Reference Design for Residential Energy Gateways

Enabling Technologies Development Workshop

September 14, 2010

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Presentation Outline

- Introduction
- Gateway Overview
- Reference Design Objectives
- Reference Design Specifics
- Future Work

Introduction

Why do we need a Residential Energy Gateway?

- Loads within the home are essentially unmanaged, substantial savings could be reaped
- The nature of future residential loads (PHEVs) is not fully known and management of these loads is important as to not overtax the grid
- Implementation of residential demand response
- Increase level of home automation
- Educate/Involve consumer in home energy management

Introduction

Why do we need a reference design?

- Current Gateways lack communications over multiple mediums (ZigBee, Wi-Fi/Ethernet, Zwave)
  - HEN elements communicating over ZigBee will not communicate directly with Wi-Fi/Ethernet HEN (Home Energy Network) elements
  - This is burdensome to the consumer
- Allows smart appliances of different manufacture to be a part of the HEN
- This provides the consumer with more options

Reference Design Objectives

Essential Gateway *Functions* Include:

- Communicate with an outside entity to determine the current and/or future cost of electricity and system status (normal, emergency, partial curtailment, etc.)
- Know from previous communication with the resident(s) how to prioritize various load usages against price, time-of-day, day-of-the-week, weather, etc.
- Communicate with an electric meter (either the revenue meter or a separate meter) to determine current whole-house electricity usage.
- Communicate with electrical loads (appliances) to control or suggest current and/or future operation.
- Communicate with loads to determine power usage.
- Display relevant information to residents.
- Accept input from residents to change (override) current operating conditions.

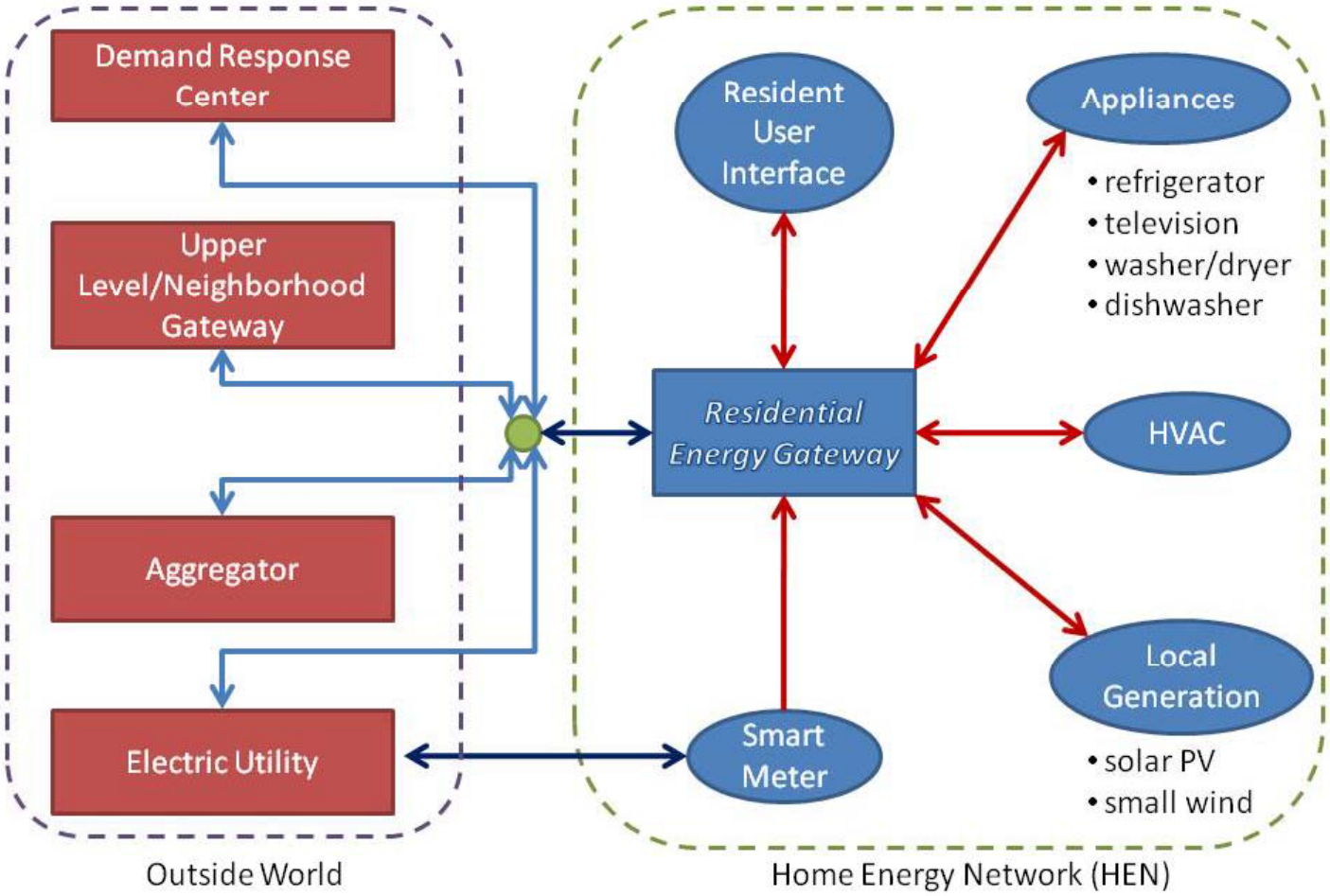
Reference Design Objectives

Essential Gateway *Requirements* Include:

- Have all of the major components that a commercial gateway would need,
- Show that it operates and performs the energy management functions needed for "smart grid" concepts currently being developed,
- Run on a computationally modest enough platform to prove economic viability for a commercial product,
- Have strong modularity so various organizations can work independently,
- Demonstrate connectivity using several networking media,
- Provide for secure operation,
- Be field upgradeable for core software upgrades as well as addition of new modules,
- Provide flexibility for various user interface options.

Reference Design Objectives

Residential Energy Gateway Reference Design



Reference Design Objectives

Gateway Project Overview

- Phase 1 (July 2009 – Jan. 2010): Develop a conceptual reference design to demonstrate feasibility.
- Phase 2 (Jan 2010 – Oct. 2010): Develop a working prototype and simulate/test Gateway functionality.
- Phase 3 (Oct. 2010 – Oct. 2011): Using the Gateway as a test bed, investigate advanced issues related to residential load management.
  - Control strategies based on demand response
  - Refine web-UI

Reference Design Issues/Assumptions

Centralized vs. Distributed System

- Should the Gateway physically reside within a single device (such as a computer, or router-like device)?
- Should the Gateway reside within individual components of the Home Energy Management System (such as appliances and the advanced meter)?
- A distributed system could realize most, if not all, of the desired Gateway functionality.

Reference Design Issues/Assumptions

The Advantages of a Centralized System

- Optimization within the residence is a possibility.
- It is not necessary to require appliances to communicate with the outside world, individually. Doing so would be difficult as there is no guarantee that a single communication standard will emerge nationwide, this will increase the complexity for all appliances rather than just for the gateway.
- There is a central user (resident) interface, rather than having separate interfaces on each appliance. In this configuration, setting user preferences (how to respond to price changes, for example) does not require running around to all of the appliances and using a different user interface in each for that purpose.
- A single user interface would greatly increase user education possibilities, generally regarded as an important part of modern energy management.

Reference Design Issues/Assumptions

Operating System

- If mass quantities are produced, a royalty free OS would be a logical choice, such as Linux or freeBSD
- Cisco routers utilize VxWorks as an OS, widely available
- Netbooks can utilize Microsoft Windows or Linux
- Some communications protocols, such as ZigBee, may not be compatible with Linux
- Given this constraint, the application software should be written in a way that it is easily portable from one OS to another

CHOICE: Arbitrarily choose OS for development, however, write code that is OS independent

Reference Design Issues/Assumptions

Software Application Language

- Compiler type languages: C, C++, C# and Java
- Scripting Language: PHP, Javascript, Python
- Scripting languages are easier to use, but lack the organization and execution efficiency of compiler-type languages
- Of the compiler languages, C++, C# and Java are object oriented (OO)
- C++ probably has the most efficient execution and smallest footprint, although Java is the most portable

CHOICE: Java, for the factors listed above and the presence of a large developer's community and widely available packages for mathematics, GUIs and networking.

Reference Design Issues/Assumptions

Software Framework: Open Services Gateway Initiative (OSGi)

- Writing the application software completely from scratch is not feasible given the time constraints on this project.
- OSGi is a software framework which supports a dynamic module system for Java
- Software originally intended for home automation market
- Software framework is incorporated into reliable IDEs, which includes support for creating OSGi bundles
- OSGi supports a run-time environment in which bundles can be installed, uninstalled, etc. independently of one another
- OSGi bundles are created using a relatively simple Java interface
- OSGi software framework is widely (but not fully) supported in various industries (a full list is available here: http://www.osgi.org/About/Members)

Reference Design Issues/Assumptions

Communication Protocols

- Perhaps the most sensitive part of the project, as all interested parties will need to adopt uniform communication protocols to communicate with the Gateway
- Possible communications protocols include: Ethernet, WiFi, IEEE 802.15.4 (ZigBee), Pager, Cellular networks, radio frequency communications.
- ZigBee is possibly the best-known standard built on IEEE 802.15.4
- PG&E,SDG&E and SCE meters support communications based on ZigBee
- Although ZigBee adoption could be difficult considering membership and licensing fees
- Given the need to gather internet based information, the Gateway must include standard internet and wireless communications

CHOICE: ZigBee & Wi-Fi/Ethernet for development

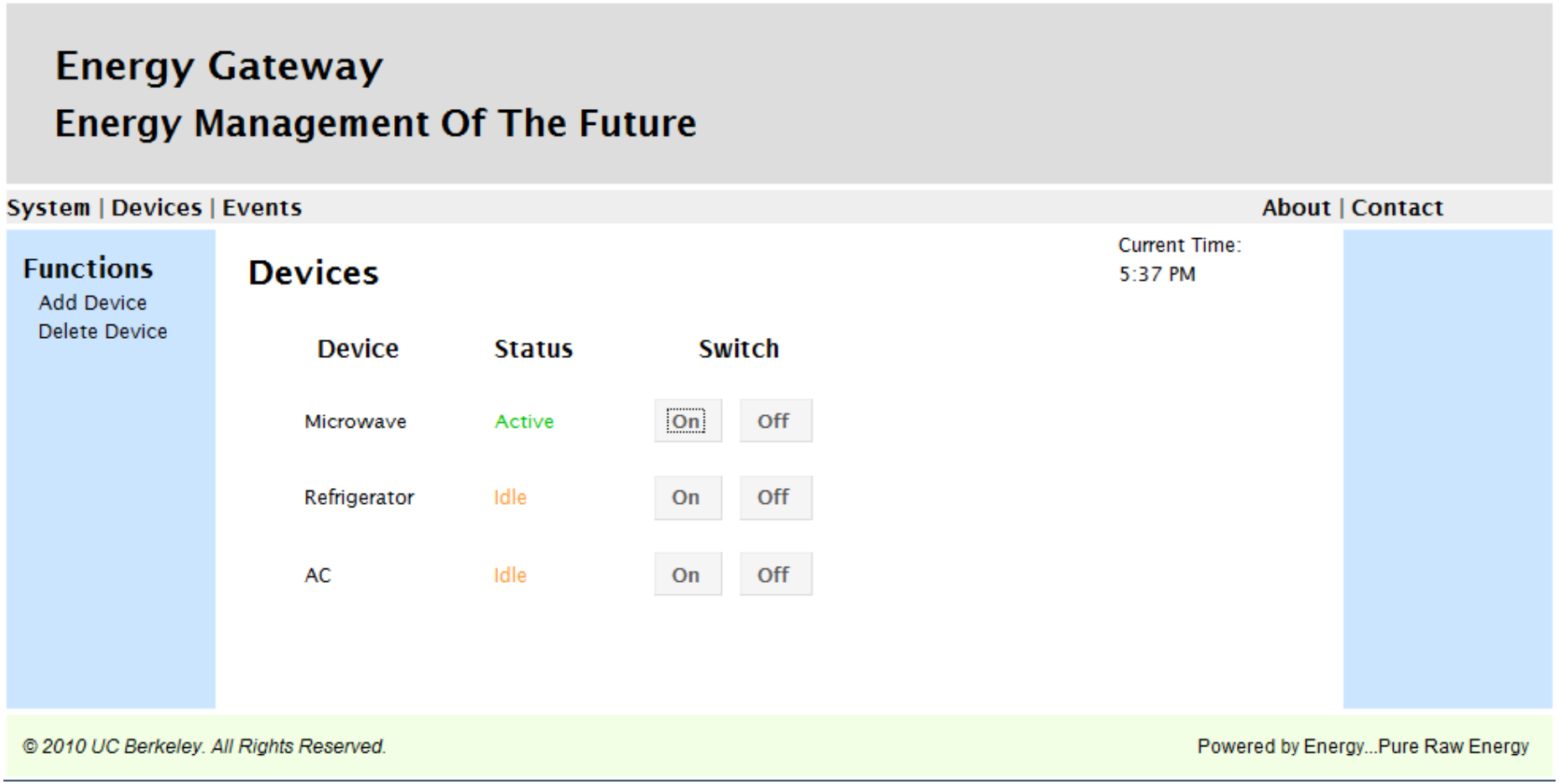
Current State of Reference Design

Gateway Bundles

- Wi-Fi/Ethernet bundle: facilitates a network socket connection between the Gateway and a simulated appliance
- ZigBee bundle: facilitates a connection over a generic ZigBee stack to a simulated appliance
- Open Automated Demand Response (OpenADR) bundle: connects via internet to Akuakom Demand Response Actuation Server (DRAS), obtains and parses DR information
- Control bundle: based on DR information, takes appropriate action to actuate appliances
- Web UI bundle: controls lifecycle of Gateway web user interface, provides the resident with “opt-in” or “opt-out” capability, allows for the installation of new simulated appliances

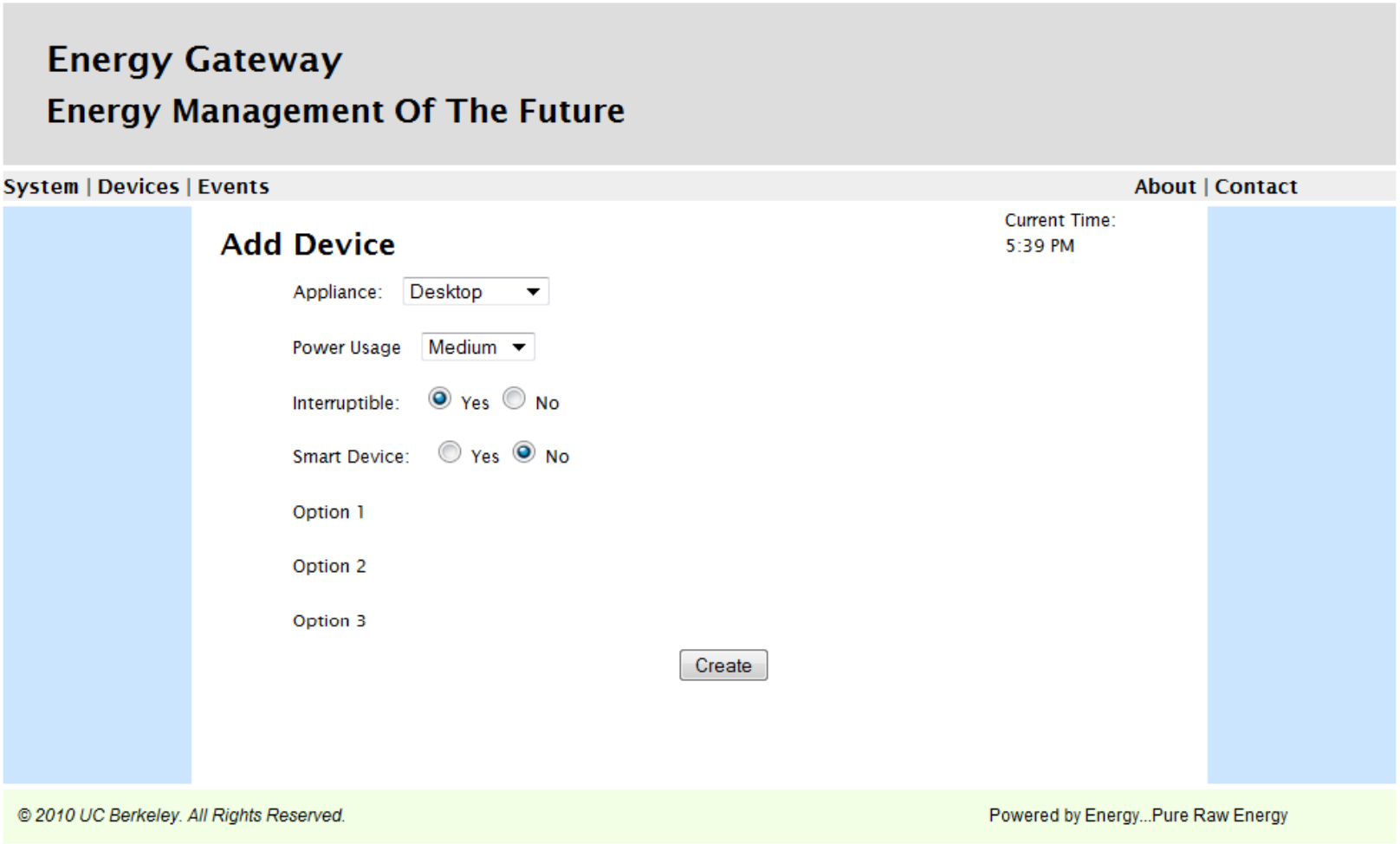
Current State of Reference Design

Website User Interface



Current State of Reference Design

Website User Interface



Current State of Reference Design

Website User Interface

Current State of Reference Design

Outstanding Issues

- Appliance registration: when connecting a physical appliance to the Gateway, we must ensure that the proper appliance is paired with the proper Gateway. We envision a procedure similar to that used by Bluetooth devices.
- Information security: must ensure that data transmitted via the Gateway is secure
- Limp-home mode: in the event of failure of the Gateway, we must ensure that the HEN continues to operate (the presence of the Gateway does not hinder the resident)
- Data management: since the Gateway will be deployed on a computationally modest platform, efficient data management is crucial

Questions

For more information, please visit
http://mechatronics.berkeley.edu/gateway.htm

Gateway Web UI pictures created by Kevin Ding