Self-management of Smart Energy Systems

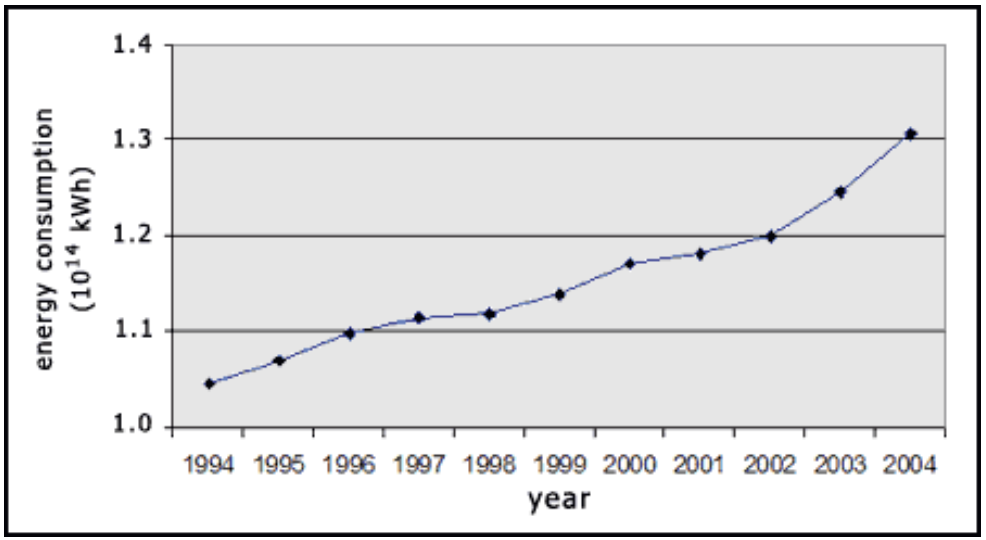
Large-scale decentralized agent-based coordination

Dr. Evangelos Pournaras

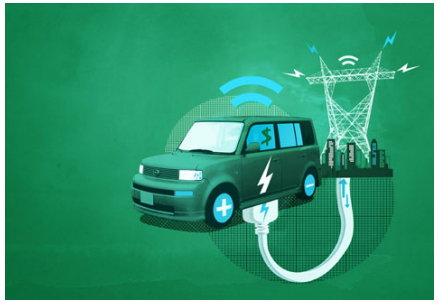
Postdoctoral Researcher

Network Architecture and Services group

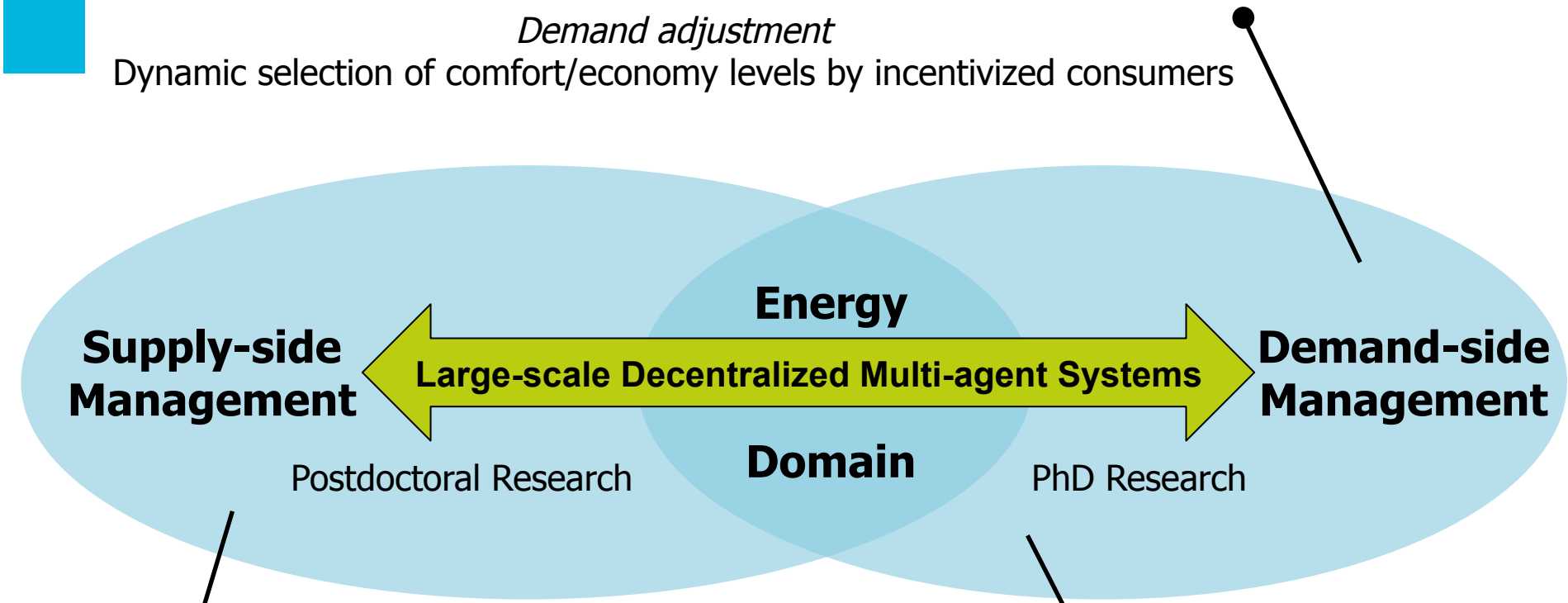
Challenges in Smart Energy Systems



Source: US Departement of Energy Information Administration

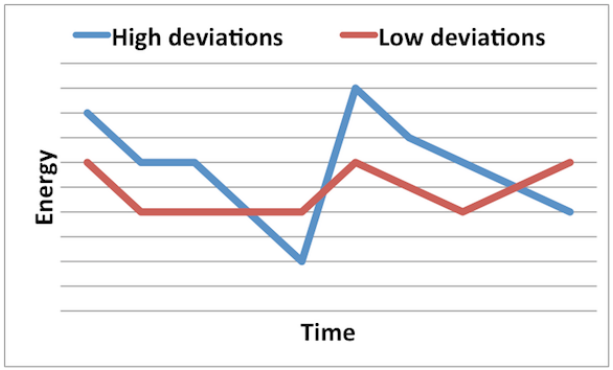


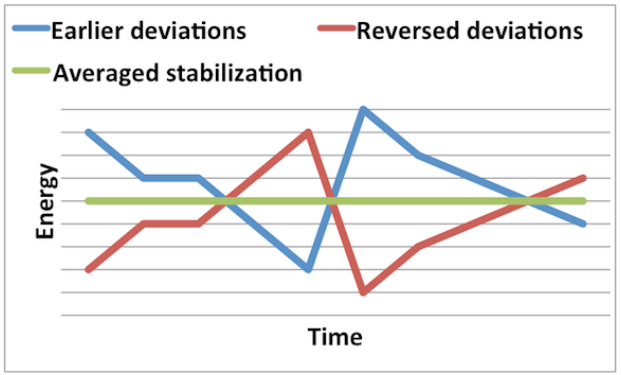
Research Overview



1. Demand Stabilization

Minimizing and reversing power peaks (deviations)
by keeping the total average energy consumption the same (load shifting)

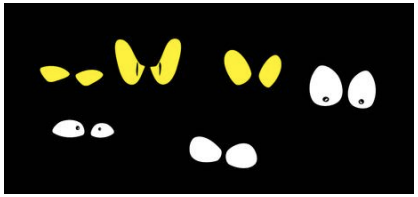


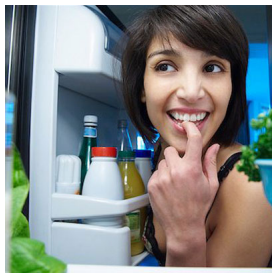


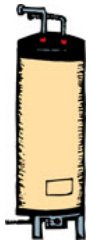
How agents can collectively stabilize the aggregate demand when they control household devices?

Planning of Household Devices

Agent-based control of thermostatically controlled devices
No user involvement



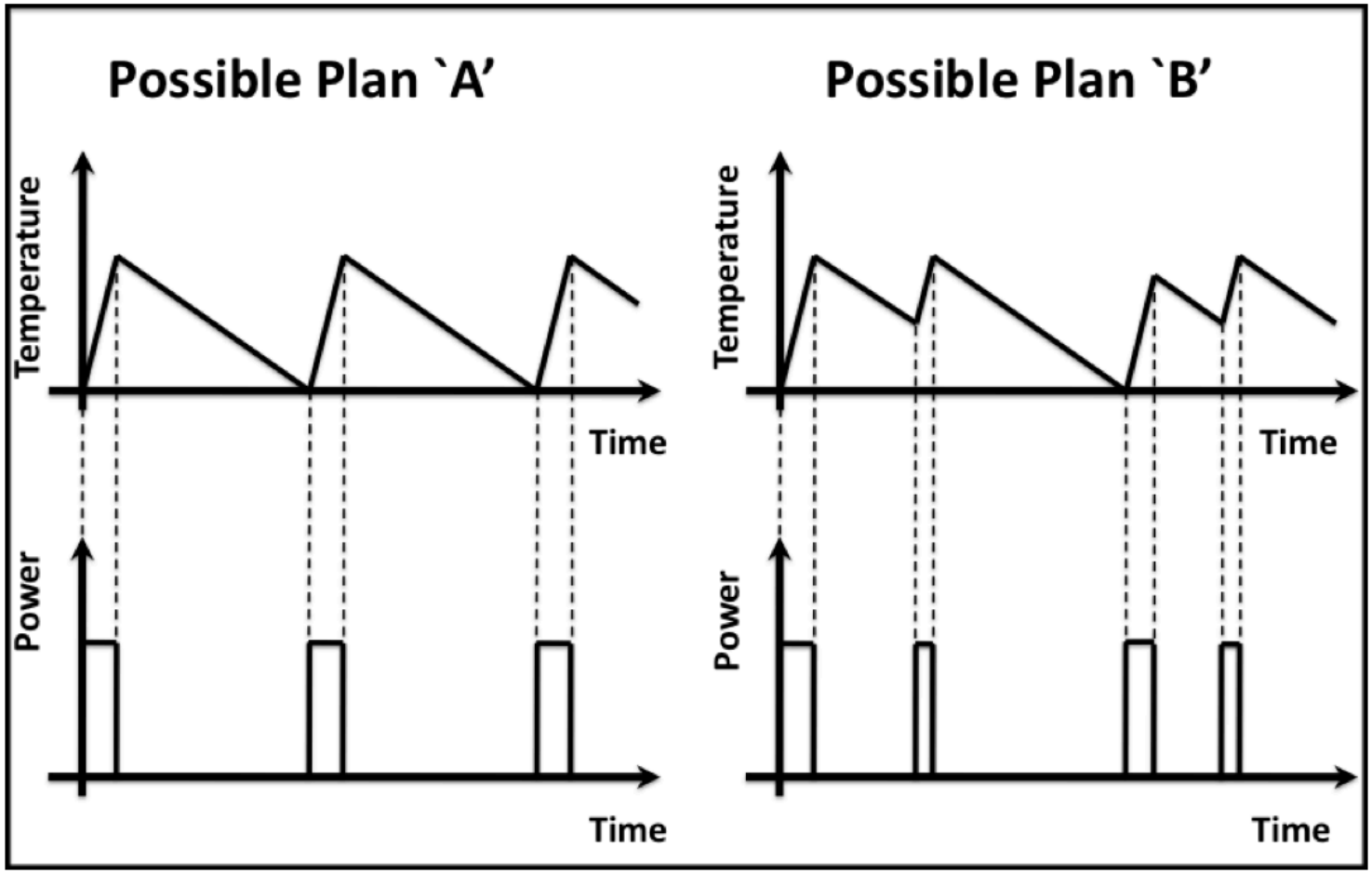




EPOS - Energy Plan Overlay Self-stabilization

Generation, selection and execution of **alternative consumption plans** for future time period

Consumption plans



Technology

Is this possible?

LG introduces its first Smart Grid-Ready Refrigerator the DIOS

Category: Environment Household - *Tags:* Household, Lg, Lge, Smart Adapt, Smart Grid, Wi-fi, Wifi

Barely 24 hours Samsung's Smart Grid Ready fridge, LG is now announcing its very own connected Smart Grid-Ready DIOS Fridge in Korea. The new smart refrigerator offers updates and information that can be accessed via smartphones and tablets. It offers three powerful smart savings options: late night saving, preferable time saving and the Smart Grid-ready.

The smart fridge also comes with Smart Adapt, which allows owners to keep their refrigerator software up-to-date with the latest upgrades, features and options. The smart fridge is also a source of useful information as it keeps track of daily schedules and dispenses regular weather reports. And instead of having to jot notes on sticky memos, family members can turn the fridge's LCD screen into a note pad to leave messages for each another.

Via LGE

4 Comments

Category ENVIRONMENT HOUSEHOLD

Available Technologies

Grid Friendly Appliance™ Controller

Battelle Number(s): 12782-E, 13538-B
Patent(s) Issued
Available for licensing in all fields

Awards Won:
R&D 100 Award - 2008
FLC Award - 2007

Summary

The Grid Friendly Appliance controller developed at PNNL senses grid conditions by monitoring the frequency of the system and provides automatic demand response in times of disruption.

(click on image for full size)

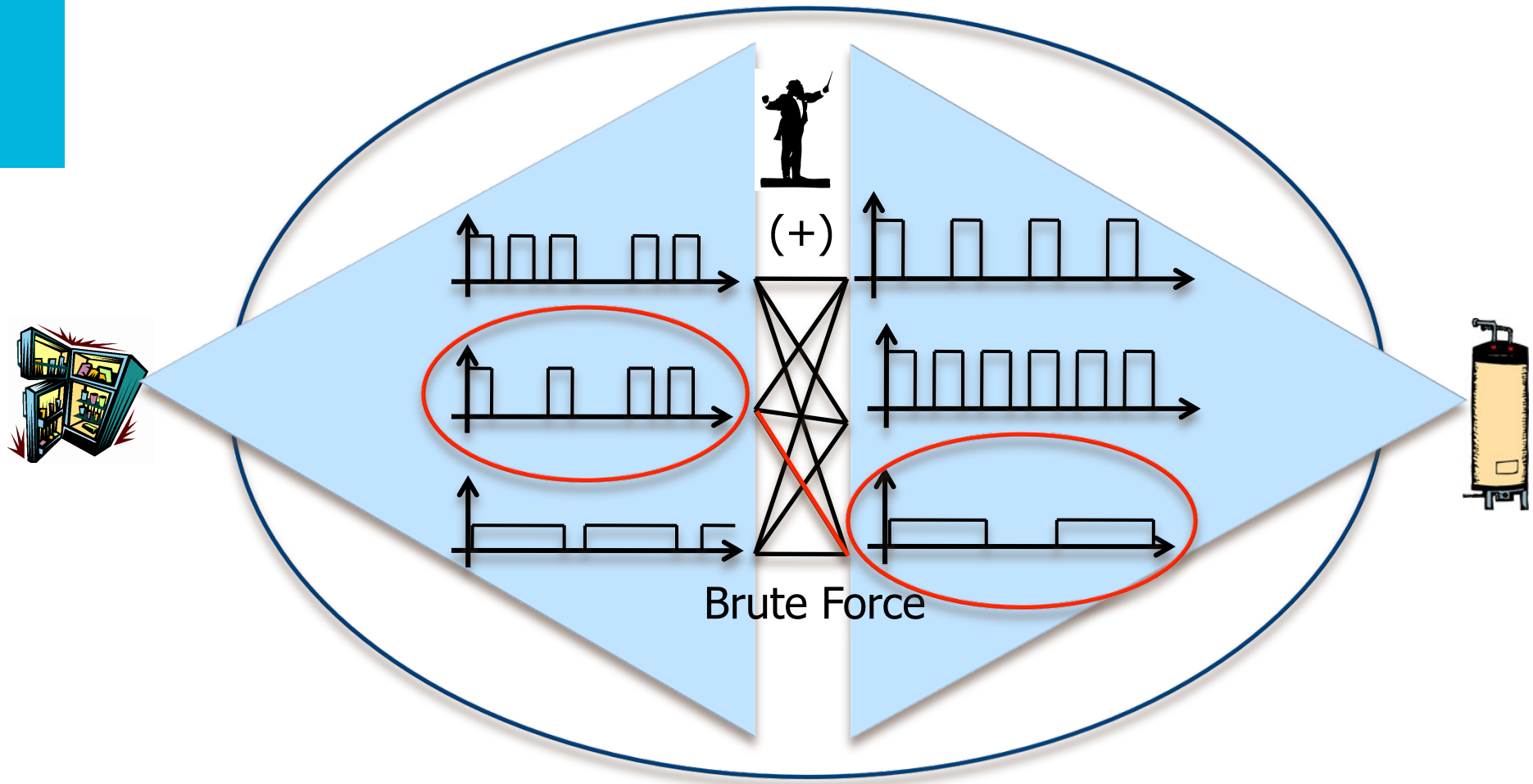
A coin-sized integrated circuit developed by researchers at Pacific Northwest National Laboratory may help solve the nation's overworked electricity grid. Called The Grid Friendly™ Appliance Controller, the circuit board would turn normal household appliances into ones that would better regulate energy usage and help prevent local and national blackouts.

Within the North American power grid a disturbance of 60-Hz frequency is an indicator of serious imbalance between supply and demand that, if unarrested, leads to a blackout. This simple computer chip can be installed in household appliances and turn them off for a few minutes or even a few seconds to allow the grid to stabilize. The controllers can be programmed to autonomously react in fractions of a second when a disturbance is detected, whereas power plants take minutes to come up to speed. They can even be programmed to delay restart instead of all coming on at once after a power outage to ease power restoration.

Advantages

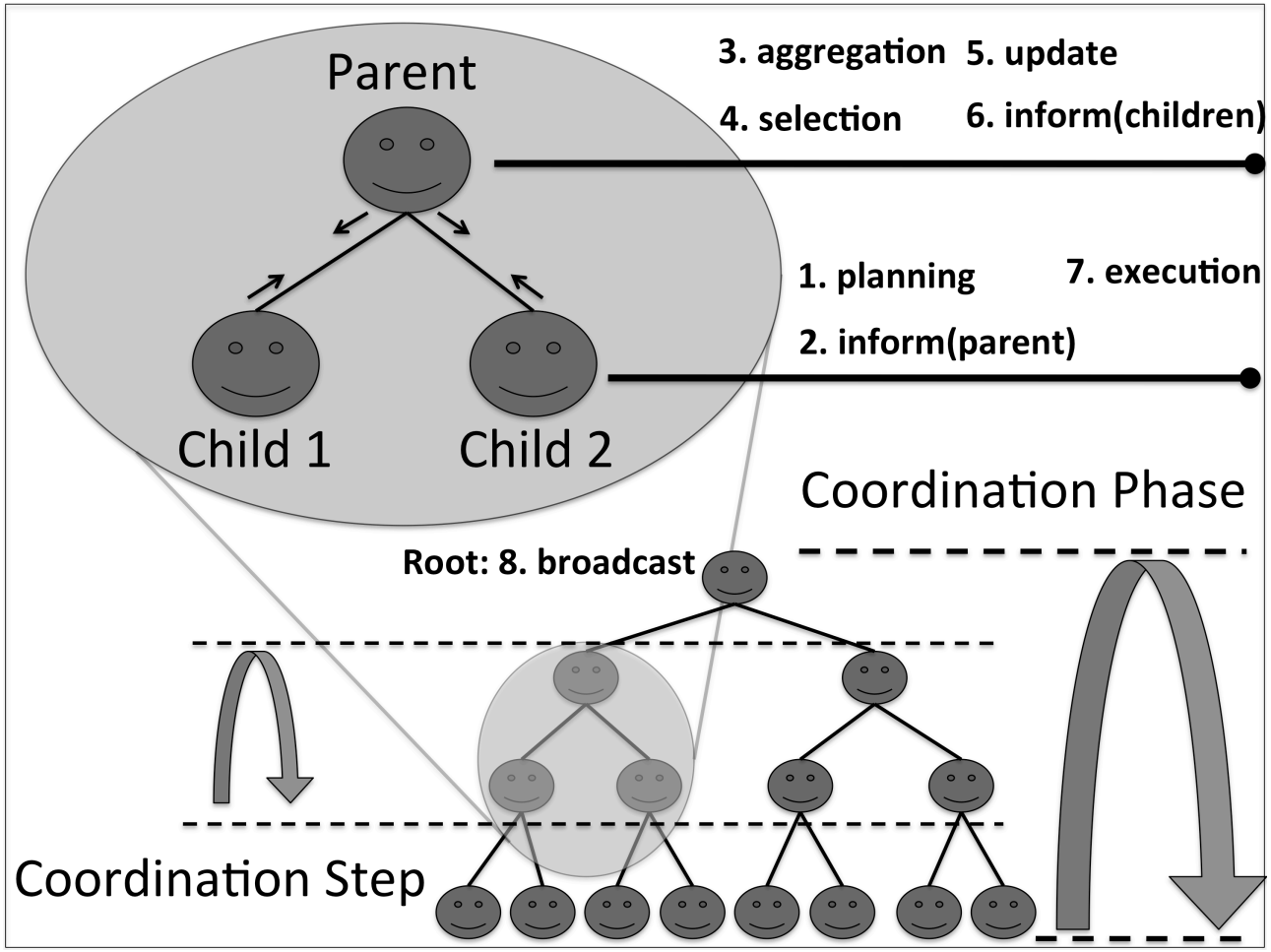
- More reliable power grids are less costly to run
- Smaller electricity bills for consumers
- More efficient power plant use
- Inexpensive
- A foundation for future grid management

Plan Selection



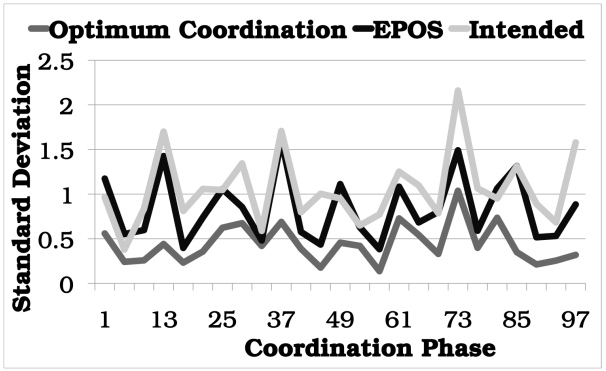
Complexity = # of possible plans$^{\#\text{ of devices}}$

Coordination

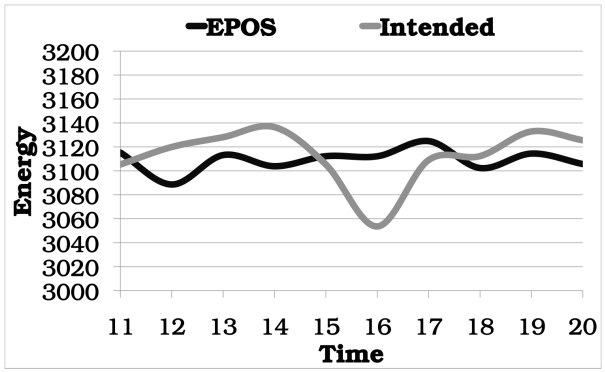


Results

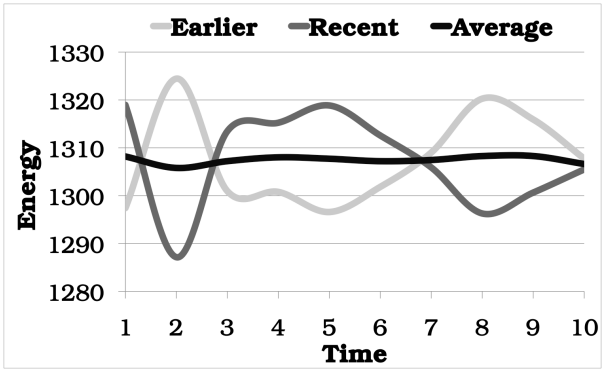
Agent-based simulations
Different devices with different consumption profiles
>3000 agents
3-5 possible plans/agent



Minimizing deviations



Minimizing deviations



Reversing deviations

Self-Organization of Trees

Sort ranked agents in a tree topology

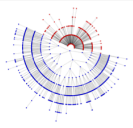
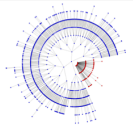
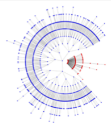
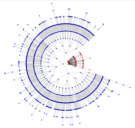
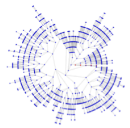
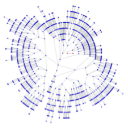
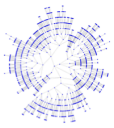
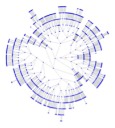
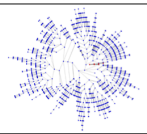
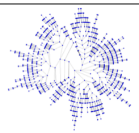
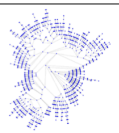
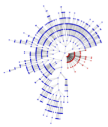
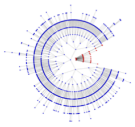
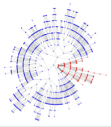
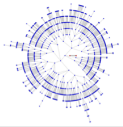
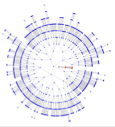
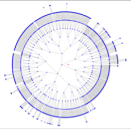
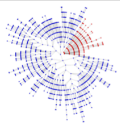
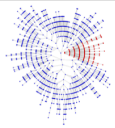
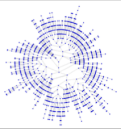
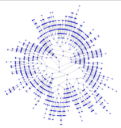
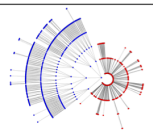
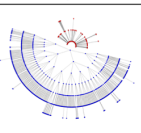
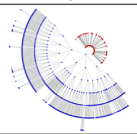
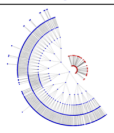
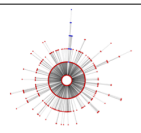
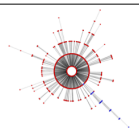
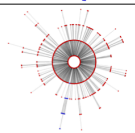
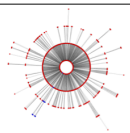
Self-organization: Gossiping, clustering and negotiation of parent-child links

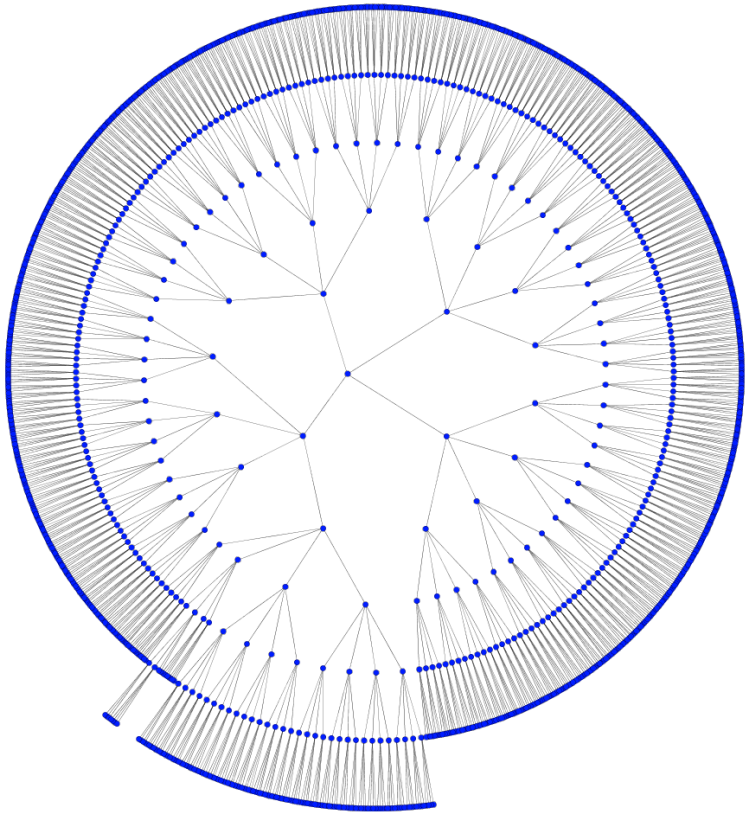
How can a tree topology be robust in a large-scale decentralized environment?

Adaptation strategies can explore performance trade-offs

Higher connectivity vs higher overall fitness

Self-Organization of Trees (cont.)

	20^{th} Epoch	35^{th} Epoch	50^{th} Epoch	350^{th} Epoch
PRESBYOPIC				
MYOPIC				
HUMBLE				
GREEDY				
TOP-DOWN				
BOTTOM-UP				
TOP				
BOTTOM				



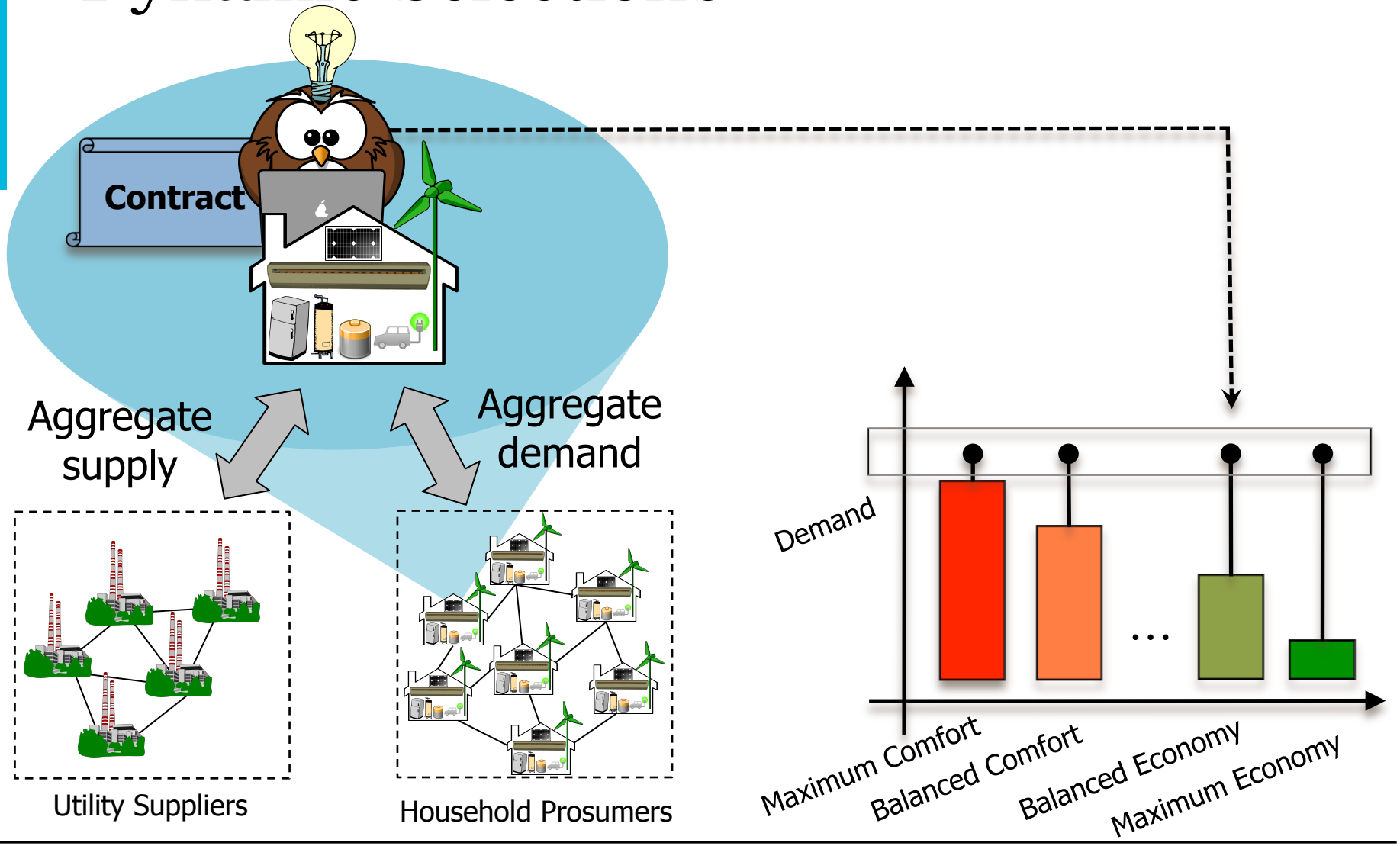
2. Demand Adjustment

Decreasing (or increasing) demand

How can adjustments of demand be achieved when incentivized consumers dynamically select between a number of pre-defined comfort/economy levels?

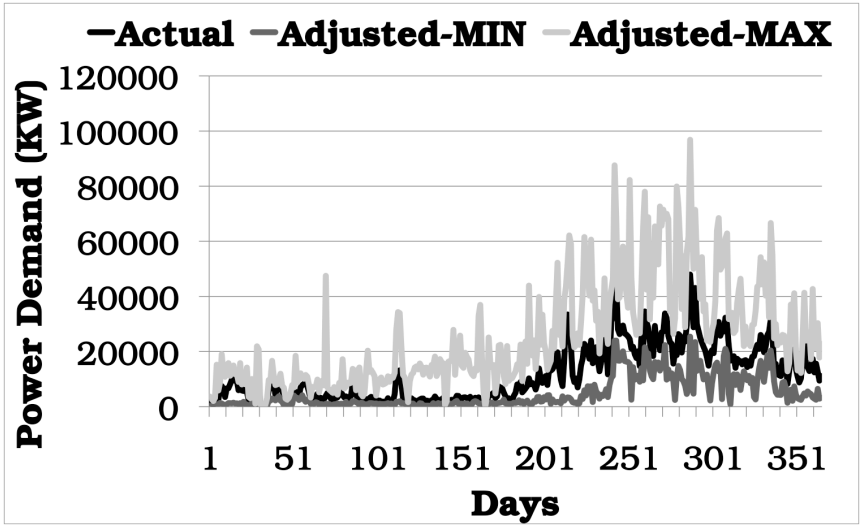
ALMA – Adaptive Load Management by Aggregation

Dynamic Selections



Validation

Validation using real analytical data
Olympic Peninsula Smart Grid Demonstration Project



Dynamic Decentralized Aggregation

History: Detection and elimination of duplicate and outdated input values

How can aggregation functions be computed in a decentralized fashion if the input values distributed in a network change?

Bloom filters: Data structures for efficient storage of historic information

Current Work

Preventing and minimizing the impact of cascading failures

Combining **complex networks** and **power flow dynamics** in a distributed environment

Distributed agent strategies that redistribute power flow based on entropy

Future Work

1. Inter-dependent networks

2. Use of operating reserves, e.g. batteries

Self-management of Smart Energy Systems

3. Privacy preserving self-management

4. Quality of Service in Smart Energy Systems

Questions?

More information

http://evangelospournaras.com

e.pournaras@tudelft.nl

Evangelos Pournaras, Multi-level Reconfigurable Self-organization in Overlay Services, PhD Thesis, Delft University of Technology, March 2013

E. Pournaras, M. Yao, R. Ambrosio, M. Warnier, Organizational Control Reconfigurations for a Robust Smart Power Grid, book chapter in Internet of Things and Inter-cooperative Computational Technologies for Collective Intelligence, in the Springer Book Series "Studies in Computational Intelligence", Vol. 460, Chap. 8, pp. 189-206, Jan. 2013

E. Pournaras, M. Warnier, F.M.T. Brazier, Local Agent-based Self-stabilisation in Global Resource Utilisation, International Journal of Autonomic Computing (IJAC), Vol. 1, Nr. 4, pp. 350-373, 2010

E. Pournaras, M. Warnier and F.M.T. Brazier, Adaptation Strategies for Self-management of Tree Overlay Networks, in the proceedings of the 11th IEEE/ACM International Conference on Grid Computing, pp. 401-409, Brussels, Belgium, Oct. 2010

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE