Distributed Control of a Swarm of Buildings Connected to a Smart Grid

TerraSwarm

http://terraswarm.org/

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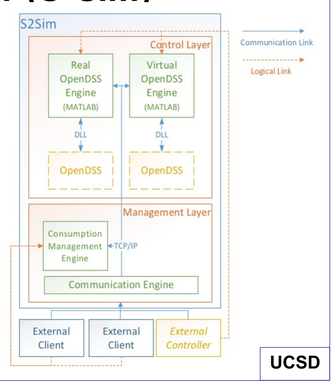
Goal: Provide an interface to test large scale distributed sense and control systems with application to smart buildings and grid

Smart Grid Swarm Simulator (*S²Sim*)

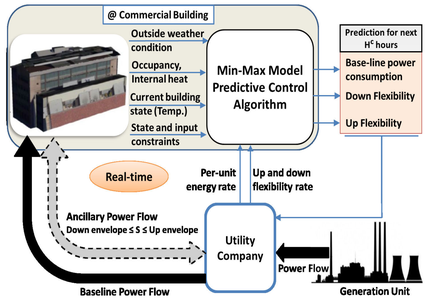
- Enables evaluation of the quality of distributed control of smart buildings
- Provides a price signal to each client to adjust the overall power consumption to ensure grid stability
- Currently six clients, from UCSD, UCB, Caltech, UMich, UPenn, CMU
  - How independent building control tools affect each other as well as the grid



UCSD

MPC-based HVAC Controller

- Flexibility of commercial buildings HVAC system is a significant regulation resource
- Defined and quantified flexibility of building HVAC systems

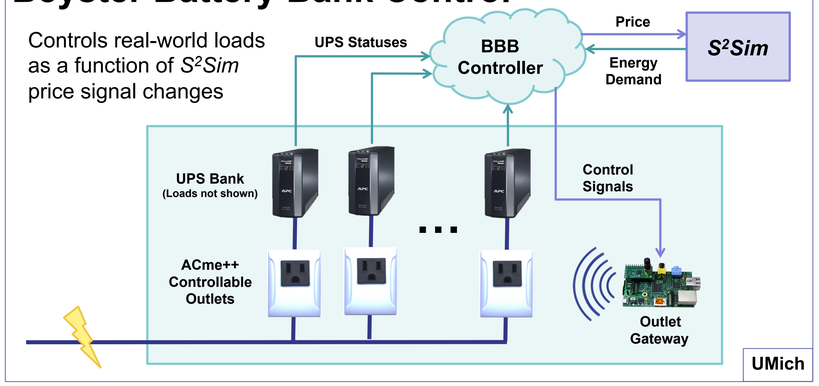


- Designed an MPC framework to guarantee building climate control and grid flexibility requirements
- Implemented *contractual framework* for costs/benefits to building and grid

UCB

Beyster Battery Bank Control

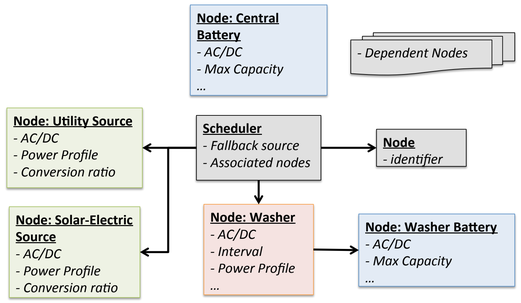
Controls real-world loads as a function of *S²Sim* price signal changes



UMich

HomeSim

- Residential energy simulation platform
- Can emulate neighborhoods
- Replicated and connected to *S²Sim*

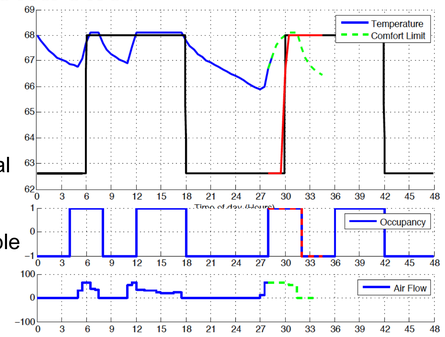


- Pricing feedback from *S²Sim* based on consumption, which affects *appliance rescheduling, battery charge/discharge periods, matching solar energy with demand*

UCSD

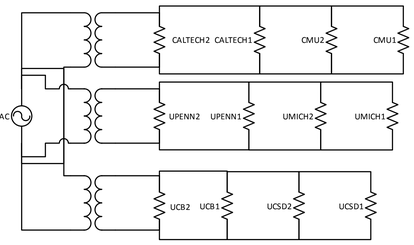
STL-based HVAC Controller

- Resistor-capacitor network to model heat transfer
- MPC to satisfy formal specifications in Signal Temporal Logic
- Maintains a minimum comfortable temperature when the room is occupied while minimizing the cost of heating based on observed prices



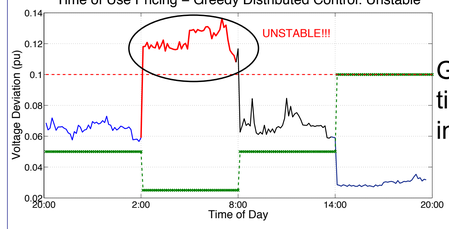
Caltech

Smart Distributed Coordination



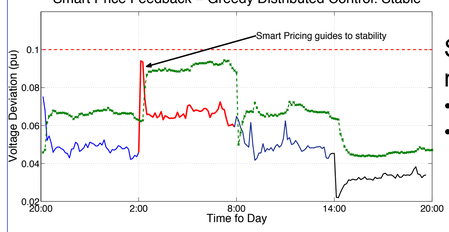
Current circuit can support up to 12MW, corresponding to a typical small US town with approx. 10000 residents

Time of Use Pricing – Greedy Distributed Control: Unstable



Greedy individual control with time-of-use pricing may lead to instability

Smart Price Feedback – Greedy Distributed Control: Stable

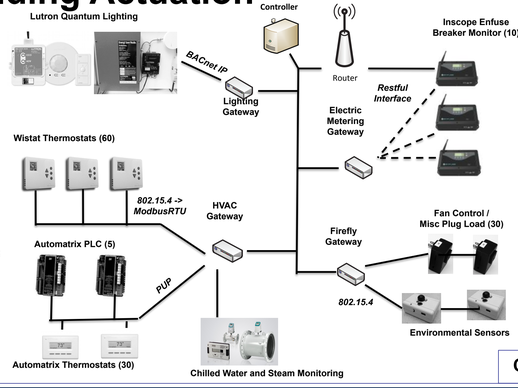


Smart distributed coordination restores stability
- Pricing feedback
- Stability feedback

Real-time Building Actuation

40,000 sq ft, 5 story, 140 room, built in 1962 with classrooms, auditorium, offices and labs

- Sensing and control from 6 building automation systems
- Live data streaming into S²Sim
- Load shedding based on S²Sim pricing signals



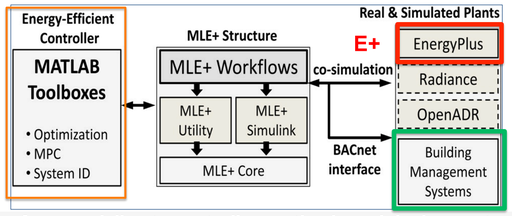
CMU

HVAC Control with MLE+

Use price signals for demand response

Matlab toolbox for integrated modeling and controls for energy-efficient buildings.

Co-simulate with realistic EnergyPlus buildings



Graphical front-end for workflow from modeling to controller synthesis and deployment

UPenn

B. Aksanli, A.S. Akyurek, M. Behl, M. Clark, A. Donze, P. Dutta, Patrick Lazik, M. Maasoumy, R. Mangharam, T.X. Nghiem, V.Raman, A. Rowe, A. Sangiovanni-Vincentelli, S. A. Seshia, T. S. Rosing, J. Venkatesh. **Distributed Control of a Swarm of Buildings Connected to a Smart Grid,** *1st ACM International Conference on Embedded Systems For Energy-Efficient Buildings (BuildSys), 2014*

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