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THE SMART GRID – CHARGING EVS

GRANT BY THE MINISTRY OF ENERGY

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(Smart) Motivation

- The Smart Grid is here
- Much work on up-to-date information for smart production (and distribution)
- Good for the energy provider…
- *Focus on the consumer..*
- Smart homes can plan consumption according to dynamic pricing
- Cooperate for better "bargaining"

Motivation – a simple case…

- Smart homes' consumption is complex (multiple appliances and daily activities/schedule)
- A (somewhat) simpler consumption pattern – Electric Vehicles (EVs)
- A 2-years study (granted by the Ministry of Energy)
- Our part – EV charging in day-to-day practical scenarios
- Find methods to induce cooperation for better "bargaining"

V2G-enabled charging problem

EVs charging

- Electric Vehicles (EVs) are an important part of the transition plan to a low carbon economy
  - Expected to contribute ~50% to the total electric energy consumption
  - Can stress the distribution system causing performance degradations and overloads
  - The Smart Grid relates to advanced methods of balancing load
    - Use computerized interactions to achieve load balancing
    - Lower dependability on non-renewable, highly polluting energy sources

Main advantages of V2G-enabled EVs

- Charge in a well-balanced pattern in order to avoid overloading the smart grid
- Charge at a low demand time in order to store energy to be used at peak hours (helps the provider)
- Sell back the energy stored to reduce costs (helps consumer)

A day-to-day EVs charging problem

- Many EVs are expected to be charged during the same time phase
  - Between the times that the majority of the population is driving to work and back home
  - *Multiple EVs parked in large parking lots*
- This pattern may lead to large demand peaks
  - If tackled by extending the grid infrastructure can reduce the positive effects on the environment
  - A better way is to attempt to find a peak reducing schedule for the EVs charging

A major goal - peak-reducing schedule

- Find a schedule that will reduce the peaks and balance the load

- Take into consideration that different consumers:
  - Have different time constraints
  - Need different amounts of energy
  - Have different willingness to pay

Game theoretic approach

Game theory vs. EV charging

- Game theory assumes rationality of players
  - The inherently self-interested nature of EVs meets game theoretic assumptions

- Game-theoretic model can be designed in order to capture the problem dynamics
  - A mechanism can be applied to the game to ensure a desirable result

EV charging game

- Resource allocation game - the cost of resources depends on the demand
  - EVs select what time-slots to charge in
  - Background load + EVs selections ➔ ***costs***
  - Each player is able to both produce resources and consume resources (e.g., ***charge*** or ***discharge***)
  - A sequence of rational "responses" leads to a stable state
  - Theoretically "predictable" result of the game

Example

EVs charging game example

Require 2

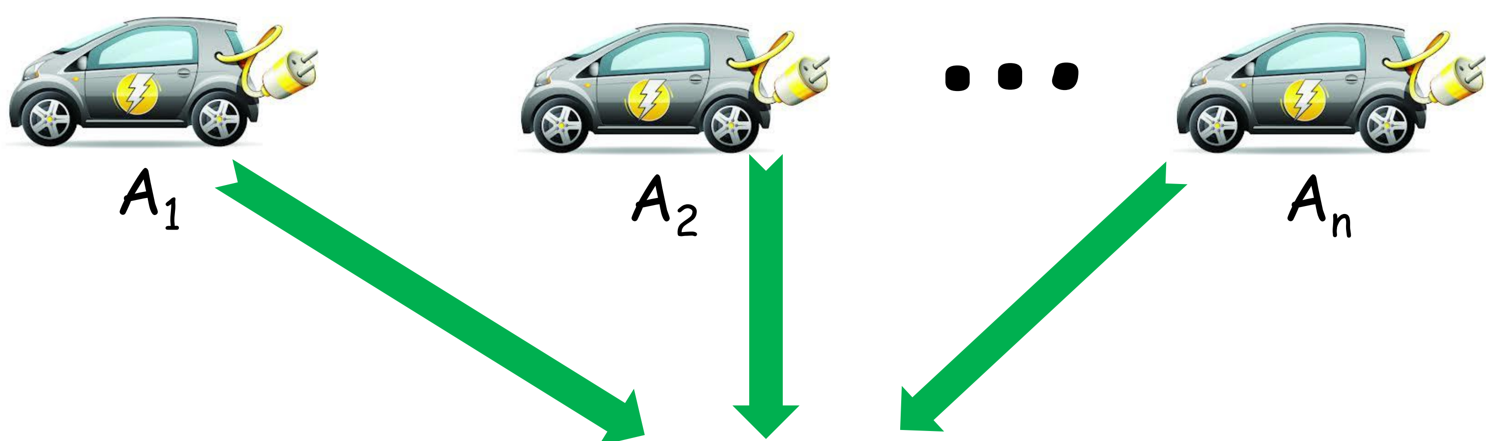
Request	t_1	t_2	t_3
	■	■	

Require 1

Request	t_1	t_2	t_3
		■	

Require 2

Request	t_1	t_2	t_3
	■		■



	t_1	t_2	t_3
Background Load	8	5	10
Total load	10	7	11

EVs charging game example

Require 2

Request

t_1	t_2	t_3
■	■	

A_1

Payment: 10 + 7

Require 1

Request

t_1	t_2	t_3
	■	

A_2

Payment: 7

• • •

Require 2

Request

t_1	t_2	t_3
■		■

A_n

Payment: 10 + 11

	t_1	t_2	t_3
Background Load	8	5	10
Total load	10	7	11

EVs charging game example

Require 2

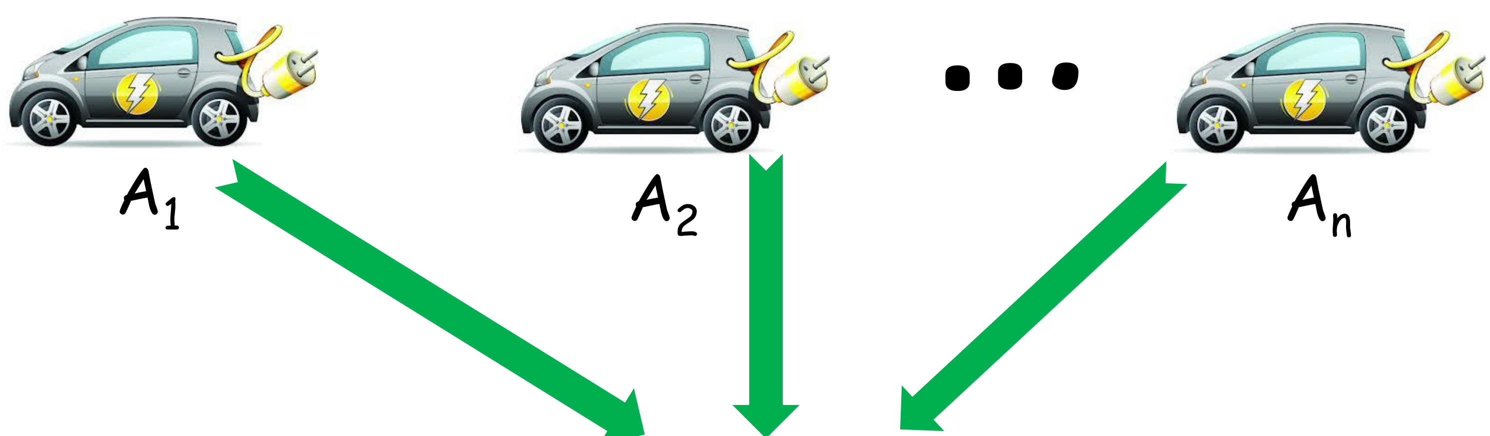
	t_1	t_2	t_3
Request			

Require 1

	t_1	t_2	t_3
Request			

Require 2

	t_1	t_2	t_3
Request			



	t_1	t_2	t_3
Background Load	8	5	10
Total load	10	8	10

EVs charging game example

Require 2

Request

t_1	t_2	t_3

Require 1

Request

t_1	t_2	t_3

Require 2

Request

t_1	t_2	t_3

A_1

Payment: 10 + 8

A_2

Payment: 10 + 8 − 11

...

A_n

Payment: 8 + 10

	t_1	t_2	t_3
Background Load	8	5	10
Total load	10	8	10

EVs charging game example

Require 2
Request

t_1	t_2	t_3

Require 1
Request

t_1	t_2	t_3

Re[illegible]

A_n

P[illegible]

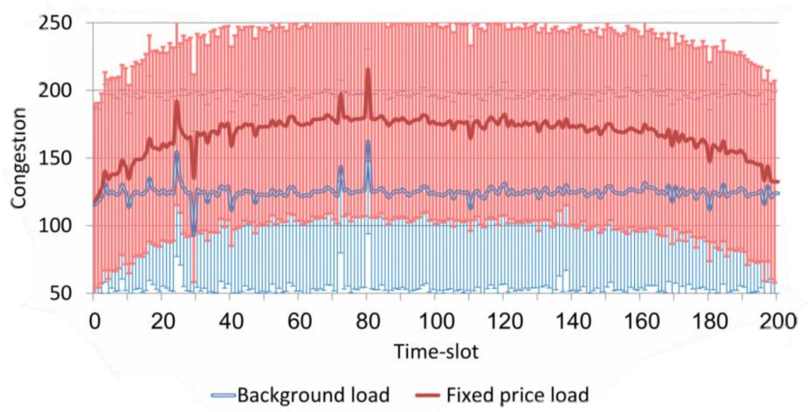
Payment: 8 + 10

Stable state! (PNE)

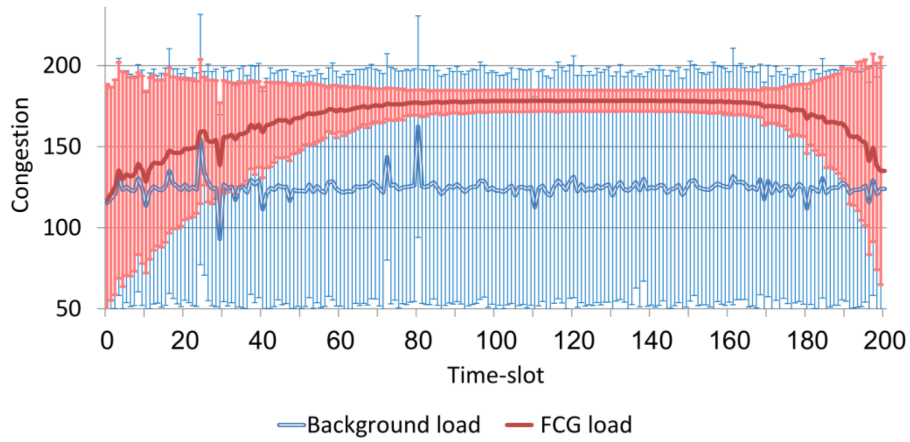
	t_1	t_2	t_3
Backg[illegible] Load	8	5	10
Total load	10	8	10

Controlling predictability

Background vs. Fixed Pricing



Background vs. FCG



$V = 500, \qquad T = 200$

Note the difference in the standard deviation which corresponds to the predictability of the solution

Conclusion (*take home*)

- Simple mechanisms for balanced charging exist
- Consumers (EVs) play a selfish game and benefit
- Similar mechanisms can be designed for smart homes
- The overall dynamic-pricing model can be designed to include the producer (electricity distributor)
- All benefit - our group's second result
- ➔ first steps towards a start-up of smart meters software on the smart grid…

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Questions?