Developments in CTA-2045 and Grid-Responsive HPWH Controls

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ACEEE Hot Water Forum

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for the US Department of Energy

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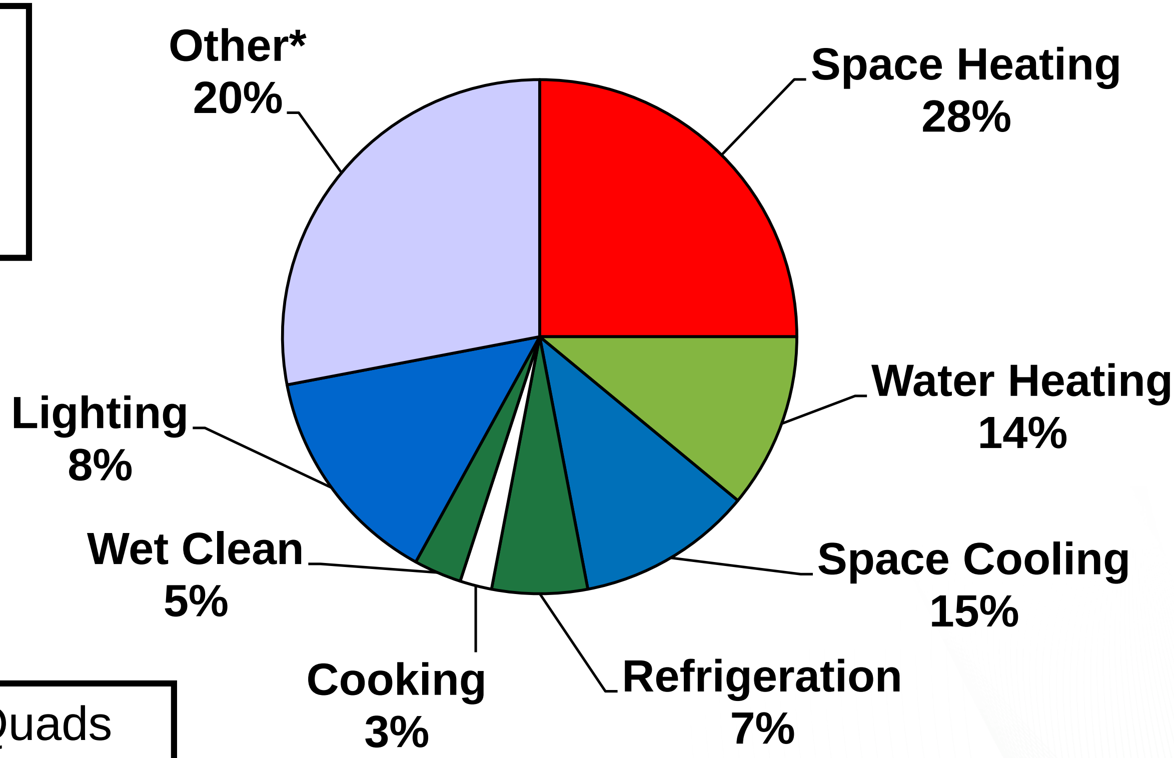
Residential Water Heating Energy Consumption

Water heating accounts for 2.9 Quads of primary energy



Electric – 1.44 Quads
Gas – 1.31 Quads

2015 total consumption: 21.1 Quads

*Televisions, computers, small appliances, electronics

The New Face of Water Heating

Demand Response

Big Data

Construction Codes

Smart Appliances

Future Regulation

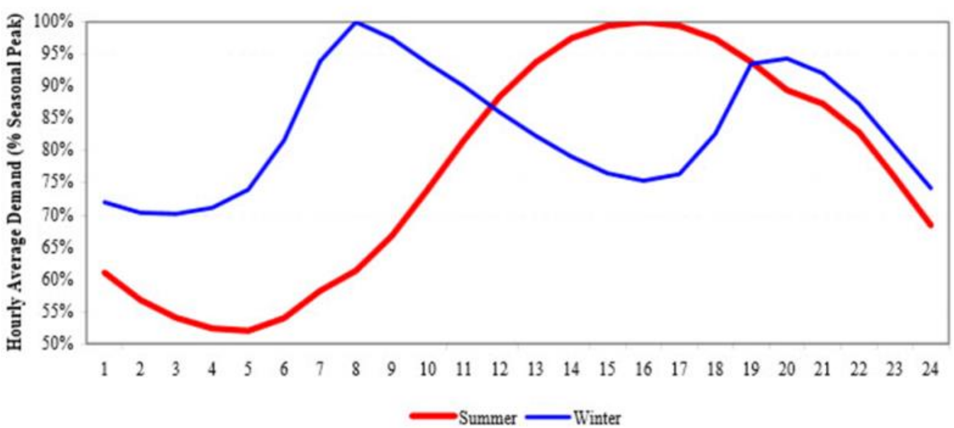
Home Connectivity

Energy Efficiency

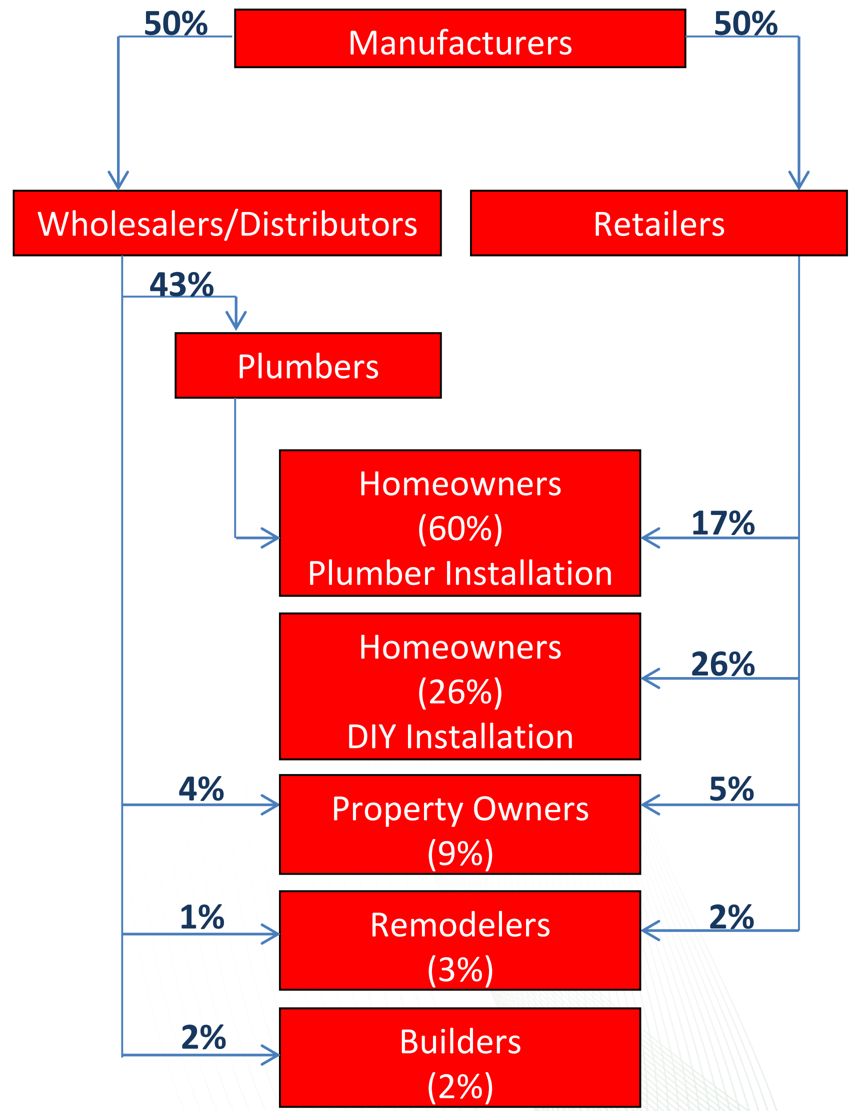
Renewables

Water Heaters – Market Factors

- 50% of water heater purchases are made through “big box” stores such as Home Depot and Lowes
- Most water heaters are purchased by homeowners/plumbers



- Utilities can benefit from HPWHs:
  - Provide load shifting during peak demand periods
  - Curb need for more power plants



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Potential Energy Shifting Capability

- Number of Electric Water Heaters: ~55-60 million[1 2]
- Annual Electricity Consumption of ERWHs: 126,000 GWh[3]
  - If all replaced w/ HPWH (63% more efficient): 47,000 GWh[4]
- Assume full reduction during peak period (so 25% shift-able – 6 / 24 hours)
  - ERWH: 32,000 GWh annual
  - HPWH: 12,000 GWh annual

Daily National Energy Shifting Capability

ERWH:
88 GWh = 25%

HPWH:
33 GWh = 25%

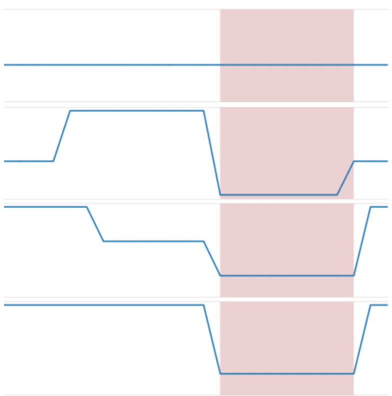
- Footnotes:
  - [1] PNNL estimate
  - [2] LBNL estimate
  - [3] RECS 2009
  - [4] Evaluation of the Demand Response Performance of Electric Water Heaters, July 2014, PNNL, ET Mayhorn, et al

HPWH - Potential Benefits

- Potential benefits to homeowner through higher efficiencies
  - research at ORNL has shown efficiency improvements of 9% with potential for up to 18% using advanced control strategies
- Potential benefit to utilities through load shifting and storing excess renewable energy
  - energy consumption during peak periods can be reduced to zero with minimal or no impact on performance
  - heat water when excess renewable energy is available
- Smart controllers can learn consumer (usage) and utility (peak periods) behavior and develop a strategy for controlling tank temperature to meet needs of both

HPWH Load Shifting – ORNL Test Results

- % of time tank water < 115°F



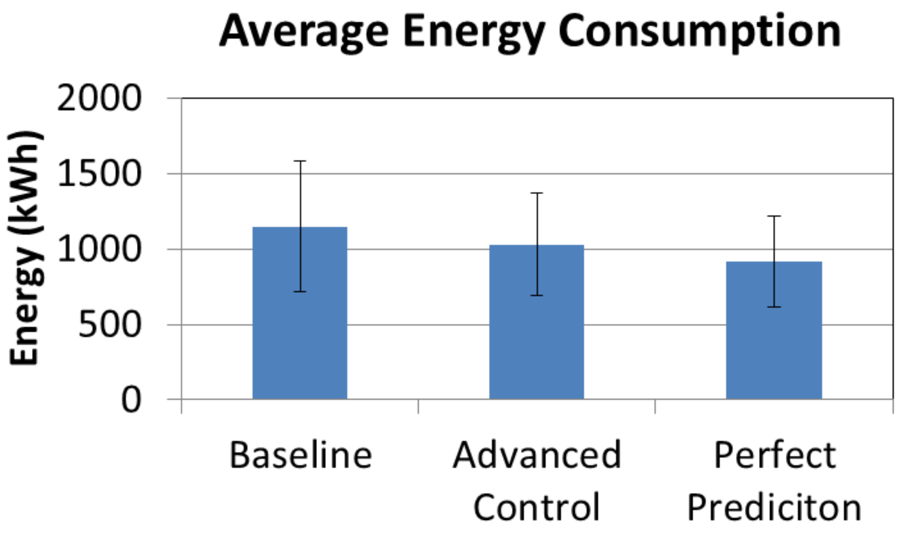
	Low Water Consumption (kWh)	Medium Water Consumption (kWh)	High Water Consumption (kWh)
Baseline	5%	9%	5%
Schedule 1	0%	0%	1%
Schedule 2	0%	5%	1%
Schedule 3	0%	0%	0%

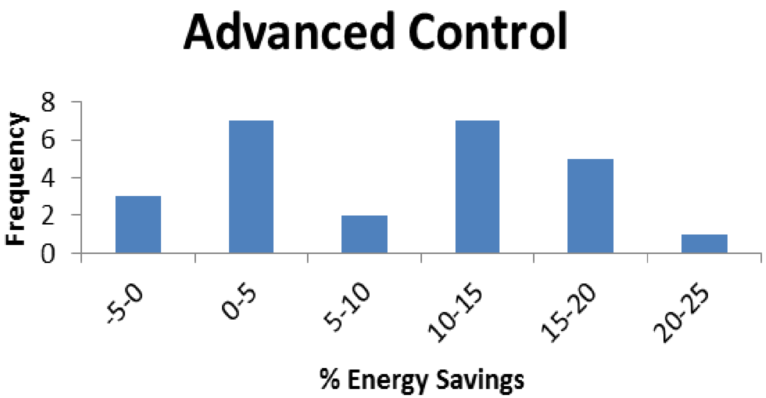
Advanced HPWH Control

- Maximize energy efficiency of HPWH by eliminating electric resistance use with advanced tank temperature set point control.
  - Forecast future water draws
  - Tailor control to homeowner usage and utility requirements
  - Set point control algorithm
  - Input hot water draw data from real homes into HPWH computer models to simulate energy savings from advanced control
  - Spot checked modeled result with HPWH in Lab

Advanced HPWH Control – ORNL Test Results

- 25-home study

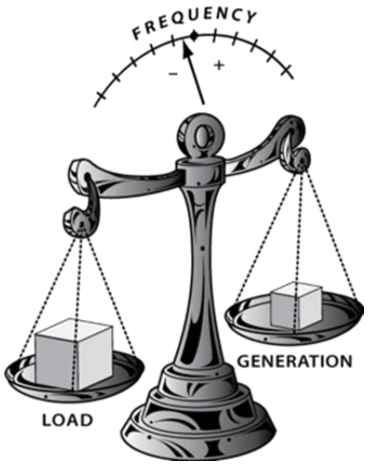




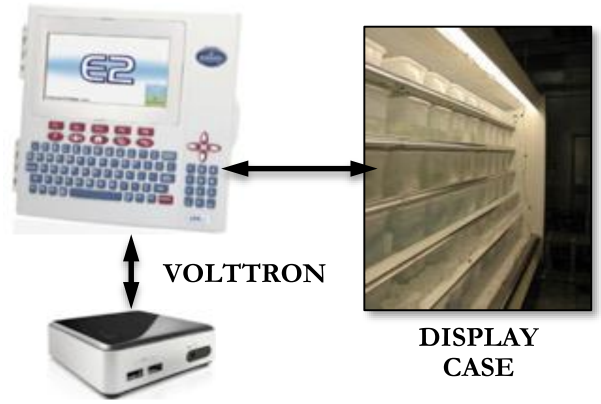
	Advanced Control Savings	Perfect Prediction Savings
Average	8.9%	18.5%
Standard Deviation	7.4%	8.2%
Minimum	-0.8%	3.9%
Maximum	24.4%	39.5%

Transactive Energy – Energy Efficiency & Grid-Responsive

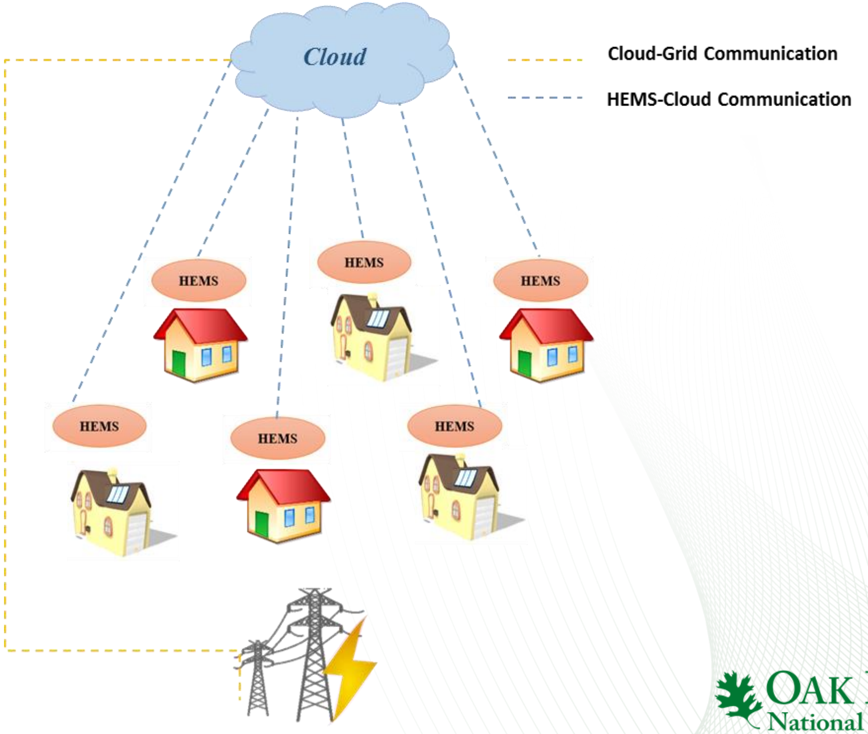
- High-speed wide area control of loosely coupled loads
- VOLTTRON Platform
  - Unlocking load control potential
  - Demonstrated in supermarket application



Buildings projected to be 80% of load growth through 2040



EMERSON
Climate Technologies



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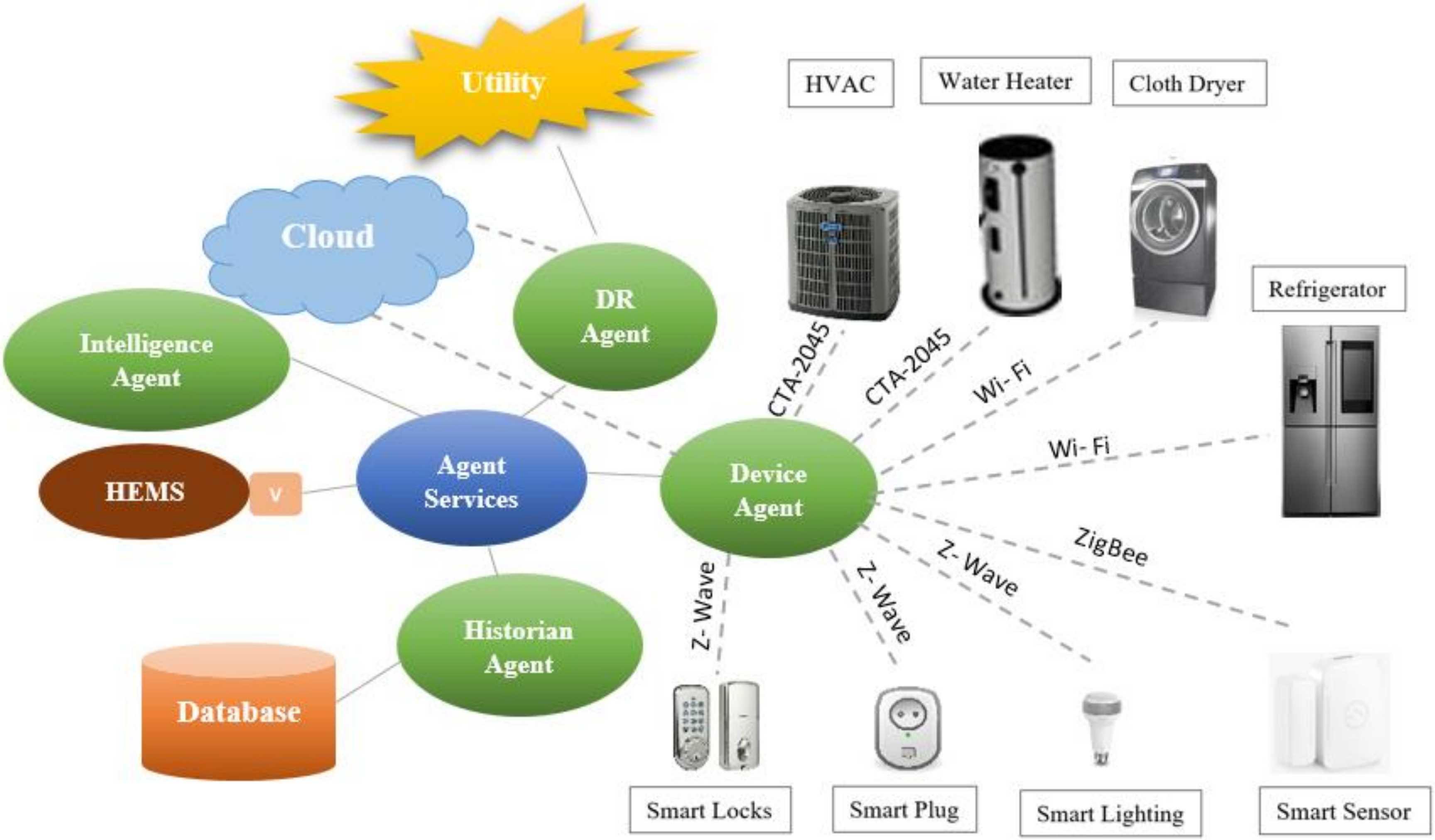
Approach – Using Volttron as the Backbone for Services



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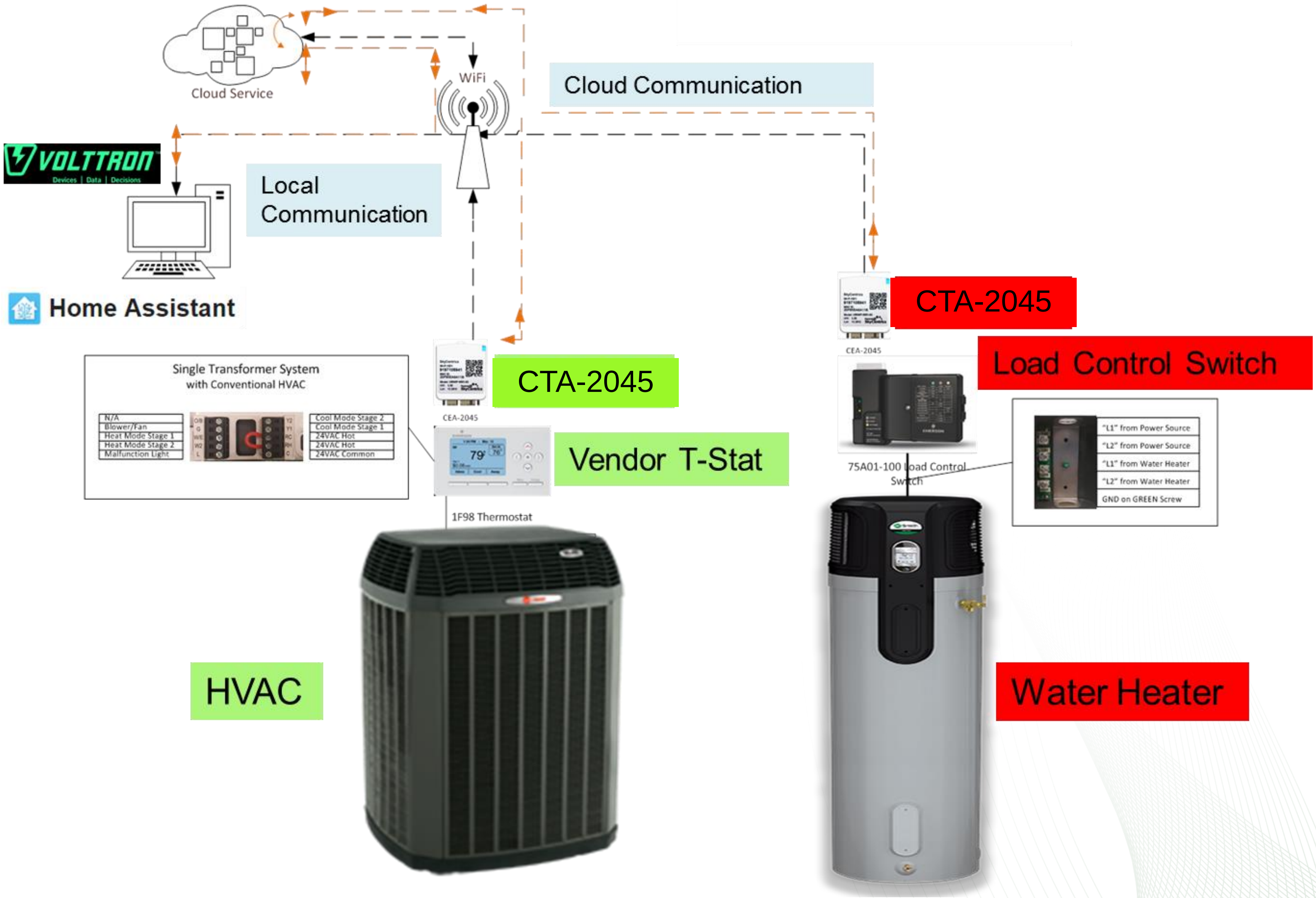
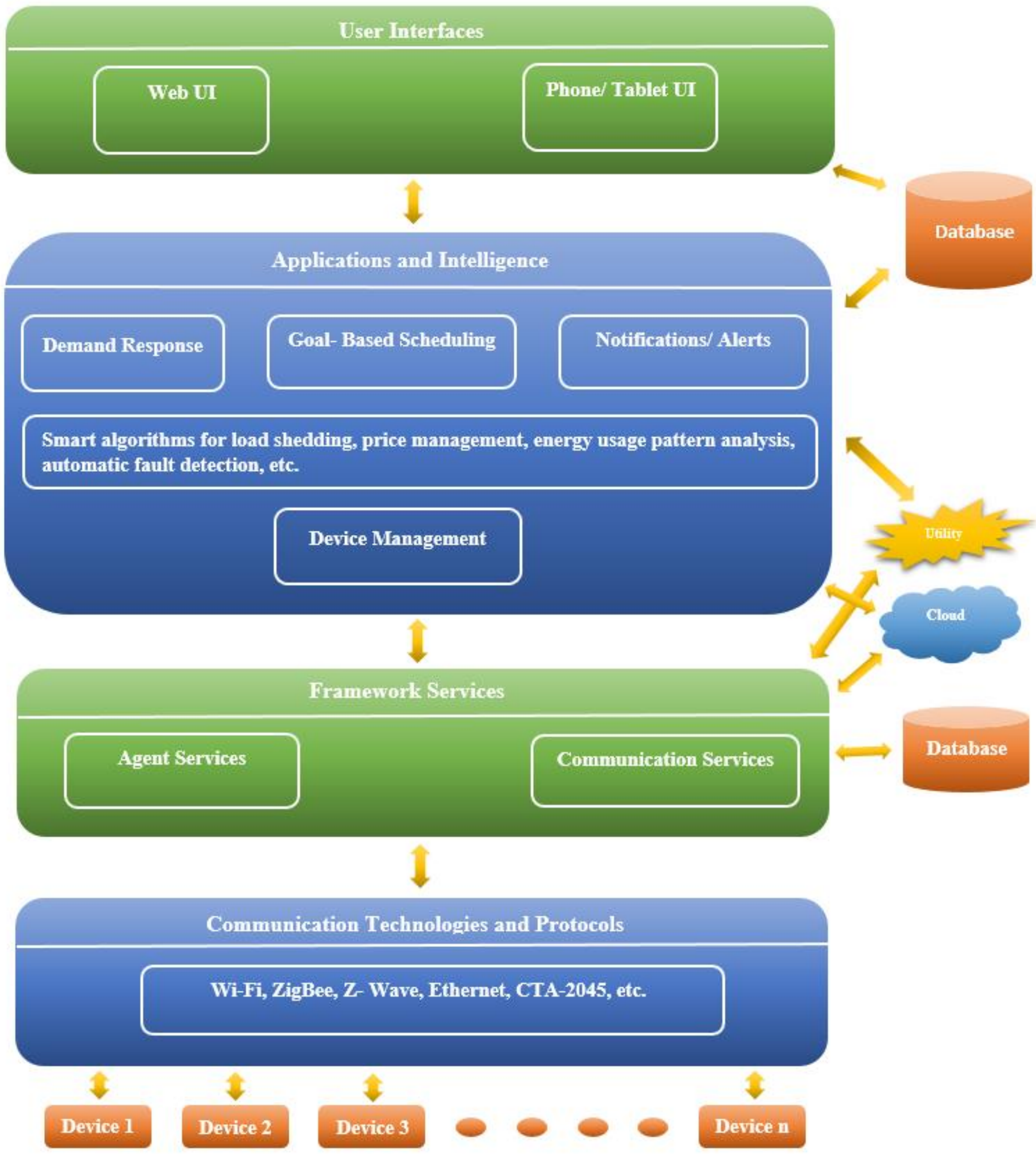
Approach – Employ Cloud and Local Communication



Software Architecture



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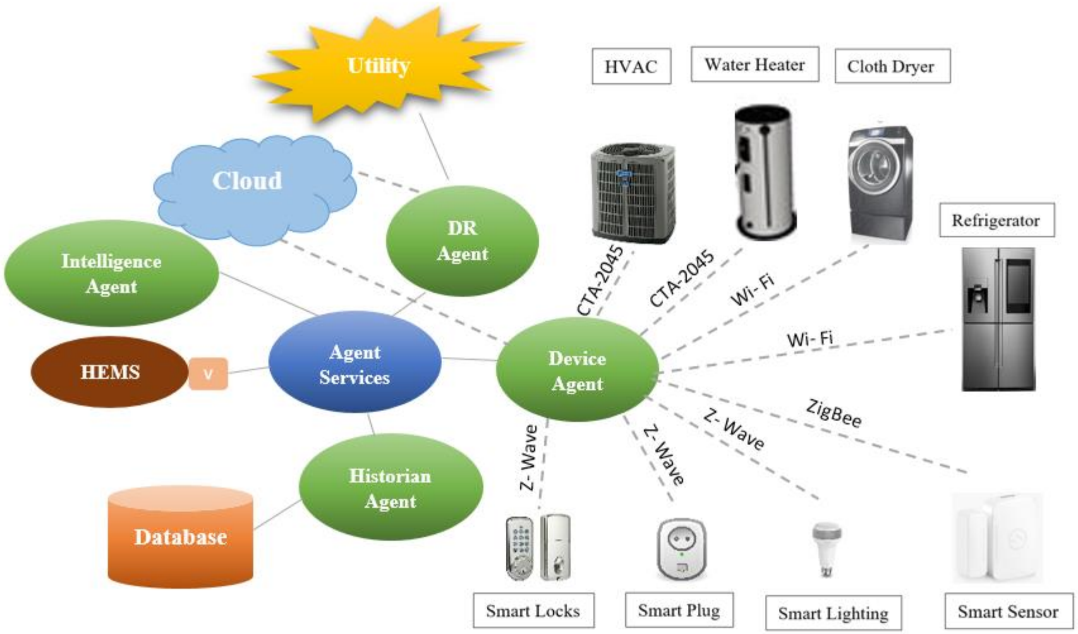
Agent Services

- All agent services are implemented on top of VOLTTRON
- ***Intelligent Agent*** is responsible for goal-based scheduling and notifying appropriate devices
- ***Historian Agent*** is responsible for data retrieval from database
- ***Demand Response Agent*** is responsible for communication with utility
- ***Device Agent*** is responsible for monitoring and controlling devices



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Progress and Accomplishments

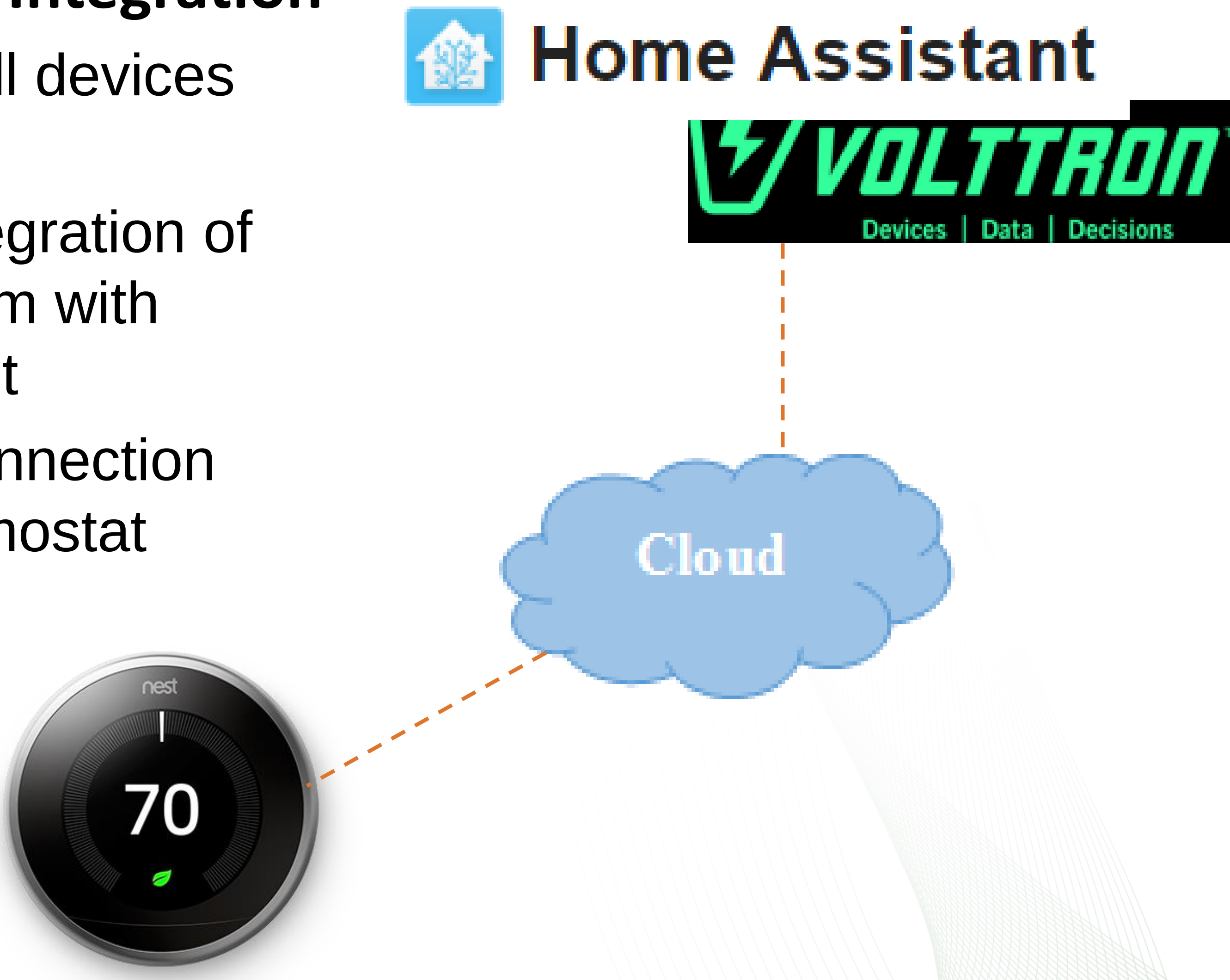
HVAC/WH Connections

- Obtained hardware (CEA-2045 plug, Emerson (White Rodgers) thermostat, A.O. Smith load control switch
- Evaluated communication options
  - vendor cloud service
  - local communication
- Established connection with Emerson T-stat and CEA-2045 plug using SkyCentrics cloud service
- Established connection with Emerson T-stat locally

Progress and Accomplishments

HEMS/Volttron Integration

- Goal: control all devices using Volttron
- Completed integration of Volttron platform with Home Assistant
- Established connection with Nest thermostat



Next Steps

- Complete end-to-end communication with HVAC and water heater and demonstrate HVAC/WH control in laboratory
- Develop demand response control algorithms
- Develop fault detection and diagnostics capability

Next Steps and Future Plans

- Deploy HEMS in test house to evaluate functionality, reliability, and energy/demand control/cost savings
- Develop partnerships and expand homeowner amenities
- Add additional devices/ components to the HEMS
  - lighting
  - security

Home Assistant

VOLTTRON™ Devices | Data | Decisions

Conclusions

- Transactive Energy requires self-aggregating, wide-area responsive loads to enable novel grid services
- Water heaters can be used as grid-responsive loads with improved delivery temperatures and energy savings
- To maximize peak load shifting, energy savings, and delivery temperatures, a set point profile should be tailored to a family's specific water use pattern
- Open-source platform like CTA-2045 standard and VOLTTRON provide unique resources for demonstrating potential

Discussion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