Demo Abstract: eHome: An Cyber-Physical Energy-aware Smart Home System

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Abstract

⓪punchlineIn this demonstration, we look at modern residential buidlings entirely as a cyber-physical energy system and propose a smart home system called *eHome* that incorporates both embededing sensing and networked information processing. eHome correlates the sensors and acutators and serves as the intelligent agent of the home energy and control flow. Our system includes distributed generation (DG), smart energy management with appliance load identification, estimation and usage monitoring, hardware controller as well as mobile and social platform. Together, and by combining embeded sensing and trending information input (e.g., time-of-use pricing and internet wheather data), eHome can bring "ambient intelligence" in the home as well as a challenge towards zero-net energy building (ZNEB). We propose the eHome design architecure and discuss some general implementation considerations. A prototype was implemented that includes DG, sensing, and monitoring, demonstrating the promise of our system.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; D.2.8 [**Software Engineering**]: Metrics—*complexity measures, performance measures*

General Terms

Cyber-Physical System, Building Energy Management

Keywords

Smart Building

1 Introduction

①Why home energy efficiency is important? According to U.S. Department of Energy buildings energy data book, buildings account for 40% of U.S. energy comsumption, of which 54% is cost by residential building. Over the years, technological advances have helped to make home a more comfort and secure place to live that consisting of interacting heating exchange, airflow, water, saftey, access/security and movement control subsystem, but at the same time cost more and more energy.

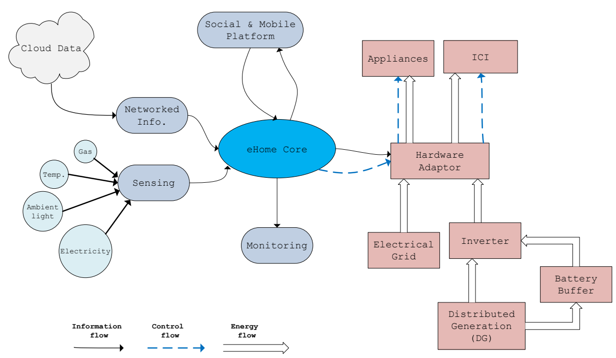

Figure 1. System Architecture

②DG and embeded senisng One way to reduce the energy is by adopting distributed generation (DG) from many small on-site energy sources deployed at homes [2]. While DG uses renewal wind and solar energy sources which can not satisfy the building energy demands at any time for most of cases. Many homes still rely heavily on the power grid. The growing in the energy demand and the lack in consumption transparency make it difficult to conserve energy. However, the advance of MEMS technology and microprocessors enable us to perceive the state of physical appliances and reason about this state using artificial intelligence techniques and then take actions to achieve specific goals all by networked sensors and actuators.

③my design We present eHome, a smart energy-aware system. It's core plays the role of an intelligent agent [1], which collects the raw data from sensors then analyzes and extracts relevant information. The energy usage and monitoring is based on the sensed data, as well as load estimation, which is used for balancing DG battery buffer and electrical grid supply. eHome also includes networked information and learnt behavioral patterns to better tune control systems for energy efficiency.

2 System Architecure

Figure 1 depicts the general architecture of our smart energy-aware system. The eHome core module, intelligent agent, records the home's aggregated device-level energy

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consumption (e.g., gas, electricity) and enviromental parameters (e.g., temperature, ambient light) and stores them in database. Also, it will stream the networked information from internet (e.g., Weather data, time-of-time energy prices, Google Calendar activities). Combining with historical data, such information enables us for energy load forcasting within next 24 hours as well as to better tune control systems. The monitoring module will server as data presentation and support simple statistic viewing and comparsion. eHome integrates the social and mobile platform module, where socilization within home could be achived by posting, twittering or finding matches of daily sensed signals. The mobile platform can be used to visual energy uage and performing user-induced operations as well.

From energy flow point of view, a large majority of our home appliances is relied on electrical grid, while DG had been used to power on ICIs (Information and Communications Infrastructure) as well as to eliminate grid demand peaks based on our networked information. A home battery storage can be used as a buffer to encouter lost of renewable sources, or not hindering user consumption patterns during time of demand peaks.

3 Implementation

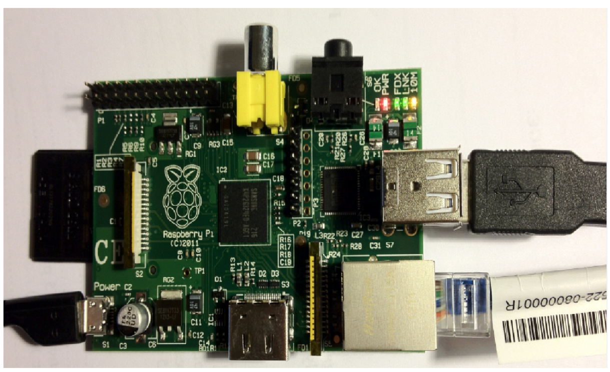

Figure 2. eHome Core: Raspberry Pi

Our system is mainly implemented on low-cost energy efficient single-board computer, off-the-shelf sensors, and open-source hardwares and softwares. We use an recently ARM based single-board computer called Raspberry Pi (Rpi) [1] to sever as eHome core. The Rpi model B has 256MiB memory and an ARM11 700MHz CPU sitting on it, runs on a fully controlable Arch Linux ARM [2] system. For the energy monitoring part, we use *emoncms*-a powerful open-source web-app for processing, logging and visualizing energy, temperature and other environmental data from the open-source energy monitoring project *OpenEnergyMonitor*[3]. For data acquistion, there is always a balance between a single sensor solution to multi-sensor solution. Single sensor is usually installed close to the household meter, i.e., smart meters. This makes it easy to deploy but without any explicit device-level consumption available, which often need addtional traning and calibration. The multi-sensor solution would have high cost and more time for installation but gain more accurate energy usage readings. In our experiments, multi-sensor solution has been used. E.g., we use JeeNode v6 from JeeLab [4] for electricity and gas metering, TI TMP421 temperature sensor on Arduino[5] for temperature sensing, and GA1A1S201WP surface-mount sensor for ambient light. Figure 2 shows the temperature sensor on Arduino and the temperature sensed for a single day.

We use a three 15 watt solar panels conntected with a 12 volt DC storage battery for energy harvesting with 300 watt power inverter, the peak output power is 45 watts, which is enough for powering most of ICIs. Figure 4 shows the daily energy consumption using *emoncms* which use both DG and electrical grid.

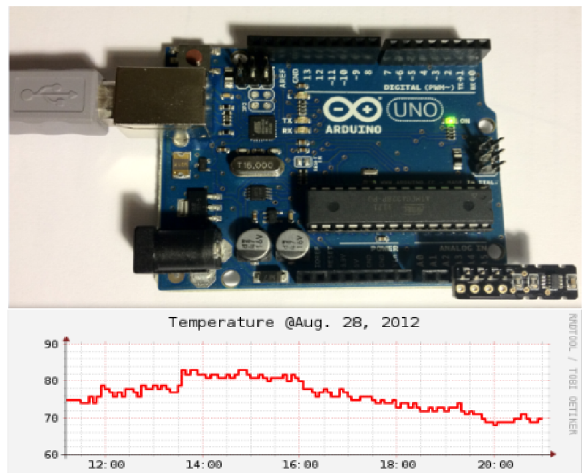

Figure 3. eHome Temperature Sensing on Arduino

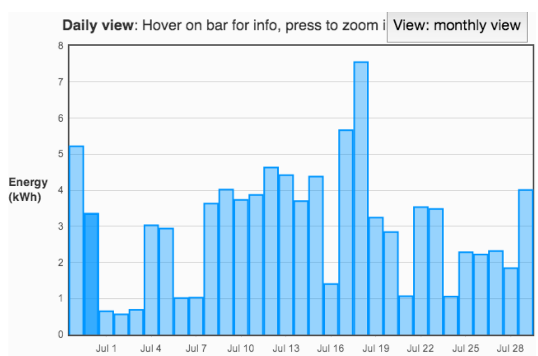

Figure 4. eHome Energy Consumption Monitoring

4 References

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