Demand Response (DR)
Enabling Technology Development (ETD)
Project

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INTRODUCTIONS

• Presenters
  • Ron Hofmann (introduction & process, consultant)
  • Paul Wright (initial subcontract, UCB Professor)
  • Roger Levy (meters and prices, consultant)
  • Alexandra von Meier (power delivery system, CSUS Professor)
  • Gaymond Yee (RONs, DR ETD project manager, CIEE)

• Behind the scenes
  • Laurie ten Hope (CEC/PIER ESI team lead)
  • Maureen Barnato (DR ETD task administrator, CIEE)
  • Karen Sharp (workshop facilitator, CIEE)
  • Art Rosenfeld (CEC Commissioner)
  • Carl Blumstein (UCOP/CIEE director, UCEI researcher)
PURPOSE OF THIS WORKSHOP

- Introduce an energy-related R&D project
  - initial funding $3 MM over 30 months
- Purpose of funding is to develop enabling technologies for a state-wide demand responsive electric power delivery system with “10/10” objectives
  - 10 times the capabilities
  - 1/10th the cost
  - Create disruptive technology
- Leverage R&D spending by other institutions
BACKGROUND

◆ CA energy crisis of 2000-2001
  - Market power (Enron, et al)
  - Aging fossil fuel plants (pollution)
  - Flaws in deregulation (AB 1890)
  - Disconnect between wholesale and retail prices

◆ Supply approach (build more plants)

◆ Demand approach (load as a resource)
ELECTRIC POWER INDUSTRY IN CALIFORNIA

- Energy companies (Enron, Calpine)
- CAISO (California Independent System Operator) manages transmission system
- UDCs (Utility distribution companies manage local distribution systems)
  - IOUs (investor owned utilities, e.g., PG&E)
  - Munis (publicly owned utilities, e.g., Alameda)
- Agencies (e.g., FERC, CPUC, CEC)
REGULATORY AGENCIES

- **FERC** [http://www.ferc.fed.us/](http://www.ferc.fed.us/)
  - Regulates the transmission and wholesale sales of electricity in interstate commerce

- **CPUC** [http://www.cpuc.ca.gov/](http://www.cpuc.ca.gov/)
  - Regulates privately-owned utilities in CA

- **CEC** [http://www.energy.ca.gov/](http://www.energy.ca.gov/)
  - Created in 1975 for siting electric power plants
  - Responsible for standards & policy analysis
BRIEF HISTORY OF RECENT CALIFORNIA ELECTRIC R&D

- Investor Owned Utilities (until 1996)
- EPRI (created by utilities in 1973)
- CIEE (funded by utilities starting in 1989 to manage energy efficiency R&D)
- PIER (created in 1996 by deregulation [AB1890] and initially funded in 1998)
- PIER [http://www.energy.ca.gov/pier/](http://www.energy.ca.gov/pier/)
- PIER has ~$60 MM/year through 2012
PIER R&D AREAS

- Environmentally-Preferred Advanced Generation (EPAG)
- Buildings End-Use Energy Efficiency
- Agricultural/Industrial/Water End-Use Energy Efficiency (AIW)
- Renewable Energy
- Energy Related Environmental Research
- Energy Systems Integration (ESI)
ESI

- Improved Efficiency and Reliability of the Transmission System (T&D)
- Distributed Energy Resources Systems Integration (DER)
- Strategic and Enabling Technologies (e.g., storage, seismic, tools for market analysis)
- Demand Response to Electricity Prices and System Contingencies (DR)
WHAT IS DR?

- Demand response (DR) for this project is the ability of electricity users to respond “automatically” to time- and location-dependent price and contingency signals (that have varying amplitude and duration) to reduce/shift loads.

- DR is different from energy efficiency (EE), e.g., transient vs. permanent
DR INVOLVES THE ENTIRE POWER DELIVERY SYSTEM

- Central plants (G)
- Long distance (T)
- Step down voltages (SS)
- Short distance (D)
- Buildings (L)
- Generation (G)
- Transmission (T)
- Substations (SS\textsubscript{T})
- Sub-transmission
- Substations (SS\textsubscript{D})
- Distribution (D)
- Local transformers
- Loads (L)
WHAT ARE SOME DR ENABLING TECHNOLOGIES?

- Wireless communications
- MEMS sensors
- Network management
- Systems integration
- Low-cost packaging
- Energy scavenging and storage
- Real-time operating systems
HISTORY OF DR ETD PROJECT

- **Approved by CEC June 2002**
- **Trial workshop October 28, 2002**
  - Meters, thermostats & sensors
  - UCB, LBNL, LLNL invited
- **First proposal funded March 2003**
  - 5 UCB research teams
  - Disruptive technologies (10/10)
WHY START AT UCB?

- **Disruptive (10/10) technologies**
  - Smart dust (integrate more for less)
  - Tiny OS (self-organizing networks)
  - Pico radio (low-power communications)

- **Leverage other funding**
  - DOD (e.g., DARPA)
  - Private Industry (e.g., Intel)
  - CITRIS (e.g., sensor test bed)
Pico radio
Ultra-low energy
(<5nJ/bit)
Ultra-low power
(<100 µW)

TinyOS
Event-based operating system for sensor networks.

Smart Dust
Ultra-small
(<1 mm³)

*this slide provided by Cliff Federspiel, UCB
INITIAL APPLICATIONS

- Long lead-time items
  - Meters
  - Thermostats
  - Appliance Sensors (future)
  - Distribution Line Sensors (future)
- Simplest to define
  - Straightforward specifications
GOALS OF A “10/10” METER

- Installed costs of <$50
- Flexible communications capability
  - Cannot be “stranded”
  - Compatible with water and gas metering
- Support for dynamic tariffs and DR
- System Platform capable of supporting
  - Sensors
  - Actuators
  - Communications Links
GOALS OF A “10/10” STAT

- Installed cost <$30
- Communications range 10-300M, efficient wireless network
- Easy installation
- Scavenge Energy for operation
- Support for dynamic tariffs and DR
- Increased functionality, humidity, comfort, etc.
- Clear and intuitive user interface
 INITIAL SUBCONTRACT

◆ Integrate silicon-based radio, computer, memory, sensors, and power supply into one chip

◆ Research Team
  - Ed Arens, Cliff Federspiel (Architecture, buildings)
  - David Culler (Intel, TinyOS)
  - Jan Rabaey (BWRC, Pico radio)
  - Dick White (BSAC, sensors), Kris Pister (Smart dust)
  - Paul Wright (ME department, energy scavenging)
Specific UCB technologies

1. PicoRadio
   Low Power
   FBAR-MEMS

2. Tiny-OS
   Flexibility
   Sensor nets

3. energy scavenging

4. BSAC
   Sensors

5. SmartDust
   MEMS

6. Demand Response Platforms
   Thermostats
   Meters
1.) PicoRadio Project (Rabaey)

- DARPA originated project in 1998
- Low power radio: Version 1

Figure 15: Injection Molded Final Product
PicoRadio Project Version 3

- A digital network processor chip (4mm x 4mm in size)
- An analog RF front-end chip with transmitter, receiver, amplifier and filters (1mm x 1mm in size)
- 4 FBAR resonators (MEMS devices from Agilent) (0.2 x 0.4mm each)
- Flash memory (6mm x 9mm)
- A temperature sensor
- Voltage regulator or DC/DC converter
- Super-capacitor for support of Energy Scavenging
PicoRadio Project

**Summary: how PicoRadio relates to DR**

- Over the next two years (to 2004/5) platforms will integrate the above sub-components using high-density fine pitch interconnection technology
- CMOS radio with MEMS FBAR resonator means very low power – very cheap (10x10)
- Will operate from Energy Scavenging (>10yr life)
2.) Motes + TinyOS (Culler)
3.) Energy Scavenging with Piezoelectric Bimorphs (Wright)

Piezoelectric generator

![Image of piezoelectric generator and circuit diagram]

6/04/03 DR Enabling Technology Development Project
MEMS Capacitive Generators

In-plane, overlap type:
Capacitance changes by changing overlap area of fingers.

In-plane, gap closing type:
Capacitance changes by changing gap between fingers.

Out-of-plane, gap closing type:
Capacitance changes by changing gap between two large plates.
4.) BSAC Sensors (White)

- Current
- Voltage
- Temperature
- Occupancy (optional)
BSAC Motes + Sensors

- Mica Board
- Basic Sensor Board
- 1 Degree Accuracy Thermistor
- Fused Deposition Modeling (FDM) Casing
5.) MEMS & SmartDust

- MEMS chip 3-axes
- CMOS - 2x2 mm
- 900Mhz

Diagram:
- XL
- Multiplexer
- X, Y, Z
- ADC
- μP
- RAM
- RF Tx
- RF Rx
- Battery or Energy Scavenging

Bright Future

- The approximate cost of semiconductor manufacturing today gives an integrated approximate cost-estimation method that
  \[ 1 \text{ sq. mm. Silicon} = 10\text{cents} \]
- In 2004/5 PicoRadio will therefore cost about $10, plus another $10 for the capacitor etc. By 2008, costs will reduce as research naturally evolves towards CMOS and MEMS-based systems.
September 2003 Demonstration

Temp Nodes

MicaMote  BlueMote

Interface

September ‘03 Demo
New Thermostat

Energy Source

“Scavenging”
Vibration/Solar

FDM Packaging of Thermostat

Control Implement

PicoRadio3 + Agilent
FBAR resonator + OS
COMPANION DR PROJECT

- Large Commercial and Institutional (LC&I) DR Demonstrations and Case Studies (Mary Ann Piette, LBNL)
  - Stake in the ground study to establish state-of-the-art DR capabilities and R&D needs
  - Send a dynamic tariff to LC&I buildings
  - Determine automatic DR capability
  - Report results in a form that will help make policy and R&D decisions possible
TECHNICAL ADVISORY COMMITTEE (TAC)

- Joe Desmond (Infotility, real-time messaging)
- Joe Hughes (EPRI/E2I, industry standards)
- Roger Levy (consultant, business processes)
- Belvin Louie (PG&E, meters)
- Don Pezzolo (consultant, communications, thermostats)
- Mary Ann Piette (LBNL, buildings, energy monitoring)
FUNDING MECHANICS

◆ Research Opportunity Notices (RONs)
  - Meters (posted 10/02)
  - Thermostats (posted 10/02)
  - System Integration (posted 6/03)
  - Network Management (posted 6/03)
  - Technology adoption (may be posted late 2003)

◆ Proposal Process
PROPOSAL TOPICS

◆ Meters & Thermostats
  ◦ Silicon radios (e.g., LLNL microwave)

◆ System Integration
  ◦ Complimentary to CEIDS & DOE GridWise
  ◦ Collaborate with California utilities

◆ Network Management
  ◦ Collaborate with industry (e.g., Cisco)
PROPOSAL STRATEGIES

- One RON
- Part of one RON
- Combine RONs (e.g., UCB proposal)
- Combine pieces of different RONs
- Collaborate
- Leverage funding
- Start with R&D design phase (<$250 K)
RESEARCH OPPORTUNITY NOTICE (RON)

- RONs are posted at CIEE website in PDF file format and presented at semi-annual workshops
- 8-10 weeks to get through funding process from receipt of proposed tasks
**PROPOSED R&D TASKS**

- **R&D tasks should be informal proposals**
  - < 5 written pages or
  - < 30 presentation slides

- **Discuss R&D ideas with Ron Hofmann and Gaymond Yee before submitting**
Separate TACs for each RON
Reviewers may sit on more than one TAC
Provides review
3 possibilities
- Recommend
- Suggest changes
- Reject
SUGGEST REVISIONS & TEAMS

Key elements
- Multi-disciplinary
- Collaboration
- DR relevance

3-8 year timelines
- Medium term
- Long term

Annual milestones

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- Multi-disciplinary
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Annual milestones
RECOMMEND TASK R&D FOR FUNDING

- DR ETD Project Manager
  - Gaymond Yee
- DR Program Advisor
  - Ron Hofmann
- CEC Contract Manager
  - Laurie ten Hope
REJECT

- Doesn’t address open DR ETD RONs
- Isn’t multi-disciplinary
- Isn’t collaborative
- Can resubmit new proposed R&D tasks after discussions
CEC APPROVAL

- Laurie ten Hope (CEC Contract Manager)

RON

- proposed R&D tasks
- TAC review
  - reject
  - recommend for funding

suggest revisions & teams

CEC approval
- task funding

reject

recommend for funding
Maureen Barnato (DR ETD administrator)

Formal procedures to be posted at CIEE website

For UC, it’s a familiar process

- RON
- proposed R&D tasks
- TAC review
- reject
- recommend for funding
- CEC approval
- task funding
- suggest revisions & teams
DR ETD TEAM

- **Project management**
  - Gaymond Yee

- **Task administration**
  - Maureen Barnato

- **Information website**
  - [http://ciee.ucop.edu/dretd/](http://ciee.ucop.edu/dretd/)
REMAINING AGENDA

- Roger Levy
  - meters and prices
- Alexandra von Meier
  - power delivery system
- Gaymond Yee
  - research opportunity notices
- Ron Hofmann
  - Q&A and closing remarks