Transactive Whole Homes as Integrated Assets (Connected Neighborhood)

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8/22/2018

Funded by Office of Energy Efficiency & Renewable Energy (EERE), Building Technology Office (BTO)
The Effect of Emerging Technologies on the Electric Grid

- **Over 20 billion** connected devices predicted to be in use by 2020
- There is an immense opportunity for a management system which can **control, coordinate, and shape the power use** of these devices
- **41%** of the energy consumption in the United States is from buildings
- Advanced sensing and controls have the potential to save energy in buildings up to **40%**

The grid needs a **reliable and scalable** energy management system to:
- Enable **communication** and **control** of loads
- Coordinate the effects of growing numbers of **renewable energy resources** and more **sophisticated loads**
- Support **demand response**(DR) via seamless information exchange and control/optimization execution
Project Objective

• This project addresses need for an Open-architecture control platforms for transactive energy ready buildings

• Two architectures are under investigation and will be deployed on two neighborhoods:
  – Alabama (Centralized - large microgrid resources)
  – Georgia (Distributed – generation and storage resources are at each residence)
Alabama Power (Centralized Theme)

STATUS

• Alabama Project has been actively in development since the start of FY17
  1. Neighborhood with 62 homes completed construction
  2. Residential buildings provide HVAC (Carrier) and Water Heater (Rheem) as controllable resources.
  3. All homes currently using VOLTTRON deployments running in the cloud
  4. All homes are using VOLTTRON agents for optimization (testing underway)
  5. Microgrid Hardware Installed and Operating:
     • PV System: 420kW
     • Energy Storage System: 250kW, 681kWh
     • Generator: 400kW
     • Microgrid Controller: ORNL Developed CSEISMIC Controller
Transactive Methodology

• Microgrid controller and VOLTTRON ‘negotiate/transact’ a load/price
• Microgrid controller optimizes resources and creates 24 hour pricing offer
• VOLTTRON allocates price signals to resources (loads) which optimize and provide total load projection
• This process iterates until Microgrid controller meets minimum convergence criteria
### VOLTRON-Based Architecture Applied to Connected Neighborhood

<table>
<thead>
<tr>
<th>Agent</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Home Interface</strong></td>
<td>Data Pass through and collector of optimization and electrical consumption projections for Aggregator agent</td>
</tr>
<tr>
<td><strong>HVAC Interface</strong></td>
<td>Translates HVAC decisions and status to vendor API</td>
</tr>
<tr>
<td><strong>Water Heater Interface</strong></td>
<td>Translates Water Heater decisions and status to vendor API</td>
</tr>
<tr>
<td><strong>HVAC Optimizer</strong></td>
<td>Utilizes building specifications, forecasted weather data, building parameter data, price forecast, and HVAC status data to optimally schedule HVAC and provide expected electrical consumption.</td>
</tr>
<tr>
<td><strong>Water Heater Optimizer</strong></td>
<td>Utilizes predicted water consumption, price forecast, and Water Heater status data to optimally schedule Water Heater and provide expected electrical consumption.</td>
</tr>
<tr>
<td><strong>SoCo Interface</strong></td>
<td>Pulls data from Southern Company API which includes weather, building specifications, historical load measurements by circuit, device credentials, and historical data.</td>
</tr>
<tr>
<td><strong>Aggregator</strong></td>
<td>Distributes price and weather data to all Single Home VMs, and collects optimization results from homes.</td>
</tr>
<tr>
<td><strong>Microgrid Interface</strong></td>
<td>Collects price information from Microgrid Controller (CSEISMIC) and sends info to Aggregator. Collects Load information and sends to CSIEMIC</td>
</tr>
</tbody>
</table>
Optimization and Modeling

- Developed low cost computational models of:
  - Building Envelope
  - HVAC performance
  - Water Heater Performance
  - Water Heater Model.

\[
\text{objective} = \min \left( \sum_{t=0}^{t} \text{Pelec}(t) \times \text{Price}(t) + \sum_{t=0}^{t} \text{Discomfort}(t) \right)
\]
Validation on Hardware

- Yarnell Station actual home in a neighborhood
- Yarnell has been retrofitted to mirror the connected neighborhood homes.
  - Carrier Greenspeed® home comfort system with an Infinity Touch thermostat
  - Rheem hybrid electric water heater
  - SiteSage
- Provides a baseline for establishing the optimization and control framework validation.
- Demonstration of tuned models for optimization and control.
Validation on Software

Test Beds

- Computational Validation Testbed developed
- Testing large scale implementation of the data architecture
- Physical server with 128 cores and 128 GB of memory that be can allocated
- One Virtual Machine per home connected to virtual communication interfaces that simulate device communications and utility interface
Simulation Test Bed

- Device interfaces exist in gui and non-gui format
- Agents displaying information and performing iterations for control and opt.

- On test-bed simulation test on 1, 8, 50 homes.
- Displayed 50+ virtual machines running and communicating.

51 Virtual Machines Simulating 50 Homes
Transactive Whole Homes as Integrated Assets (Connected Homes)
Project Overview

• Develop **Open-Source Home Energy Management System** (HEMS) using VOLTTRON™ as a platform
  – Integrate **existing HEMS** into VOLTTRON™
  – Enable supervisory **control of different loads**
  – Enables the full potential of connected equipment in residential buildings by increasing the flexibility of loads to achieve **improved energy efficiency, reduced energy costs, reduced peak demand, and improved comfort**.
  – Enable **home-level and neighborhood-level aggregation and coordination**
  – Generate an agent blueprint to bring in **variety of devices**
    • Cloud based communication: RESTful API
    • Local communication: CTA- 2045

• **Deliver software and hardware** for end-to-end demonstration
  – Yarnell Station research home
  – Southern Company – Connected Neighborhood
Software Architecture

- **User Interfaces**: Facilitates interaction between the user and the software.

- **Applications and Intelligence**: The implementation of many applications provided by the software is in this layer such as DR, scheduling, notifications/alerts, etc.

- **Framework Services**: This layer provides VOLTTRON platform-centric services, including access to the communication message bus (publish/subscribe), agent services, etc.

- **Communication Technologies and Protocols**: This layer includes various communication technologies and protocols that will be supported by the software.
HEMS-VOLTTRON Integration

General method to transform any HEMS to a Multi-Agent system by HEMS-VOLTTRON integration

If the existing HEMS provides an API, the transformation can be done using the API

If not, the integration between HEMS and VOLTTRON can be done using the machine-to-machine protocol MQTT
Home Assistant-VOLTTRON Integration

- Home Assistant (https://home-assistant.io/) is an open-source home automation platform implemented in Python
- Performed integration using home-assistant API and in a VOLTTRON driver framework
- Extended home-assistant implementation to add support for more devices
- Incorporate optimization into the system
- The code is available at: https://github.com/VOLTTRON/volttron-applications/tree/master/ornl/HomeAssistant-VOLTTRON-Integration-Agents
HEMS System Overview
HEMS- VOLTTRON Integration
Thank You!

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