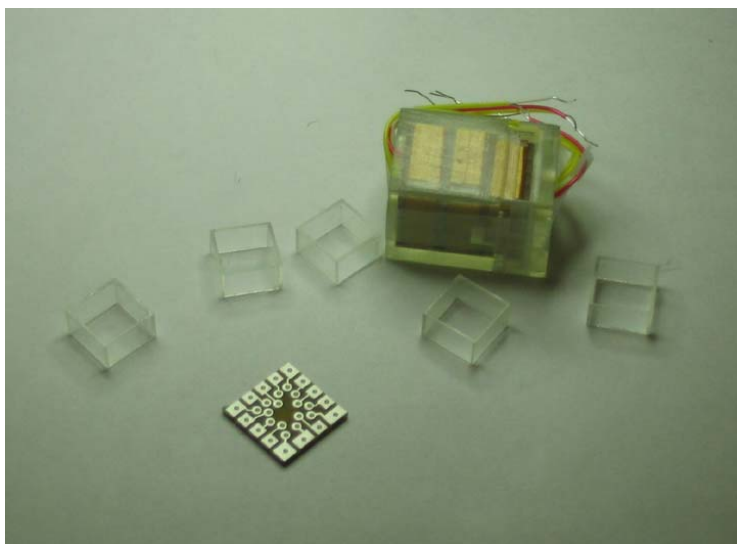
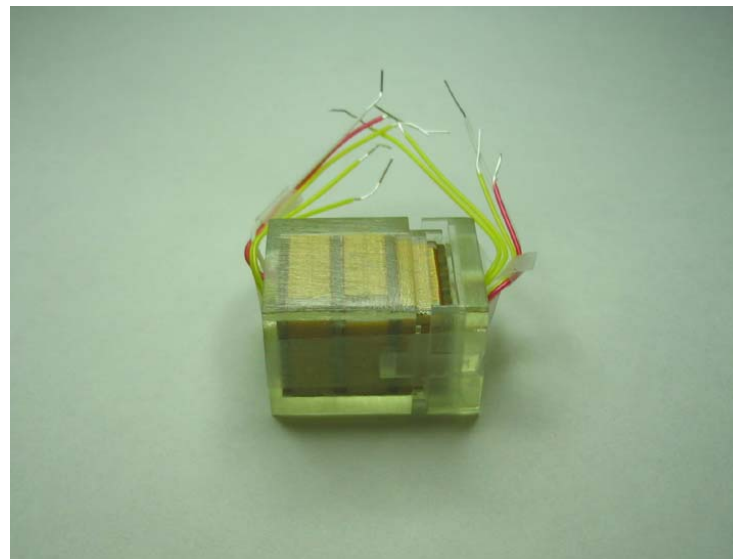
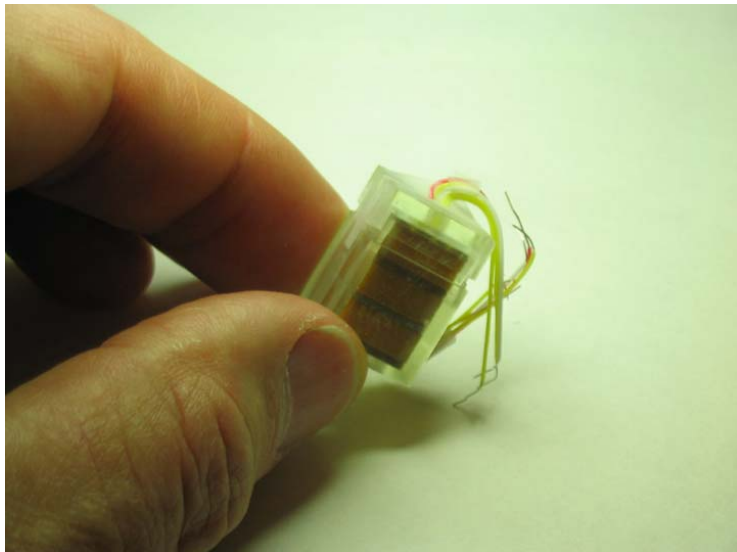
Automation

Distributed throughout
all computers in the
system





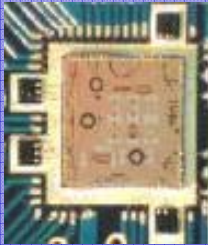
Beginning Micro-integration: PicoCube January 2007





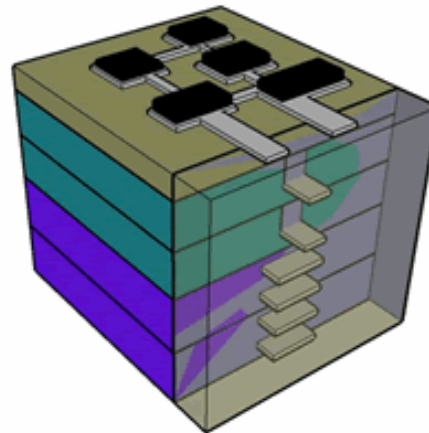
Micro-integration of Wireless Sensor Networks

Low Power Radio



“Disappearing Computer”

B. Gates, *Economist* (2003)



“Picocube”

Power Storage



Sensor



Renewable Power



Supply