Partnership for Innovation
An Open-source Hardware/Software Solution

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PPT slides will be available at
www.saifurrahman.org
INNOVATION: Why it is needed

- Problem is not easily understood
- Problem is multidimensional
- Problem requires many resources
- Solution needs to be multidisciplinary
- Solution requires university-industry collaboration
- Solution requires end-user participation

Electric Power Sector Challenges

- Peak Load Reduction
- Energy Efficiency
Inefficiency in Electricity Consumption

- Peak load exceeds 16,000 MW only 5% of the time
- Peak load of 19,140 MW

Peak Load and its Duration

- In the US 20% of the load happens only 5% of the time
- In Australia 15% of the load happens less than 1% of the time
- In Egypt 15% of the load happens only 1% of the time
How is the peak load managed in the US today

**Electric Utility – Smart Cooling Rewards ($40/year)**

Utility installs an A/C cycling switch on home outdoor cooling system

- AC Cycling Switch
- Testing the AC Cycling Switch
- Installing the AC Cycling Switch
- AC Cycling Switch Installed
Drawback of the Current Approach

- Air conditioning is turned off when needed the most
- Homeowner has no control after the initial consent

Proposed Solution

- Electric utility sends a signal through the smart meter or home internet gateway
- Home Energy Management (HEM) system optimizes appliance/equipment operation to provide the peak load reduction requested, but maintains customer comfort
- The homeowner gives the utility the peak load saving it wants, but on his/her own terms

Virginia Tech Solution

Control multiple non-critical loads
Example of Load Priority and Preference Settings

<table>
<thead>
<tr>
<th>Load</th>
<th>Water Heater (WH)</th>
<th>Space cooling (AC)</th>
<th>Clothes Dryer (CD)</th>
<th>Electric Vehicle (EV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1. Priority setting</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>#2. Preference setting</td>
<td>110-120°F</td>
<td>76°F (±2°F) Not to exceed 85°F</td>
<td>Finish the job by midnight</td>
<td>Fully charged by 8AM</td>
</tr>
</tbody>
</table>

Home Energy Management Unit Setup

- External control signal from a utility
- Demand limit (kW)
- Gateway
- Distribution board & meter
- Load Controller
- Data communication & control signal
Web Services for Demand Response Applications

Utilities Control Center

Smart meter

Firewall

Internet

Web services

DR signal from utility

Appliances

HEM = Home energy management system

HEM User Interface

Seen on an iPad

Virginia Tech Home Energy Management System

HEM = Home energy management system
Utility-Industry Partnership

Electric Utility:

Dominion Virginia Power

High-tech small manufacturers:

AMTI  EIT  IWT

Advanced Manufacturing Technology, Inc. (AMTI)
EIT, LLC.
Innovative Wireless Technologies (IWT)

From the Residential to the Commercial Sector
Energy Efficiency Issues

- Buildings are responsible for over 40% of the total energy consumption in the U.S. A large majority of these have no building automation systems (BAS).
Breakdown of Electricity Usage

Improve energy efficiency and facilitate demand response applications.

Three major loads in buildings:
- HVAC
- Lighting loads
- Plug loads

Electricity use in buildings

Source: EIA - Commercial Building Energy Consumption Survey (CBECS)
http://www.eia.gov/consumption/commercial/data/2003/index.cfm?view=consumption#e1a

Study Diverse Building Types

- VT Architecture building, Alexandria, VA
- Long Branch Nature Center, Arlington, VA
- VT building, Blacksburg, VA

Map of Virginia showing locations.
Virginia Tech Architecture Building

3 floors
15,000 sq ft

Exterior lighting

Entrance to Parking Garage

Long Branch Nature Center in Arlington
Retail/Office Building, Blacksburg

Hardware/Software Deployment for Small Buildings
Software on Various Embedded Devices

- **Raspberry Pi**
  - CPU: 700 MHz ARM processor
  - RAM: 512MB SD
  - Ethernet: 10/100 RJ45
  - USB 2.0: Available
  - Price: $35
  - Size: 3.4”x2.2”

- **beagleboard**
  - CPU: 1GHz ARM Cortex-A8
  - RAM: 512MB SD
  - Ethernet: 10/100 RJ45
  - USB 2.0: Available
  - Price: $55
  - Size: 3.4”x2.1”

- **pandaboard**
  - CPU: Dual core 1.2GHz ARM Cortex-A9
  - RAM: 1GB SD
  - Ethernet: 10/100 RJ45
  - USB 2.0: Available
  - Price: $220
  - Size: 4.5”x4.0”

HVAC Controller Details

- HVAC can be controlled via smart thermostat
  - VTOS
  - Wi-Fi
  - ZigBee
  - Wi-Fi
  - Wi-Fi
Lighting Controller Details (ZigBee/WiFi)

- VTOS
- ZigBee-enabled step-dimmed ballasts - mesh network
- WeMo light switch/Philips Hue communicates with VTOS

Plug Load Controller Details (ZigBee/WiFi)

- VTOS
- Digi XBee smart plugs can form a mesh network
- WeMo smart plugs can communicate via WiFi
Laboratory Setup for Device Discovery Process

Once the discovery agent gets device information, device discovery status is displayed in the User Interface dashboard.
Summary

- **Peak Load Reduction**
  - Simple concept, but innovation is in making it possible without customer discomfort

- **Energy Efficiency Applications**
  - How to attract consumer interest – simplicity in design and applications

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**Thank You**

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