Demand Response Electrical Appliance Manager

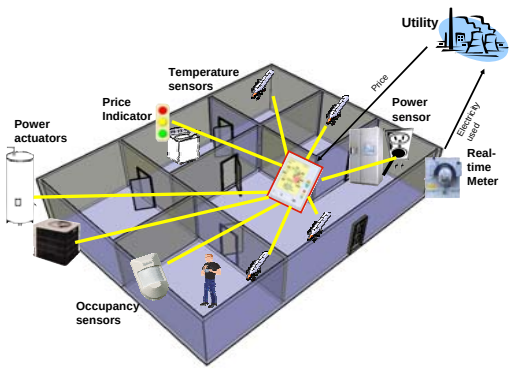
User Interface Design, Development and Testing

Prof. Edward Arens, Architecture
Charlie Huizenga, Research Specialist, CBE
Graduate Students: Therese Peffer
Anna LaRue, Xue Chen, and Jaehwi Jang
Alex Do, Ken Langford, and Colleen Whitney

Background

In order to reduce peak electricity loads, California utilities are considering demand response pricing which entails charging a dynamic rate per hour instead of the current static tiered rate. Our goal involves developing technology to enable this paradigm within the residential market.

The Demand Response Electrical Appliance Manager (DREAM) is the central control and user interface hub for the distributed wireless network that is the framework of UC Berkeley's demand response enabling technology endeavor. The DREAM replaces the typical residential programmable setback thermostat and adds several demand response functions. This device uses multiple temperature sensors and occupancy sensors to optimize comfort and energy consumption. The DREAM receives and displays the current and forecasted price of electricity as well as past and current energy consumption. It can control other appliances as well as let the user know the current cost of running a specific appliance.



Problem Statement

The electrical demand of a California residence can increase in the summer months by 50% to nearly 100% compared to the rest of the year. Electrical utilities attribute at least 15% of the summertime peak load to residential air conditioning, but refrigeration and miscellaneous loads such as clothes washing/drying and television/computer use also contribute.

About half of the households in California have air conditioning, mostly homes in the Central Valley. This number is increasing rapidly due to new home construction in the interior region of the state as well as increasing demand even in milder climates.

Thermostats

Approximately half of the households in California have programmable thermostats, which have been required in new houses as an energy savings measure for the past 20 years. However, only about half of these households use the energy saving setback features of the thermostat. A recent informal survey indicated that some people found the thermostat difficult to program, while others found that the thermostat wasn't flexible enough to accommodate their changing schedules.

Popular Comfort Thermostat:

Easy to use, but no programmable setback for energy savings

Popular Setback Thermostat:

Sometimes programming is difficult or too rigid to allow for changing schedules.

DREAM prototype:

Combines ease of use of comfort thermostat with smart flexible control system.

DREAM Goals

The DREAM consists of a controller, a user interface, and multiple wireless sensors and actuators to accomplish the following functions:

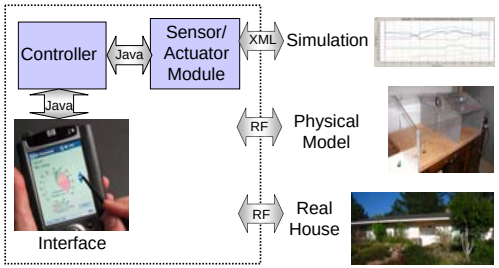
Pricing and Billing

- receive daily changing price signals from an electrical utility
- display current price and 24-hour price forecast
- display current price on appliances and current cost to run
- display projected bill against budget allocated towards bill
- display current and aggregated electricity usage and cost

Temperature and Ventilation Control (setback thermostat)

- sense temperature at multiple locations via wireless sensors
- display indoor and outdoor temperature
- automatically control residential HVAC equipment
  based on price and occupancy
  based on occupant temperature preferences
- program set to optimize for budget or set by preferences
- manual control of residential HVAC equipment (fan only etc)
- hold current temperature or switch to away mode
- override current temperature

Control of simulated, model, or real houses



- optimize HVAC equipment by adapting to house parameters such as size and mass by learning heating and cooling decay rates
- optimize thermal comfort vs. equipment electricity consumption by learning occupancy thermal preferences and patterns

DREAM Interface

For a class project, four graduate students developed and tested a graphic user interface for the DREAM.

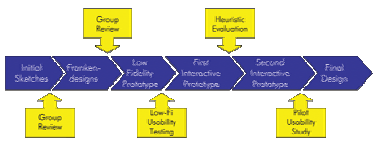
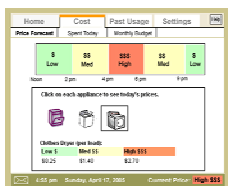
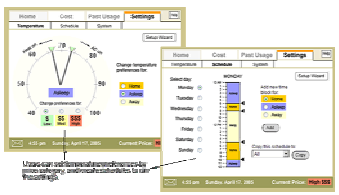


Diagram by Alex Do

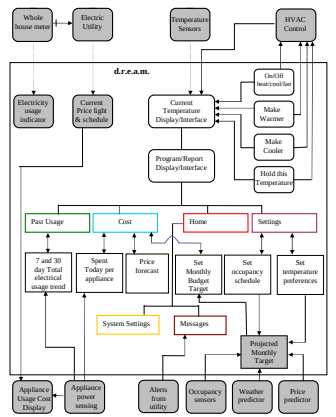
We developed a paper prototype, tested with subjects, proceeded with a Java-based prototype which underwent evaluation, and then a final Java-script/html prototype for a second user test.

The final design incorporated the user-friendliness of the comfort thermostat, and added wizards and help videos to walk the users through the unfamiliar features of this demand response device. Below left is the cost feedback page and right is the setting screen for temperature and schedule.





DREAM Interaction Flow Diagram



While not all features of the DREAM were implemented for this test, we used the above flow diagram to plan for the final prototype. The next step is to implement the design with Java and continue user testing.

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Center for the Built Environment
390 Wurster Hall
University of California
Berkeley, CA 94720-1839