Smart Grid Simulation

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Christoph Doblander

Joint work with: Christoph Goebel, Hans-Arno Jacobsen

Department of Computer Science,

Chair for Application and Middleware Systems (I13)

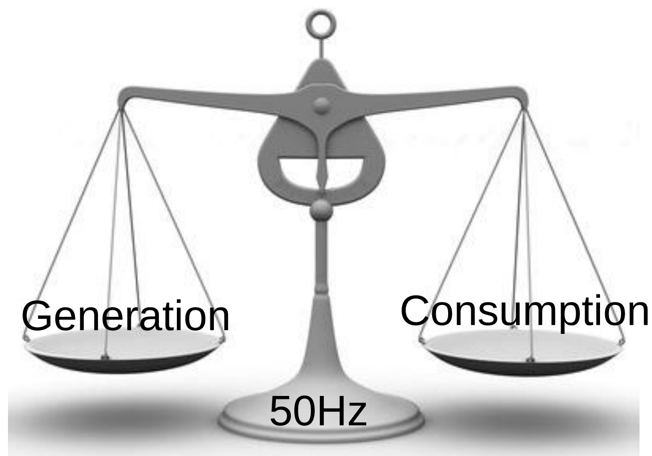
Smart grid, balancing both sides

wikipedia.com

wikipedia.com

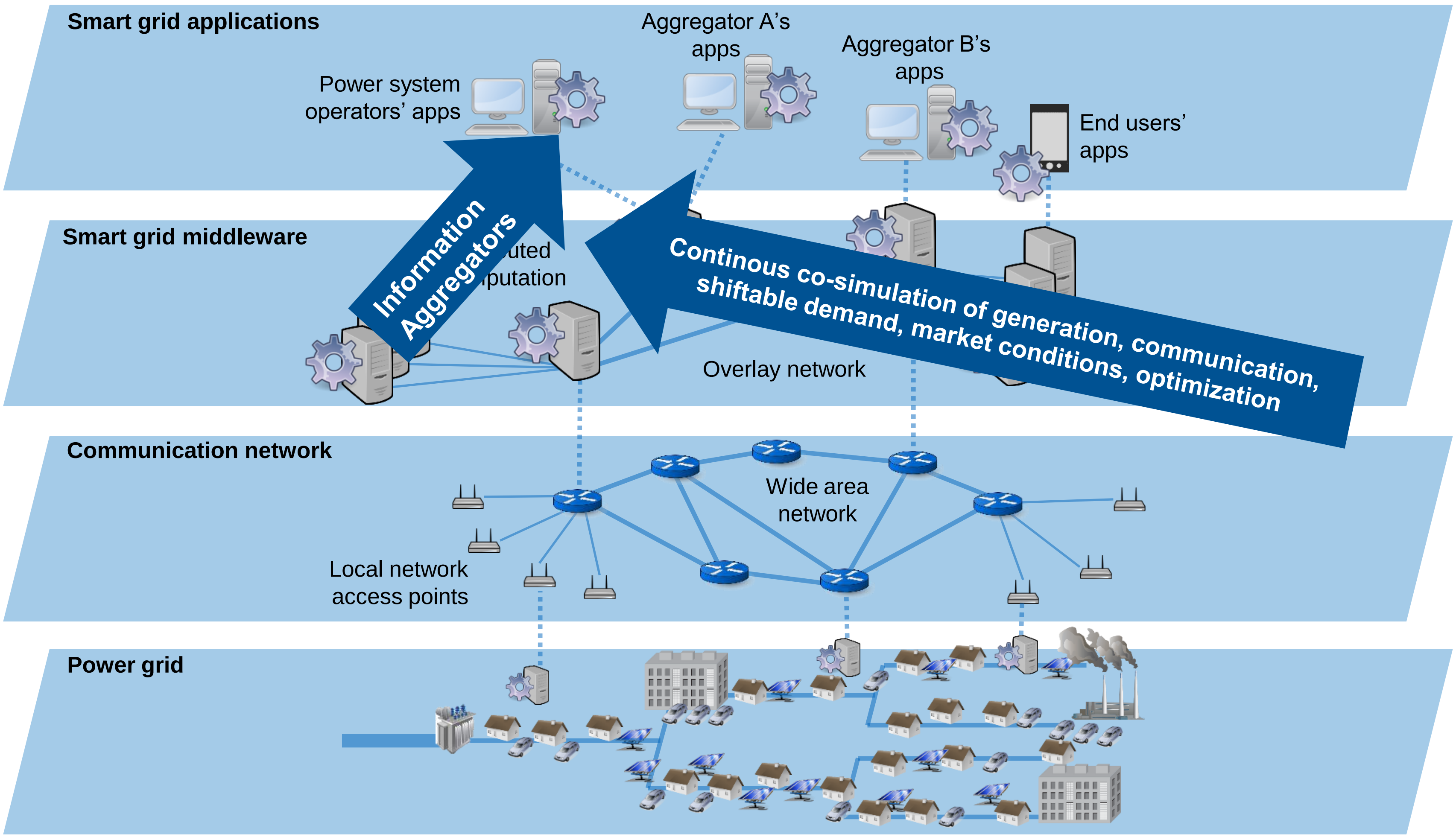
flickr.com/wfiupblicradio

siemens.de



rwe.de

Smart grid vision



Imagine the case ...

- The mobile phone network of a specific operator fails. Does uncontrolled battery charging overload the grid?

- High latencies in the GSM network occur. How far from the optimal is the distributed optimization performing?

- Two aggregators with competing optimization algorithms control car charging. Could this scenario lead to an overheated transformer?

wikipedia.com

Motivation for smart grid simulation

- Many smart grid stakeholders
  - Aggregators with competing objectives can interfere
  - Fluctuating energy sources and controllable demand
  - Increased volatility on energy markets

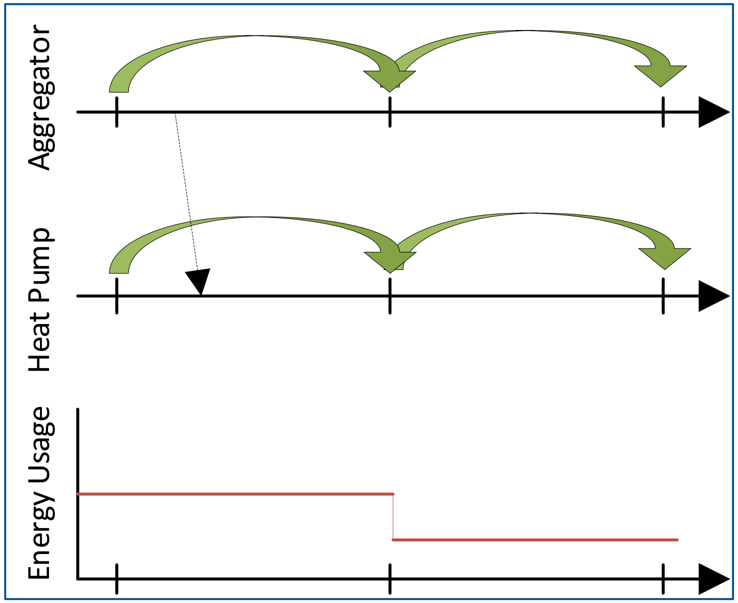
- Many communication strategies
  - Low latency e.g., responding to frequency changes
  - High latency e.g., GSM network

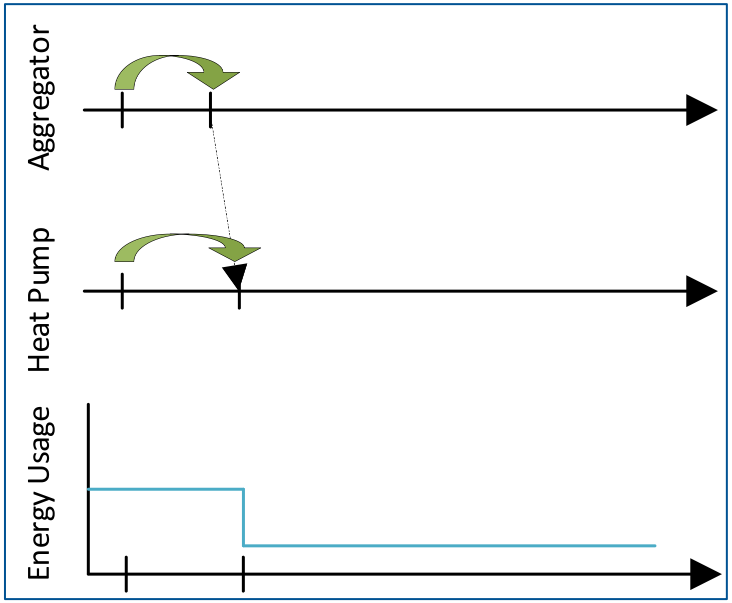
- Fault scenario
  - N-1, N-2, N-3 …..
  - Grid infrastructure, communication infrastructure
  - Byzantine behavior

→ Explore scenarios through simulation

Smart grid simulation requirements

- Discrete time
  - Fluctuating demand/generation
  - Powerflow analysis
- Agent modeling
  - Markets and control
  - Distributed optimization

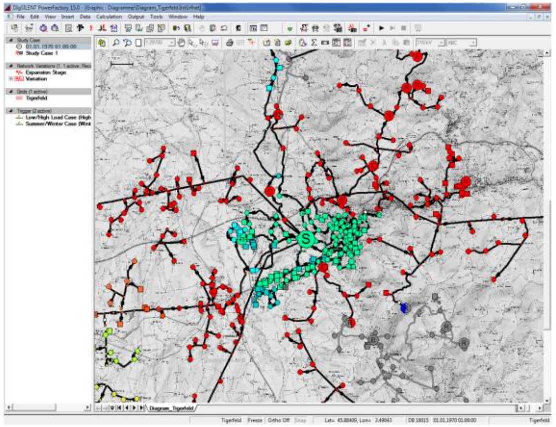




State of the art

- Research and Open Source
  - GridLab-D
  - Issues
    - Hard to extend
    - Many hard-coded U.S. grid assumptions

- Commercial
  - Digsilent PowerFactory
  - Issues
    - Most components black boxes
    - Focused on current operator needs
    - Integration



Recent approach: Mosaik

- Schütte et al. „Mosaik – Smart Grid Simulation API“
  - Python, Matlab
  - Reference data model for smart grid simulation
  - Integration of COTS, e.g.: Digsilent PowerFactory

- Issues
  - Step size must be set initially
  - Discrete time: communication between models could be realised by setting and getting properties after step
  - Accuracy ⇔ step size ⇔ performance

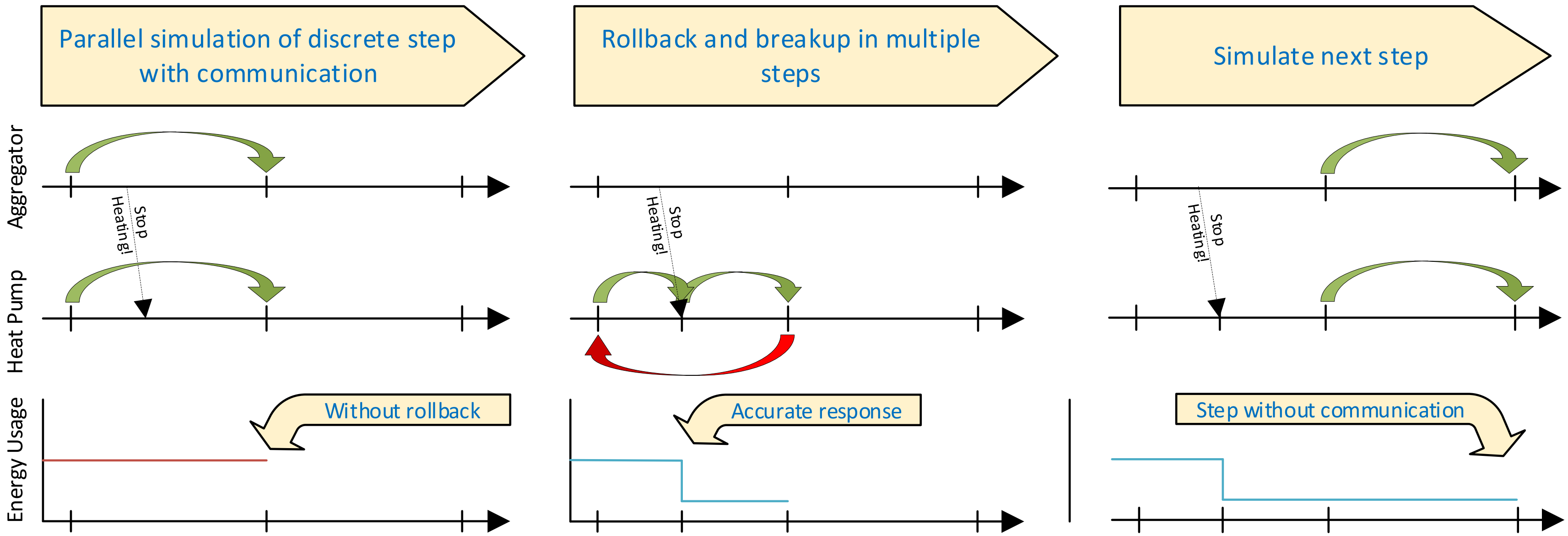
Recent approach: FMI

- FMI „Functional Mock-up Interface 2.0“
  - Targets interoperability between modeling tools (Modelica)
  - Development initiated by Daimler
  - Usage for micro grid simulation has been shown

- Issues
  - API definition very low level, C/C++
  - Not a good fit for large scale distributed simulation
    - Generated code grows with number of model instances
  - Accuracy ⇔ step size ⇔ performance

Proposed approach

- Parallelism by optimistic simulation of next steps
- In case of communication, rollback and breakup into smaller intervals
- No tradeoff between accuracy and simulation step size



Proposed interface

- Simulation and receiving messages can be composed
- State can be recomputed by replaying communication events and steps

Timeslot defintion

```
case class NextTimeslot(from: DateTime, to: DateTime)

trait GridAgent[TState] {
  def simulate(timeslot: NextTimeslot, beginState: TState) : (GridUtilization, TState)
}
```

Takes timeslot and state, computes the GridUtilization (for powerflow analysis) and **a new state**

```
trait CommunicatingAgent[TState, TMsg] {
  def receiveMessage(beginState: TState, message: TMsg) : TState
}
```

Takes a state and message, computes **a new state**

Our approach compared to Mosaik and FMI

- Advantages
  - Accurate representation of communication
  - Speedups through lookups and larger discrete time steps
  - Interactive simulation

But we can
work around ☺

16GB ~ 140 €
Batch persistence

- Disadvantages
  - Needs more memory than mutable approaches
  - Implementation has to be side effect free
    - e.g.: Random generators?
  - More coordination, latencies over network

Testing, DSL

Random seed
part of the state

Clustering
chatty models,
prioritsation

Proposed architecture

- Distribution across multiple machine by using actors
- Models should run on the JVM
  - Expressed in any JVM language (JRuby, Clojure, JPython, ...)
  - Scala DSL
  - „Bridging the Communication Gap“ with Modim (Modelica → Java)
    - Dymola, Simulation X, Wolfram SystemModeler ...
- Cluster deployment, resource management with Apache YARN
- **Respect software engineering principles**
  - Modularity, reusability, tests and documentation

Thank you!

- Questions?

Chair for Application and Middleware Systems

Prof. Dr. Hans-Arno Jacobsen
Alexander von Humboldt Professor

Technische Universität München
Institut für Informatik
Boltzmannstraße 3
85748 Garching

sekretariati13@in.tum.de
www.i13.in.tum.de

Alexander von Humboldt Stiftung/Foundation

Institut für Informatik
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  - Akka, http://akka.io/
  - Apache YARN, http://hadoop.apache.org/
  - Höger – Modelica on the Java Virtual Machine, EOOLT 2013