Optimal Co-Scheduling of HVAC Control and Battery Management for Energy-Efficient Buildings Considering State-of-Health Degradation

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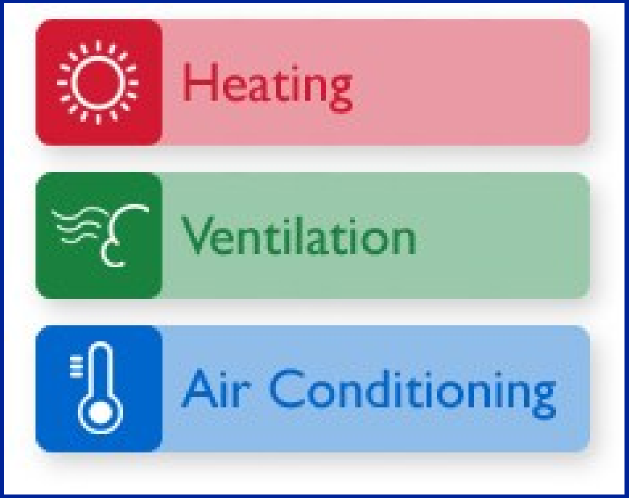
Background: HVAC system – a large portion of energy consumption

- The commercial and residential building stock is responsible for 40% of the U.S. primary energy consumption
- HVAC system accounts for 50% of the energy consumption of a typical building

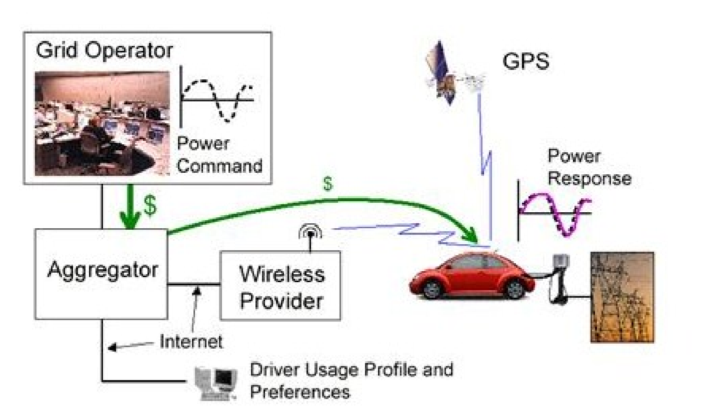


Background: The need for HVAC changes dynamically

- The need for HVAC changes over hours and days
  - As does the electric energy price
- Level of comfort of the building occupants is a primary concern
  - It tends to overwrite pricing
- Dynamic HVAC control under a dynamic energy pricing model while meeting an acceptable level of occupants' comfort is thus critical to achieving energy efficiency in buildings in a sustainable manner

Background: Other equipments in energy-efficient buildings

- Some renewable source of power
  - Such as solar panels mounted on the rooftop
- Battery energy storage system
  - Enable peak power shaving by adopting a suitable charge and discharge schedule for the battery
  - Simultaneously meet building energy efficiency and user satisfaction



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Contribution of This Paper

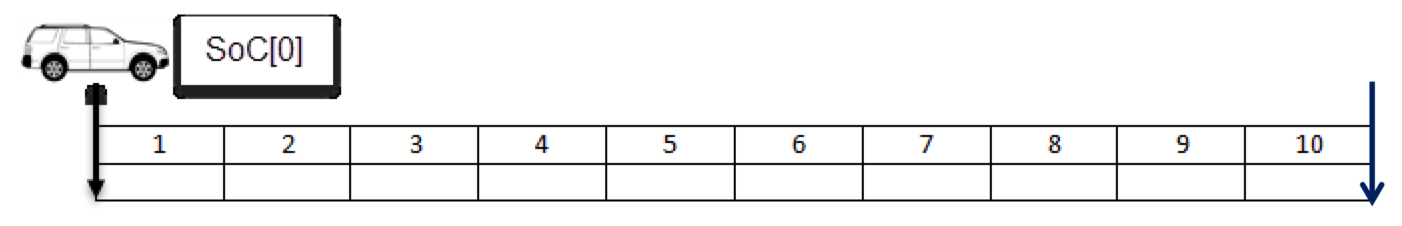
- Addresses the co-scheduling problem of HVAC control and battery management
  - Achieves energy efficiency
  - Also accounts for the degradation of the battery state-of-health during charging and discharging operations
- A time-of-use dynamic pricing scenario is assumed and various energy loss components are considered
- Global optimization framework targeting the entire billing cycle is presented
  - An adaptive co-scheduling algorithm is provided to dynamically update the optimal HVAC air flow control and the battery charging/discharging decision in each time slot during the billing cycle to mitigate the prediction error of unknown parameters.

Problem setup

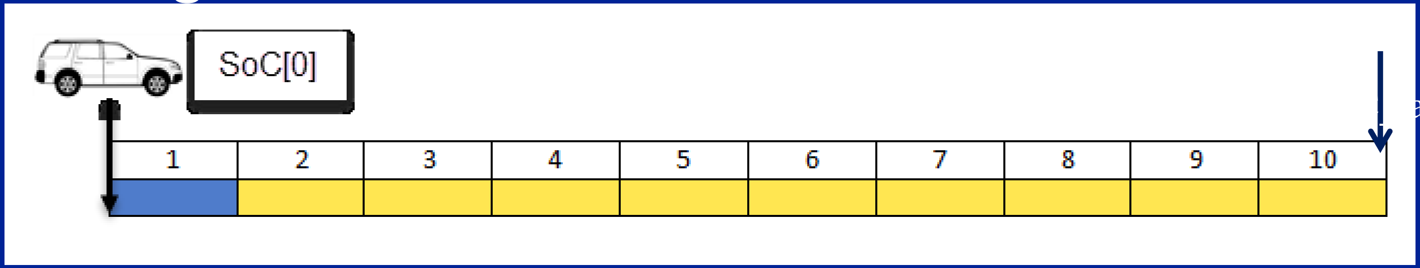
- We consider a period of N time slots, given
  - Initial building temperature condition
  - Dynamic energy price
  - Initial and target state-of-charge (SoC) levels
  - PV generation and building load (predicted)
- Objective:
  - Find optimal HVAC control and battery charging/discharging decision of each time slot
  - Minimize the total cost for all time slots
- Constraints:
  - Must meet the building temperature constraints
  - Must meet the target SoC level at the end of this period
  - The prediction error complicates the problem

An Example of Adaptive Control Algorithm

- At the beginning of the 1st time slot:
  - Set the initial SoC level and initial temperature



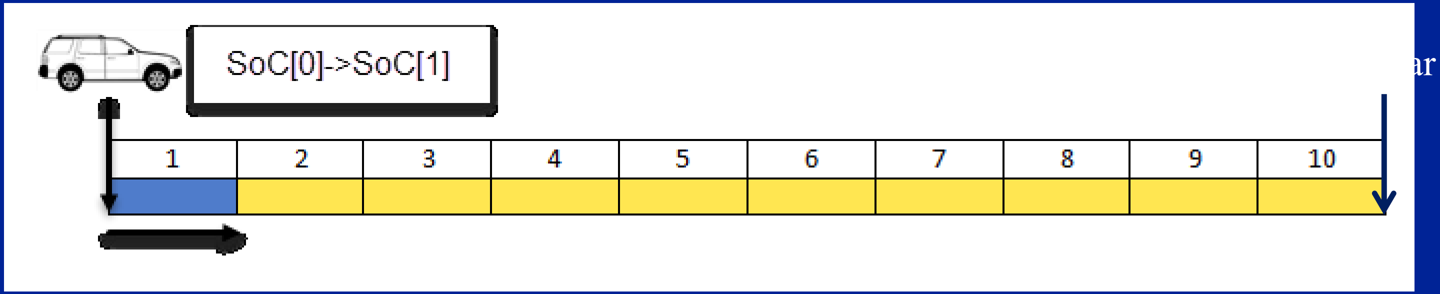
  - Find the optimal HVAC control and battery management for all future time slots



  - Only the 1st hour decision will be applied, others might be updated later

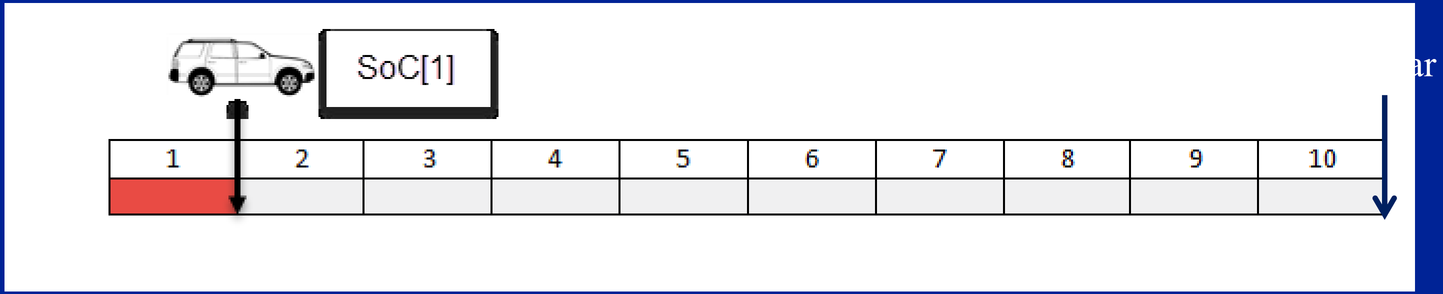
An Example of Adaptive Control Algorithm

- **When the 1st time slot unfolds:**
  - **Based on the actual PV generation and building load, the battery SoC level and building temperature is updated**

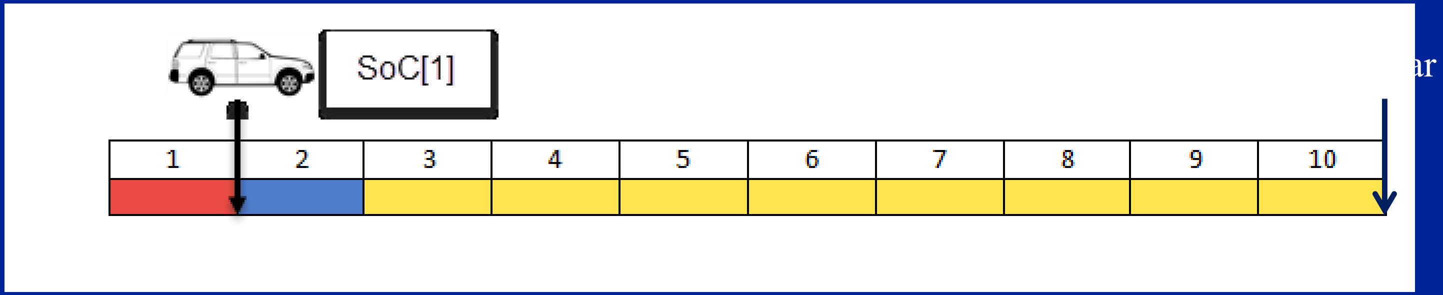


An Example of Adaptive Control Algorithm

- At the beginning of the 2nd time slot:
  - Update the SoC level and building temperature



  - Find the optimal decision for all future time slots

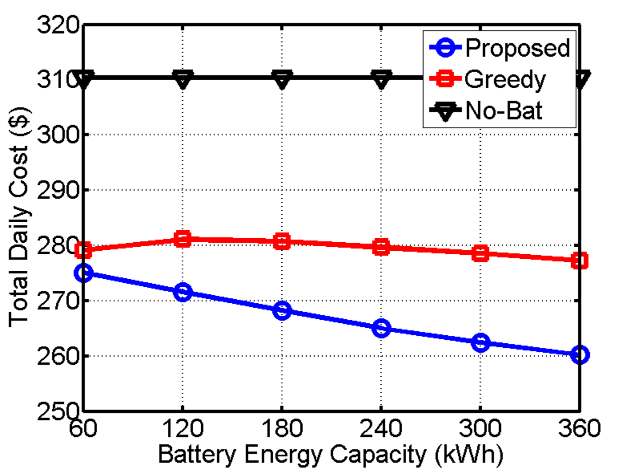


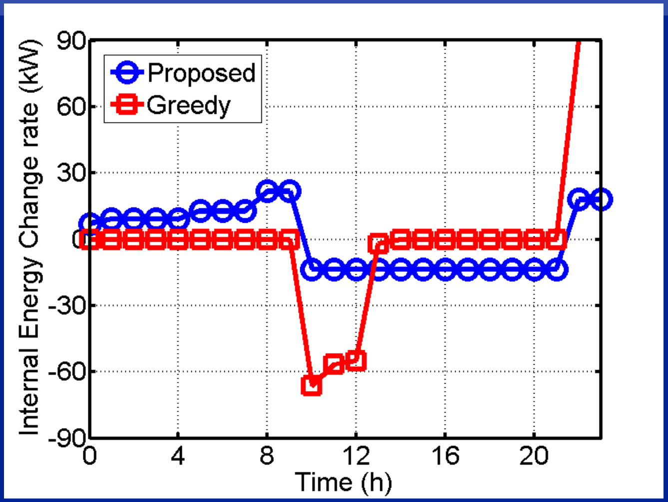
  - Repeat this process until we reach the end of the period

Experimental Setup

- We adopt the electricity pricing policy from Consolidated Edison Company
- The building temperature model is extracted from a building located at 1084 Columbia Ave
- We use PV power profiles measured at Duffield, VA, in the year 2007
- Battery models come from previous papers
- We assume a maximum of 20% prediction error

Experimental Results





- Baseline1: HVAC system without battery
- Baseline2: greedy decision: battery will be charged to the maximal SoC level during off-peak hours, and discharged to the minimal SoC level during peak hours
- Energy cost is significantly reduced in our proposed solution
- As SoH degradation is considered, charging/discharging is smoothened

Thank you

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