Coalition Formation Algorithm of Prosumers in a Smart Grid Environment

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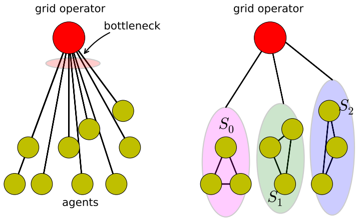
Outline

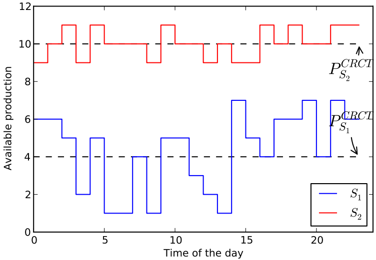
Objective

- Data/Communication oriented
- **Prosumer** scenario (agents consume, produce, and sell to the grid)
- **Minimizing** the amount of **communication** needed to maintain stability
- Avoid communication **bottlenecks**
- Organizing prosumers into virtual (logical rather than physical) **coalitions** (geographical distances are abstracted)
- Reduce the "*grid to agents*" communication flows
- How should these coalitions be formed ?



Challenges

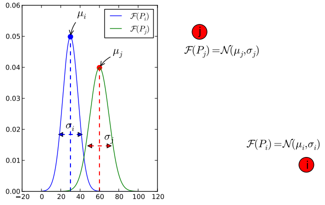
- Suppose coalitions are formed **on day d for day** $d+1$
- A **contract value** is decided for each coalition
- Over day $d+1$, coalition net productions are likely to oscillate because :
  - agents **consume freely**
  - production is based on **renewables** (lots of **uncertainties**)
- BUT, for the grid operator, coalition **productions should remain stable** at their contract values
- Coalitions need **communication** to take actions (battery charge/discharge, load shedding, backup generators)

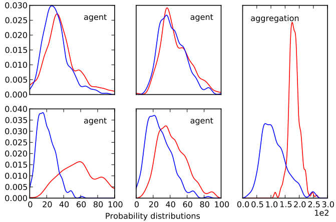


We want to minimize the amount of communication needed by forming coalition that, statistically speaking, will be likely to deviate less on day $d+1$

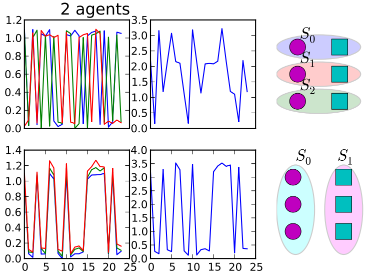
Challenges

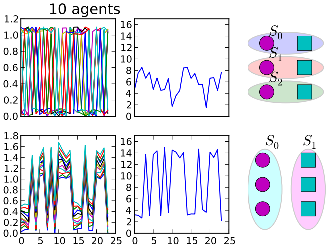
- Agents net production timeseries exhibit **diverse patterns** because of (mainly) :
  - Weather conditions at the agent location
  - The DER owned by the agents
  - The agents consumption habits
- **Probability distributions** infered from past values
- $\sigma_{ij} = \sqrt{\sigma_i^2 + \sigma_j^2 + \rho_{ij}\sigma_i\sigma_j}$
- We use the **Pearson correlation coefficient** to simplify the model
- We want to **cluster** together **uncorrelated** agents
- **Unusual** and **complex** objective

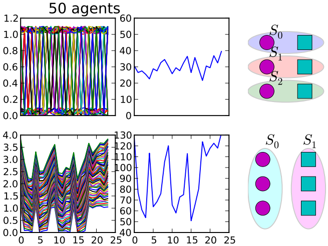




Uncorrelated / Diversity Idea







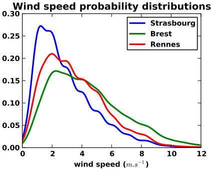
Data Issues

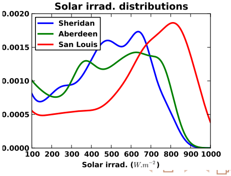
In the model, each agent is represented by the **timeserie** of its **net instantaneous production** (production - consumption)

Data

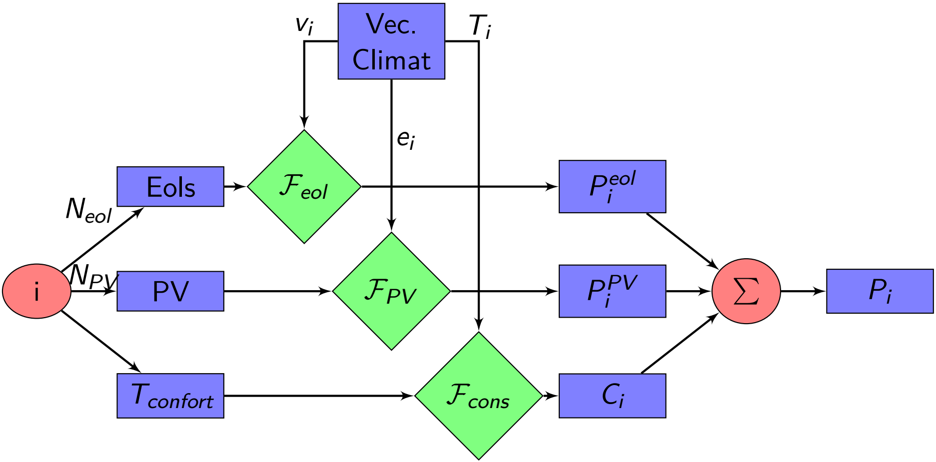
- Consumption and production data with **fine granularity**
- Geo-localized data
- "High" sampling frequency (second to hour range)

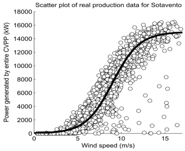
- "Real prosumers" do not really exist yet (necessity to model them)
- We use **weather data** available for stations accross a given territory
- These traces are used to generate net production traces for prosumer agents (see more details on next slide)



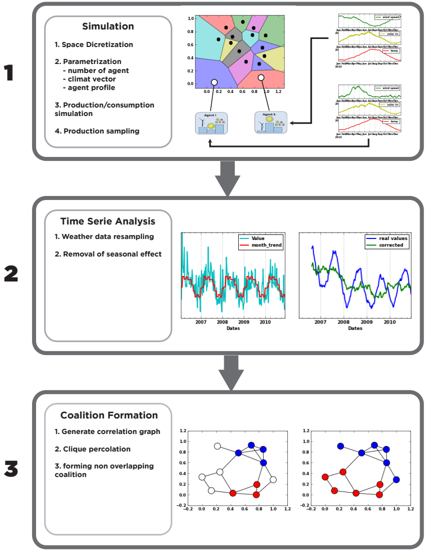


Aggregated net prosumer production model



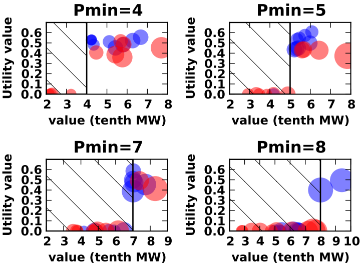


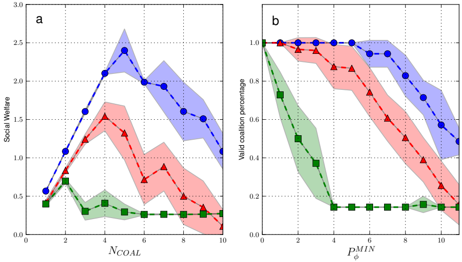
Our Method (Overall view)



- Some examples considered :
- France (Lille, Brest, Dijon, Strasbourg, Bordeaux, Marseille...)
- USA (Colorado, Kansas, Montana, Texas, Oklahoma...)
- 200 agents
- 16 zones (16 climate vectors)
- Timeseries from 01/01/2006 to 31/12/2010

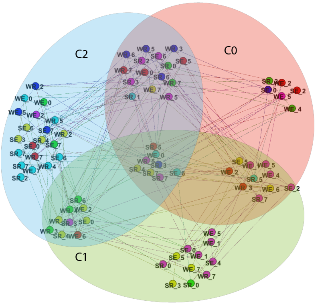
Some Results (part 1)

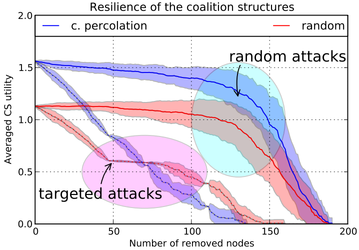


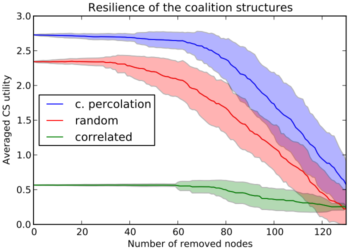


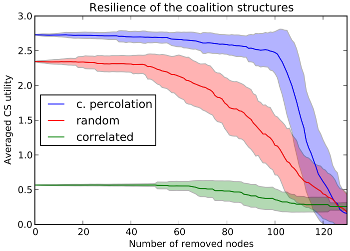
- Coalitions are able to sell (positive utility) if
  - They produce more than P_{min}
  - With a low probability of producing less than the contract

Some Results (part 2)









Conclusion and Perspectives

Up to now :

- Communication oriented
- Modeling, simulations
- Use of statistical tools, complex systems, graph theory
- Lack of available "clean" data led us to construct our own "*traces generator*"
- Stong assumptions on the electrical part

Several ways for improving :

- Using **real**, more **realistic data** as inputs
- Studying the impact of **electric constraints** on the model
- Could lead to interesting and more realistic work