Architecture and Algorithms for the LSE to Manage Thermal Inertial Loads

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Joint work with X. Geng, F.A.C.C. Fontes, P.R. Kumar, and L. Xie
Controlling Air Conditioners

Direct Control for Demand Response
Research Scope

**Objective:** A theory of operation for the LSE

**Challenges:**

1. How to design the **target consumption as a function of price**?

2. How to control so as to preserve **privacy** of the loads’ states?

3. How to respect loads’ **contractual obligations** (e.g. comfort range width $\Delta$)?
Two Layer Block Diagram

First layer: planning optimal consumption

(Energy budget, Time horizon) = (E, T)

ISO

Payment = \int_0^T \hat{\pi}(t) P_{\text{total}}^{\text{ref}}(t) \, dt

Forecasted ambient \( \hat{\theta}_a(t) \)

Forecasted price \( \hat{\pi}(t) \)

Real-time ambient temperature \( \theta_a(t) \)

LSE

\( P_{\text{total}}^{\text{ref}}(t) \)

Second layer: setpoint control

Setpoint controller

\( e(t) \)

\( P_{\text{total}}(t) \)

Aggregate power sensor

Smart thermostat

\( \Delta v(t) \)

AC population
Privacy Preserving Sensing

\[
\begin{align*}
\nu & \quad \tilde{P}_{\text{total}}(t) \\
\tilde{P}_{1}(t) & \quad \tilde{P}_{i}(t) & \quad \tilde{P}_{N}(t) \\
\quad \quad p & \quad \quad p & \quad \quad p \\
n_{1} & \quad n_{i} & \quad n_{N} \\
P_{1}(t) & \quad P_{2}(t) & \quad P_{N}(t) \\
\text{AC 1} & \quad \text{AC } i & \quad \text{AC } N
\end{align*}
\]
Simulation: 500 homes + ERCOT DA price

- forecasted ambient
- actual ambient
- forecasted price
- actual price

- target consumption
- actual consumption
Initial Conditions

The figures illustrate the relationship between $\theta_0$ (°C) and $s_0$ (°C) with the spread indicated by $\Delta_{\text{min}}$ and $\Delta_{\text{max}}$. The distributions shown are consistent across the figures, indicating the variability in initial conditions.
Parameters $\alpha$ and $\beta$

$\alpha \times 10^{-3}$ seconds$^{-1}$

$\beta \times 10^{-3}$ \(\frac{^\circ C}{kW \text{ seconds}}\)
Houston Data for August 2015

$\hat{\theta}_a(\omega,t)$ (°C)

$\pi_{DA}(\omega,t)$ ($$/\text{MWh})$

$P_{\text{total}}(\omega,t)$ (kW)
Limits of Control Performance
How Can the LSE Price A Contract
**Summary**

1. Privacy preserving aggregate sensing
2. Individual comfort guarantees
3. Contract cost $\propto$ QoS
4. Mathematically optimal, no ad-hoc fix

**Wishlist**

1. Hardware implementation of thermostatic control
2. Pilot project to implement the architecture
Thank You
Backup Slides
Details in


