Optimal Coordination and Scheduling of Demand Response via Economic Incentives

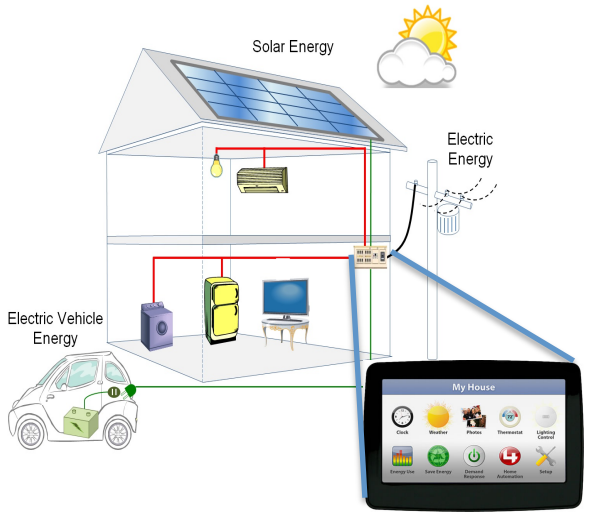
Mushfiqur Sarker, Miguel Ortega-Vazquez and Daniel S Kirschen

University of Washington

Introduction

- As consumer demand increases due to **Electric Vehicles (EV)**, stress on the distribution grid will occur

- Consumers equipped with an **Energy Management System (EMS)**



- An EMS enables:
  - Bidirectional communication
  - Scheduling consumer loads

- An aggregator can incentivize these consumers to keep the grid within its limits and maximize its profits

© 2015 University of Washington

What is an aggregator?

- Additional business-entity in the retail and/or wholesale energy market
- Does not need to own assets, e.g. generation
- In this framework, aggregator's roles are to:
  - Maintain the power grid limits, e.g. lines
  - Provide monetary incentives to consumers to motivate demand response
  - Maximizes its profit

© 2015 University of Washington

What is a consumer?

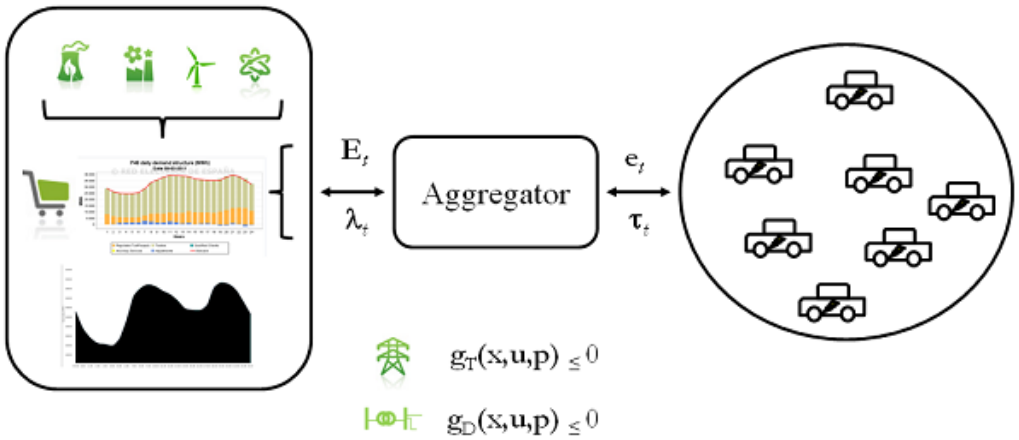
- Consumers are residential households equipped with controllable loads, e.g.
  - Electric vehicles (EV)
  - Electric water heater
  - HVAC, etc.

- Optimize load against real-time prices and incentives provided by the aggregator
- Objective: Minimize their energy bill while maintaining comfort level

© 2015 University of Washington

Aggregator ➔ Transactive Energy

- Aggregator transacts on a sub-hourly basis with its consumers to:
  - Incentivize demand response
  - Maintain the grid within its limits
  - Determine offers and bids into the wholesale energy/regulation market



Our Contributions

Framework governing aggregator-to-consumer interactions to provide **demand response (DR)** to the grid. Includes:

1) Consumer compensation for services provided

2) Potential **wear and tear on EV** batteries when providing services

3) Incentives for DR derived from an economic assessment of the use and abuse of distribution assets

4) Any tariff structure can be used (e.g. flat)

5) Consumer optimal load scheduling

© 2015 University of Washington

Methodology

A **decentralized, non-iterative** approach is proposed

- Consumers optimize to **minimize** energy costs
- Aggregator optimizes to **maximize** profits

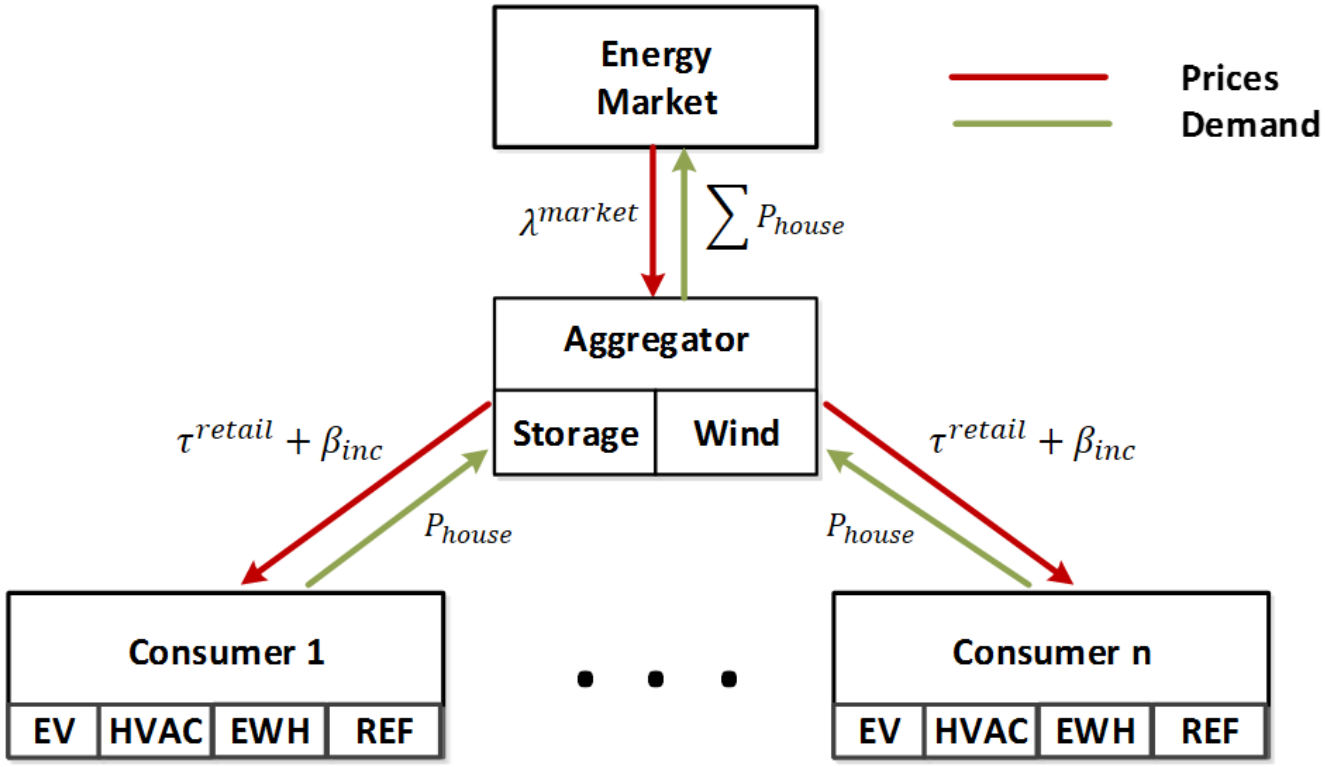
Prices are used to control consumer demand

- **Real-time pricing (RTP)** motivates consumers to shift demand to minimize energy costs
- **Incentives** are issued by the aggregator to consumers as a reward for **Demand Response (DR)**

Combination of price-based and incentive-based DR yields the most benefits

© 2015 University of Washington

Framework: Information Flow



Price information flows downstream and demand information flows upstream

© 2015 University of Washington

Process

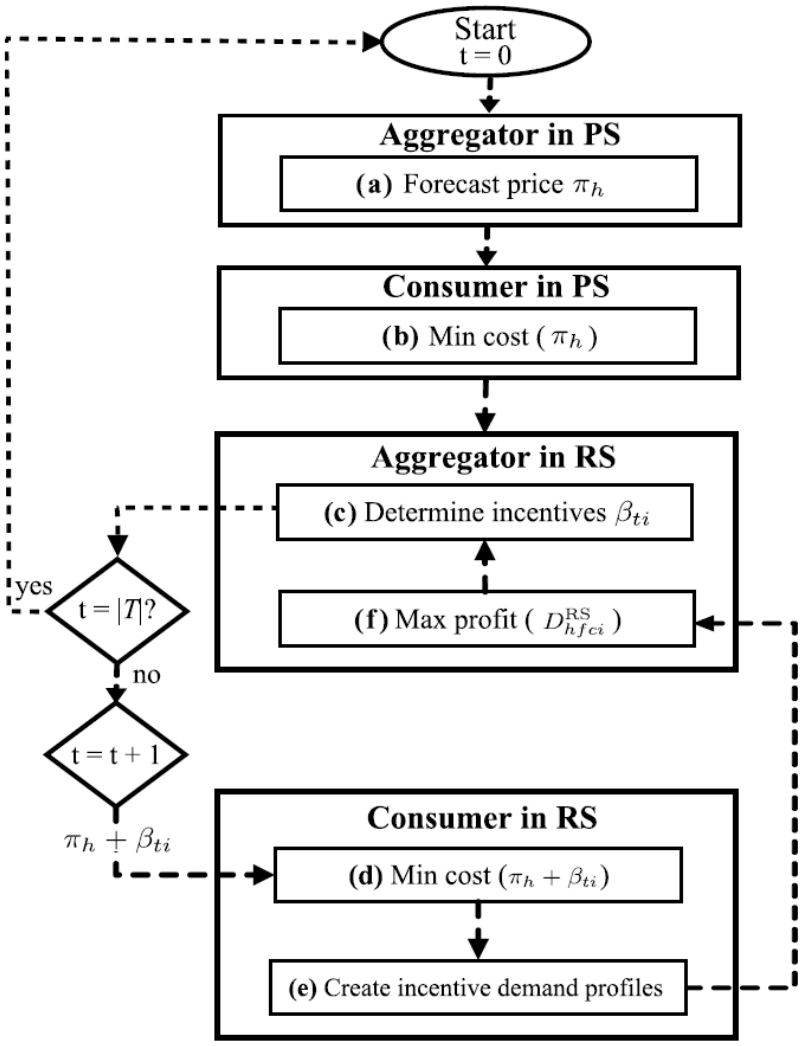
- **Pre-scheduling (PS) Stage**
  1. Consumers optimize their appliances based only on real-time prices
  2. Consumers send their power profiles to aggregator
  3. Aggregator determines if grid overloads will occur
- **Re-scheduling (RS) stage**
  4. Aggregator sends a set of monetary incentives
  5. Consumers make adjustments to PS stage profiles
  6. Revised profiles sent to Aggregator
  7. Aggregator optimizes to determines the least-cost allocation of incentives that meet its priorities

© 2015 University of Washington

Process

Optimization occurs on a day-to-day basis

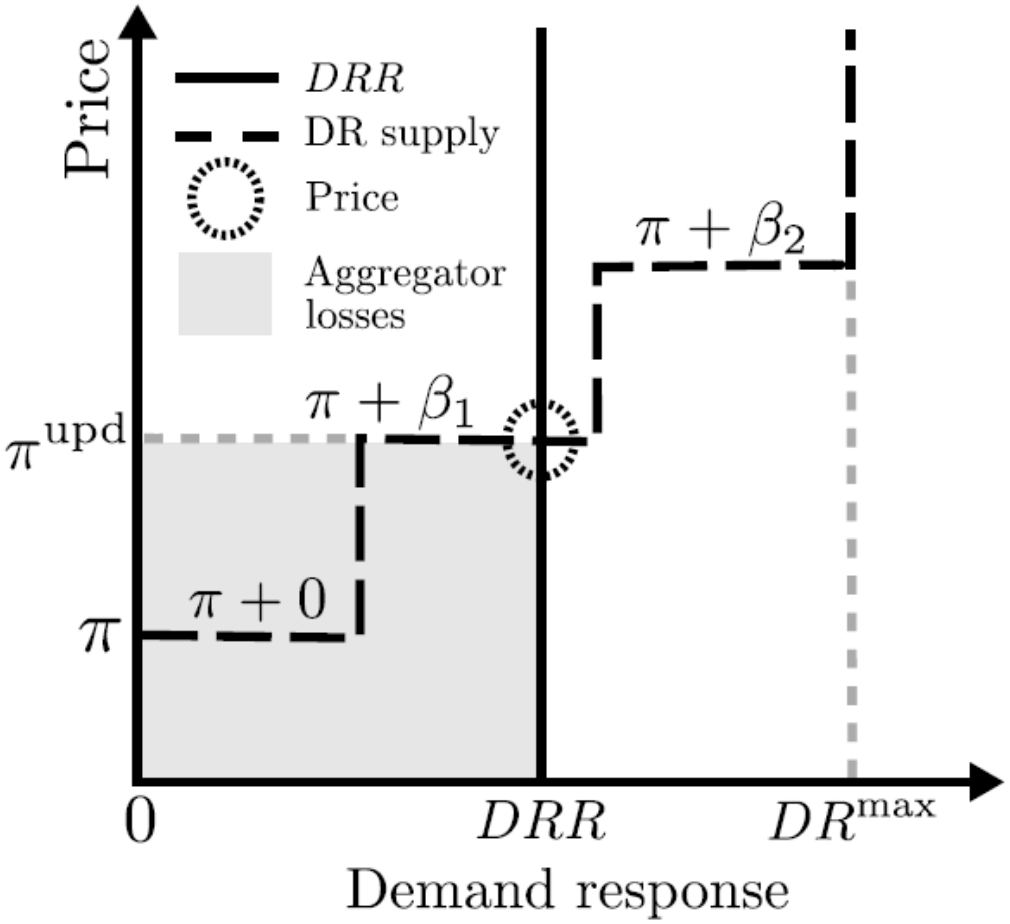
1. Aggregator sends tariff
2. Consumer optimizes (pre-scheduling)
3. Aggregator determines if issues will occur to grid
4. If so, re-scheduling occurs with incentives to motivate DR



© 2015 University of Washington

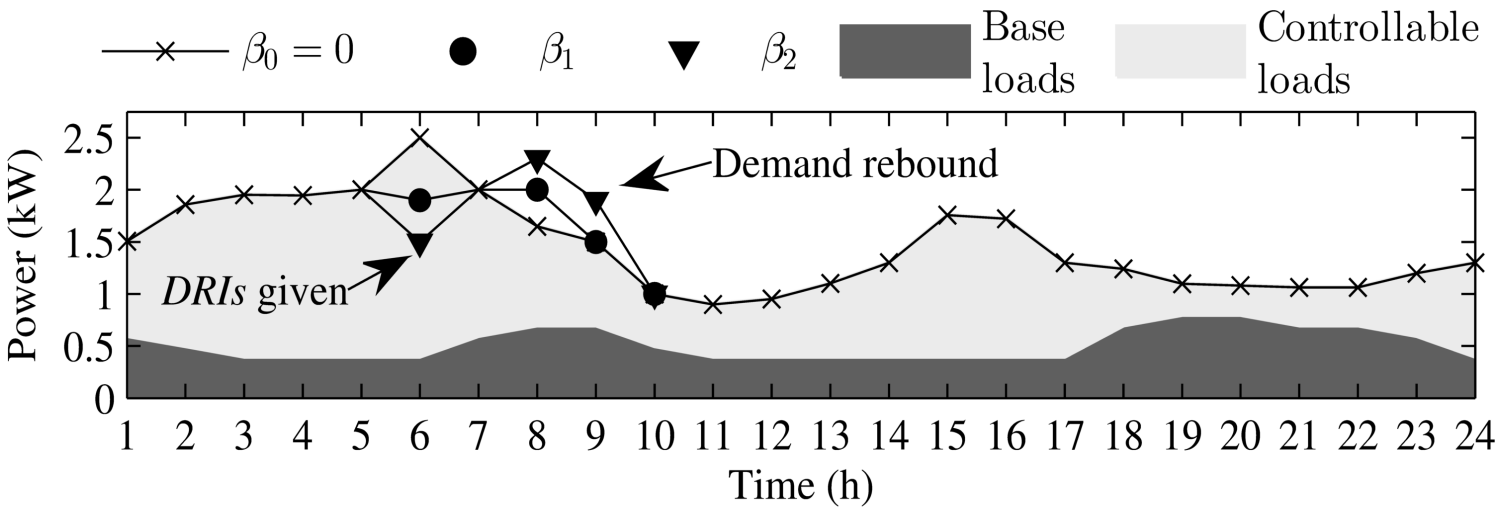
Framework: DR Supply Curve

- Consumers provide their DR capability as a response to each incentive, β
- Aggregator generates a DR supply curve
- Embeds curve into optimization



© 2015 University of Washington

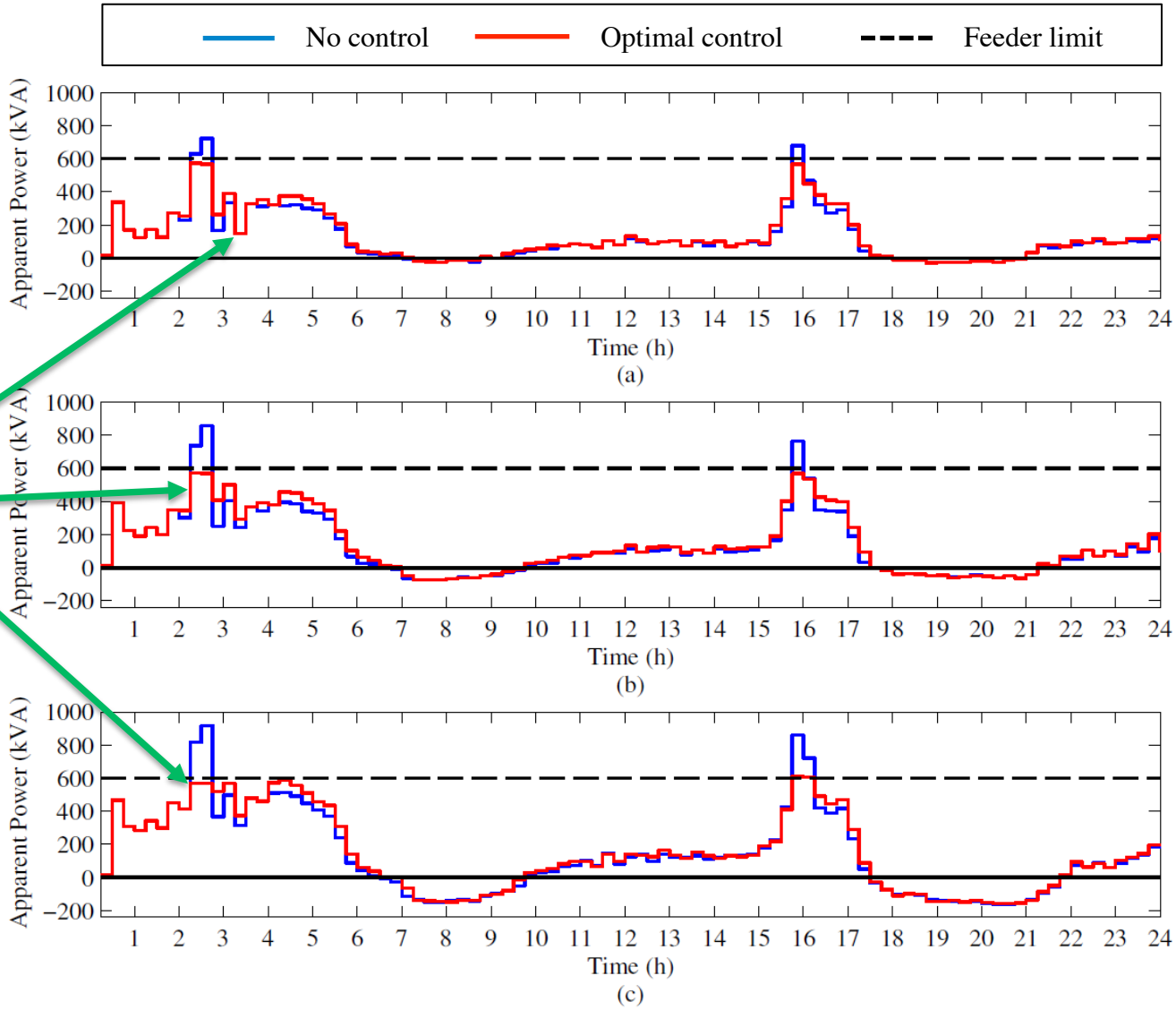
Example



- Incentives are offered to the consumer at hour 6
- Consumer optimizes and creates profiles shown above
- Aggregator receives profiles and determines if rewarding the consumer will:
    1. Mitigate grid issues, and
    2. Maximize its profits

© 2015 University of Washington

Results – Feeder Load



Load is shifted to maintain limits

Total demand for 100 consumers with (a) 30%, (b) 60%, and (c) 100% EV penetration under real-time tariff

© 2015 University of Washington

Business Case

Aggregator can provide value to all entities:

- Utilities and/or distribution system operators
  - Aggregator provides significant investment deferral benefits by managing consumer loads, e.g. EVs
- RTOs/ISOs
  - Aggregator brings the retail demand-side into wholesale
  - More participation→ more efficient markets
- Consumers
  - Aggregator compensate consumers for participation
  - Aggregator provides other value-added services

© 2015 University of Washington

Conclusions

- Consumer response depends on the value of monetary incentive offered
- If some consumers do not participate, aggregator can still maintain grid limits
- Interactions between a consumer and the aggregator is a contractual agreement

© 2015 University of Washington

References

Journal papers

1. Sarker, M.R.; Ortega-Vazquez, M.A.; Kirschen, D.S., "Optimal Coordination and Scheduling of Demand Response via Monetary Incentives," IEEE Transactions on Smart Grid, Vol.6, No.3, pp.1341-1352, May 2015
2. M. A. Ortega-Vazquez, "Optimal Scheduling of Electric Vehicle Charging and Vehicle-to-Grid Services at Household Level Including Battery Degradation and Price Uncertainty", IET Generation, Transmission & Distribution, Vol. 8, Issue 6, Jun. 2014.

Patent

1. Mushfiqur R. Sarker, Miguel A. Ortega-Vazquez, Daniel S. Kirschen. ”Operating and Business Model for an Aggregator Optimally Managing Consumer Demand via Monetary Incentives” U.S. 2014. Provisional Patent

© 2015 University of Washington