Enabling Automated Dynamic Demand Response: From Theory to Practice

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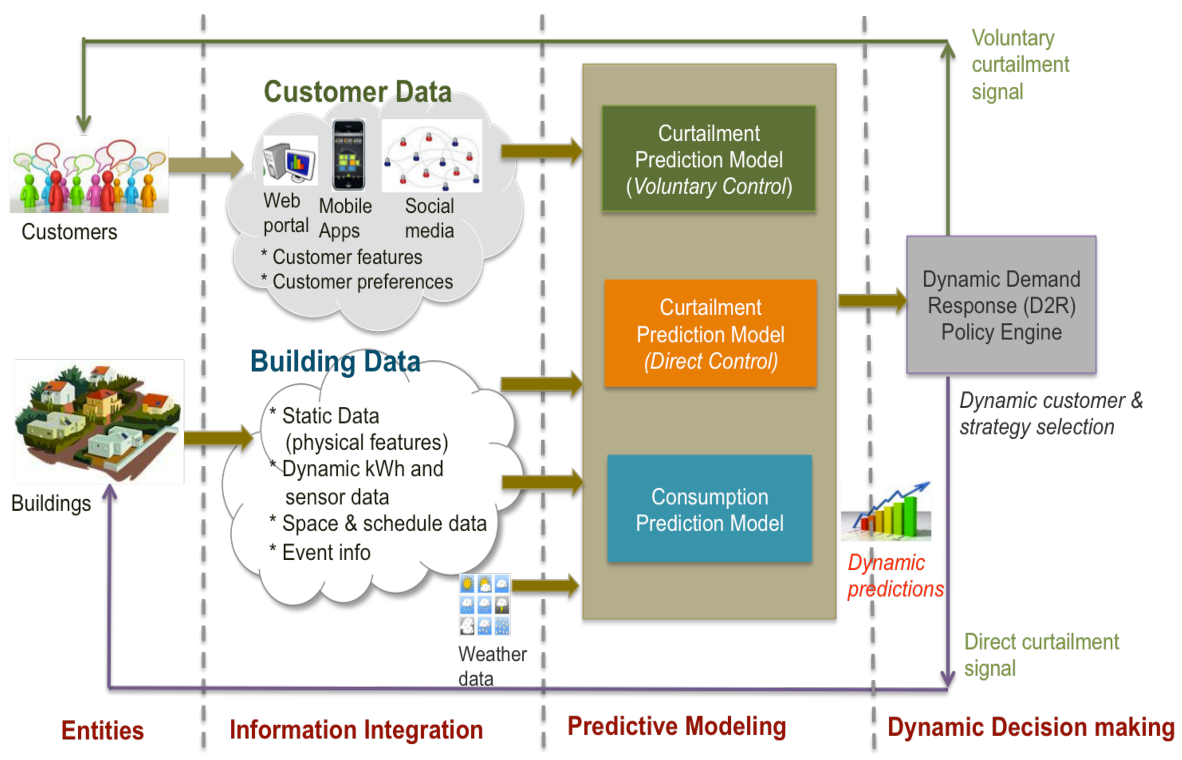
Dynamic Demand Response (D^2R)



D^2R System

Challenges and Approaches

Information Integration

Challenges:
- **Diverse** data: kWh, class schedule, temperature
- **Indirect** influencers – customer activities, natural phenomenon, infrastructure behavior

Our solution:
- We proposed a semantic information model

Privacy Guarantees

Challenges:
- Fine-grained data leads to **privacy** issues
- Need for **privacy-aware** data retrieval

Our solution:
- We proposed models for assessing privacy impacts
- Cryptonite: a secure cloud-based repository

Predictive Analytics

Challenges:
- Consumer **clustering** to reduce variability and increase prediction accuracy
- Our **partial data** models work when real-time data is unavailable

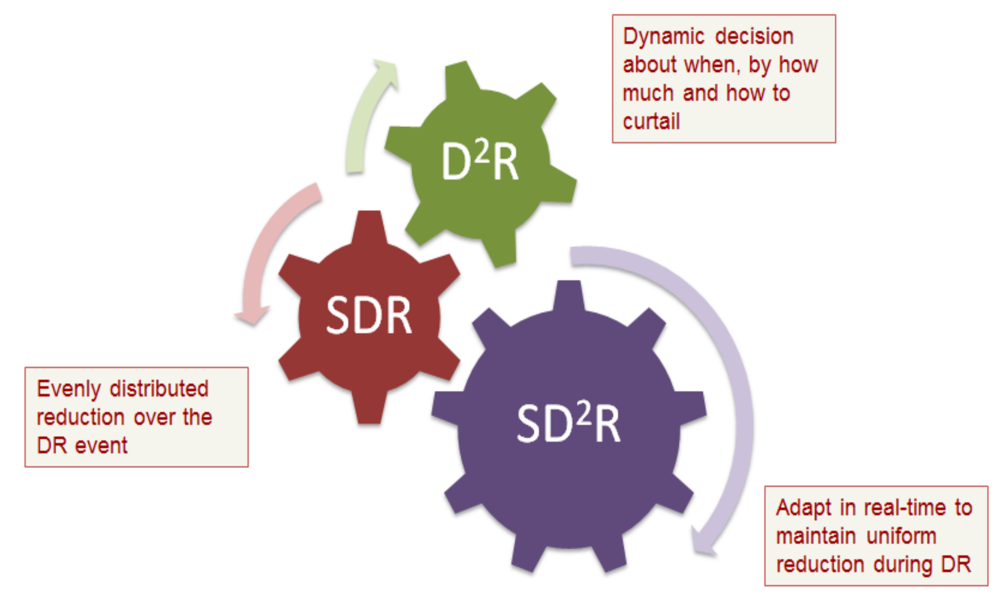
Our solution:
- New models for curtailed consumption prediction during DR.

Dynamic Decision Making

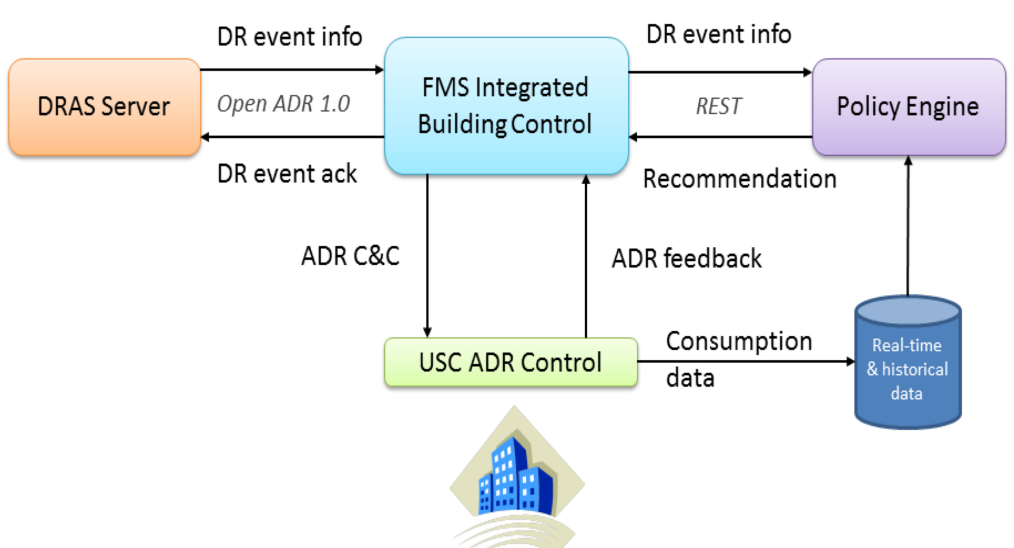
Challenges:
- **Dynamic** & **real-time** selection of customers
- **Sustainable** D^2R required to keep the level of curtailment stable during DR

Our solution:
- We formulated a **linear programming optimization** to find predicted curtailment
- We proposed fast suboptimal **heuristics**

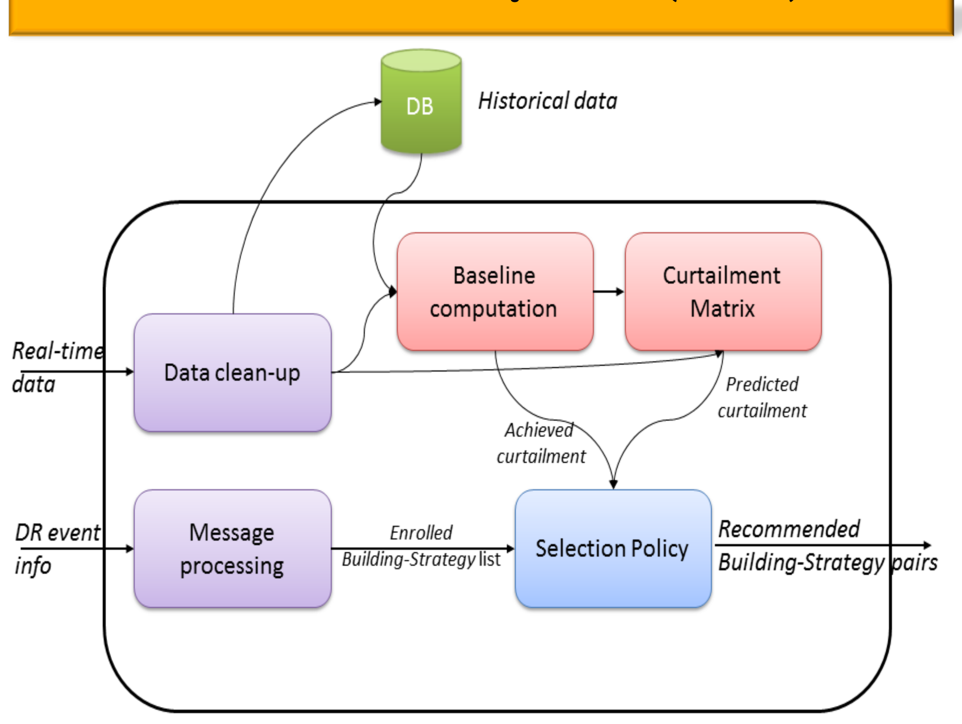
D^2R System Realization



- Dynamic & Sustainable Demand Response
  - **Stable** reduction over the period of a DR event
  - Dynamic **adaptation** to ensure reliability/sustainability
- DRAS Server
  - Demand response communication protocol
- Integrated Building Control
  - Smart meters gather consumption information
  - Direct equipment control during DR



D^2R Decision System (DDS)



- Data Cleanup
  - Interpolation of missing values
- Message Processing
  - DR event reduction target
  - DR event available customers/buildings and strategies
  - DR event duration
- Baseline Computation
  - Predicted consumption in the absence of a DR event
- Curtailment Matrix
  - Achieved reduction per building-strategy for 1 day
  - Delta between baseline and predicted consumption during DR
- Selection & Recommendation
  - Set of building-strategies that can achieve and maintain a stable reduction based on the DR event requirements
  - Feedback on the progress of the DR event

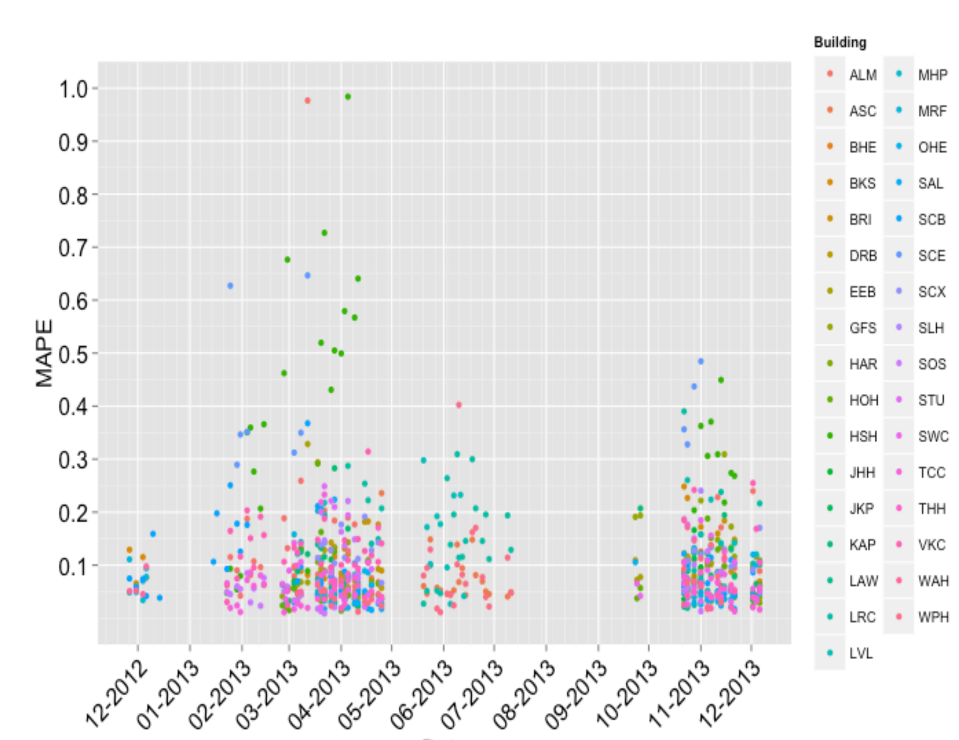
- **Demand Response** used to shape customer loads during peak hours
- **Dynamic Demand Response (D^2R)**: managing the electricity usage by dynamic decision making about **when**, for **how long**, by **how much**, and how (**whom** to pick) to optimize electricity consumption
- **DR programs**: incentives, *direct control*, *voluntary*

Deployment & Experiments

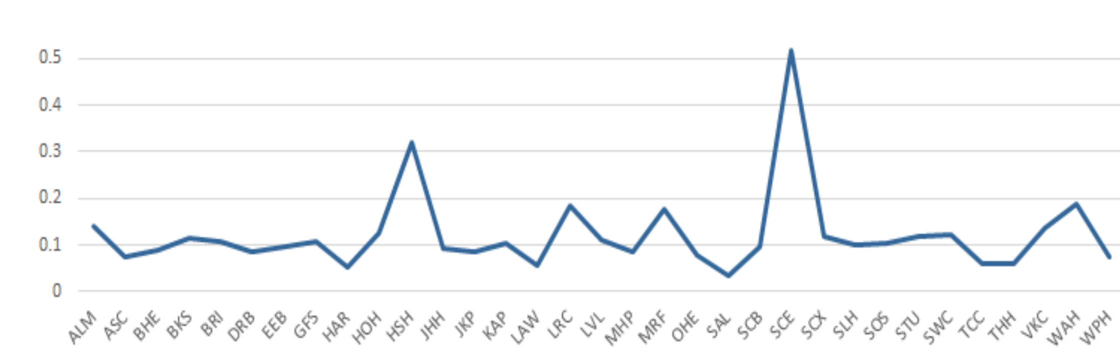
- USC – **Living laboratory** for smart grid research
- USC microgrid peaks at 27MW
- Control Center manages 170 diverse buildings, with >50K sensors

- Validated on 33 campus buildings
- More than 400 DR events (Nov 2012 – Dec 2014)
- Cross validation used for calculating MAPE error
- 9 experiments (Oct – Dec 2014) to asses the success of DR selection policy

Results
- About half the buildings have less than 10% prediction error
- Turnaround time of building-strategy selection is <1 minute
- Our customer selection method scales well for large number of customers



Errors across DR event days



Errors across buildings

Key Contributions

- Key challenges for D^2R and our approaches
- Software architecture of our D^2R system
- System integration with USC FMS & LADWP
- Results from real-life system deployment

- **Use case**: predict curtailed consumption and customer selection

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http://ganges.usc.edu/wiki/Smart_Grid

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